The Obesogenic Home Environment, Appetite, and Weight in Childhood

Alice Rose Kininmonth

Submitted in accordance with the requirements for the degree of
Doctor of Philosophy

The University of Leeds
School of Psychology

January 2022

Intellectual Property

I, Alice Rose Kininmonth, confirm that the work presented in this thesis is my own. Where work which has formed part of jointly-authored publications has been included, the contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Thesis structure

This thesis comprises a series of studies examining the obesogenic quality of the home environment and its role in children's appetite, health behaviours and weight trajectories.

This thesis is presented in the alternative format. The alternative format refers to a publication-based thesis format. Rather than the traditional chapter style thesis, it allows published manuscripts to be included in the thesis without the need for the work to be rewritten and enables the candidate to maximise academic research outputs. This style of thesis includes an overall introduction, as well as a discussion and conclusion section after the included manuscripts to bind them into a whole. Each chapter will be labelled as either a Journal Article or Thesis Sub-section. Where journal articles are presented, the formatting will be consistent with the relevant target journal. This will be clearly labelled at the start of each chapter with the most up-to-date submission status.

List of publications relating to chapters in this thesis

Kininmonth, A.R. & Fildes, A. (2022). The Home Food Environment. (2022). In (Eds) C. Evans. Transforming Food Environments. CRC Press Taylor & Francis Group: Abingdon. ISBN-10: 036748966X. DOI: 10.1201/9781003043720-2 **(Chapter One)**

Kininmonth, A.R., Smith, A.D., Llewellyn, C.H., Dye, L., Lawton, C.L. & Fildes, A. (2021). The relationship between the home environment and child adiposity: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, 18, 4. DOI: 10.1186/s12966-020-01073-9 **(Chapter Three; Paper One)**

Kininmonth, A.R., Schrempft, S., Smith, A.D., Dye, L., Lawton, C., Fisher, A., Llewellyn, C.H., & Fildes, A. (2021). The Home Environment Interview and associations with energy balance behaviours and body weight in school-aged children – A feasibility, reliability, and validity study. *International Journal of Behavioral Nutrition and Physical Activity,* 18, 167. DOI: 10.1186/s12966-021-01235-3 **(Chapter Four; Paper Two)**

Kininmonth, A.R., Schrempft, S., Smith, A.D., Dye, L., Lawton, C., Fisher, A., Llewellyn, C.H., & Fildes, A. (under review). Associations between the obesogenic home environment and childhood weight: a cross-lagged panel analysis. *International Journal of Obesity*. **(Chapter Five; Paper Three)**

Kininmonth, A., Smith, A., Carnell, S., Steinsbekk, S., Fildes, A., & Llewellyn, C. (2021). The association between childhood adiposity and appetite assessed using the Child Eating Behavior Questionnaire and Baby Eating Behavior Questionnaire: A systematic review and meta-analysis. *Obesity Reviews*, 22(5), e13169. https://doi.org/10.1111/obr.13169 **(Chapter Six; Paper Four)**

Kininmonth, A.R., Schrempft, S., Smith, A.D., Dye, L., Lawton, C., Fisher, A., Llewellyn, C.H., & Fildes, A. (to be submitted). Variation in the heritability of child appetite based on the obesogenic risk in the Home Environment. *International Journal of Behavioral Nutrition and Physical Activity.* **(Chapter Seven; Paper Five)**

Other publications I have contributed to during this thesis

Kininmonth, A.R., Smith, AD, Llewellyn, C.H. & Fildes, A. (2020) Socioeconomic status and changes in appetite from toddlerhood to early childhood. *Appetite*, 146. 104517 DOI: 10.1016/j.appet.2019.104517

Herle, M., Smith, A., **Kininmonth, A.R.,** & Llewellyn, C.H. (2020). The Role of Eating Behaviours in Genetic Susceptibility to Obesity. *Current Obesity Reports,* 9(9793):1-10. DOI: 10.1007/s13679-020-00402-0

Abstract

The obesogenic home environment is thought to play an important role in shaping children's food intake, physical activity, and screen-based sedentary activities – key energy balance behaviours deemed important for weight development. However, little is known about direct relationships between the home environment and children's weight. There is also a lack of research examining how individuals' appetite might interact with the obesogenic home environment to shape weight development. This thesis uses data from the Gemini twin cohort to address these gaps in knowledge. **Paper One** details a systematic review examining relationships between the home environment and adiposity in children ≤12 years. Consistent associations were observed between the home media environment and child adiposity. **Paper Two** updated and validated a comprehensive measure of the home environment for school-aged children and showed that children living in more obesogenic home environments had poorer diets, engaged in less physical activity, accrued more screen-time, and had higher BMI-SDS at age 12. **Paper Three** revealed strong tracking of the obesogenic home environment from ages 4-12 years, and that exposure to a more obesogenic home media environment predicted greater increases in child BMI-SDS from 4-12 years. **Paper Four** presents a systematic review and meta-analysis demonstrating robust cross-sectional and prospective relationships between appetite and adiposity in childhood. **Paper Five** applied the twin design to test the hypothesis that the heritability of appetite varies by obesogenic risk in the home environment. Findings suggested that the shared environmental influence on appetite was higher in lower-risk home media environments, suggesting that an environment with less access to media may buffer the genetic expression of an avid appetite. This thesis provides evidence for the role of the obesogenic home environment in children's appetite and weight, and specifically highlights the home media environment as a potential target for future obesity prevention and intervention strategies.

Acknowledgements

I would like to thank Professor Jane Wardle, although I never had the pleasure of being able to meet you, I am grateful for the research you undertook, for establishing the Gemini study and for moulding the incredible individuals who would become my supervisors. I am sad that I was never able to meet you but I am forever grateful for the incredible work you did, none of this would have been possible without you.

I am forever grateful to Dr Alison Fildes, Dr Clare Llewellyn, and Dr Andrea Smith for being wonderful supervisors. I cannot express how lucky I feel to have been blessed with the benefit of your intellect, expertise, scientific rigor, and unwavering support. Thank you for being so down to earth and for having a brilliant sense of humour. Learning from you and working together has been an absolute joy and I look forward to the future. I would like to extend a special thanks to Ali, for providing me with the intellectual and emotional support and guidance I needed at all times throughout this PhD. I cannot express in words how grateful I am for all you have done for me.

I am also thankful for Professor Louise Dye and Dr Clare Lawton for their support and encouragement when I expressed interest in undertaking a PhD. Thank you for taking me under your wing during my masters, guiding me and providing me with countless opportunities to gain research experience. A special thanks to Louise for her support when applying for funding and to Clare Lawton for her kind words, intellect, keen eye for detail and caring nature.

Thank you to Dr Stephanie Schrempft and Dr Abi Fisher for your insightful comments, pertinent questions and kind words of support.

I am also grateful to the Gemini families for completing the many lengthy questionnaires over the years and for taking the time to speak to me over the telephone.

This work was funded by a 1+3 Economic and Social Research Council Advanced Quantitative Methods Studentship. I would like to thank them for their financial support.

Huge thanks to my friends and colleagues who have provided practical and emotional support, as well as lots of laughter. A special thanks to Lucy for always being there for me, you are an incredible friend and I am so glad we met. Thank you to Anna for always being a friendly face and taking the time to chat when needed and to Liam for the endless banter.

Thank you to my family, for supporting me over the years, for never giving up on me and for always making me laugh. Lastly, to Ash, thank you for being my everything.

Table of Contents

Table of Figures

Table of Tables

Abbreviations

ABC	Appetite, Behaviour and Cortisol Cohort
ACTS	Activity Support Scale for multiple groups
AEBQ	Adult Eating Behaviour Questionnaire
ARPQ	Activity Related Parenting Questionnaire
ASAQ	Adolescent Sedentary Activity Questionnaire
AWP	Active Where Parent-Child Questionnaire
BASELINE	Babies After SCOPE: Evaluating the Longitudinal Impact on Neurological and Nutritional Endpoints Birth Cohort Study
BATMAN	Bob's and Tom's Method for Assessing Nutrition
BEBQ	Baby Eating Behaviour Questionnaire
BF%	Body Fat Percentage
BMI	Body Mass Index
BMI-SDS	Body Mass Index Standard Deviation Score
BMIz	Body Mass Index Z-scores
BST	Behavioural Susceptibility Theory
CAFPP	Comprehensive Assessment of Food Parenting Practices
Cascot	Computer Assisted Structured Coding tool
CATI	Computer-assisted Telephone Interview
CEBQ	Child Eating Behaviour Questionnaire
CFI	Comparative Fit Index
CFPQ	Comprehensive Feeding Practices Questionnaire
CFQ	Child Feeding Questionnaire
CI	Confidence Interval
COOL	Controlling Overweight and Obesity for Life
CR	Child-report
CSGLM	Complex Samples General Linear Model
CSLR	Complex Samples Logistic Regression
DASH	Determinants of Adolescents' Social Well-being and Health
DD	Desire to Drink

DEBQ	Dutch Eating Behaviour Questionnaire
DEXA	Dual-energy X-ray absorptiometry
DINE	Dietary Instrument for Nutrition
DNA	Deoxyribonucleic acid
DV	Dependent Variable
DZ	Dizygotic
EATS	Eating Analysis and Treatment Schedule
EDF	Energy Dense Foods
EEA	Equal Environments Assumption
EF	Enjoyment of Food
EMS	Encouragement and Modelling Scale
ENERGY	EuropeaN Energy balance Research to prevent excessive weight Gain among Youth project
EOE	Emotional Overeating
EUE	Emotional Undereating
F&V	Fruit and Vegetables
FAQ	Food Availability Questionnaire
FEAHQ	Family Eating and Activity Habits Questionnaire
FF	Food Fussiness
FHBS	Family Eating and Activity Habits Questionnaire
FMTS	Food Modelling Telephone Survey
FNPA	Family Nutrition & Physical Activity screening tool
FR	Food Responsiveness
GA	General Appetite
GDP	Gross Domestic Product
GECKO	Groningen Expert Center for Kids with Obesity
GOCS	Growth and Obesity Chilean Cohort Study
GPS	Genome-Wide Polygenic Scores
GUSTO	Growing Up in Singapore Toward healthy Outcomes
GWAS	Genome Wide Association Studies
HE	Home Environment
HEES	Home Electronic Equipment Scale
HEI	Home Environment Interview

HES	Home Environment Survey
HHS	Healthy Homes Survey
HNEQ	Home & Neighbourhood Environment Questionnaire
HOME-SF	Home Observation for Measurement of the Environment Short Form
HomeSTEAD	Home Self-administered Tool for Environmental assessment of Activity & Diet family food practices survey
HRP	Household Representative Person
ICC	Intraclass Correlation Coefficient
IMD	Index of Multiple Deprivation
ISCOLE	International Study of Childhood Obesity, Lifestyle and the Environment
IV	Independent Variable
KMO	Kaiser-Meyer-Olkin
LRBQ	Lifestyle-related behaviour Questionnaire
LSOA	Lower Super Output Area
MLSEM	Maximum Likelihood Structural Equation Modelling
MZ	Monozygotic
N	Number
NIK	Neighbourhood Impact on Kids
NOS	Newcastle Ottowa Scale
NP	Not provided
NS-SEC	National Statistics Socioeconomic Status
NW	Normal weight
OB	Obese
OR	Odds Ratio
OW	Overweight
PA	Physical Activity
PARM	Parental Modelling of Eating Behaviour Scale
PCA	Principal Components Analysis
PEACHES	Physical Exercise and Appetite in Children Study
PFQ	Parental Feeding Questionnaire
PFSQ	Parental Feeding Styles Questionnaire

PR	Parent-report
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	International Prospective Register of Systematic Reviews
RCT	Randomised Control Trial
REDCap	Research Electronic Data Capture
RMSEA	Root Mean Square Error Approximation
RR	Relative Risk
SD	Standard Deviation
SDS	Standard Deviation Scores
SE	Standard Error
SEANUTS	South East Asian Nutrition Survey
SEM	Structural Equation Modelling
SES	Socioeconomic Status
SNP	Single Nucleotide Polymorphisms
SOC2000	Standard Occupation Classification 2000 (SOC2000)
SPEEDY	Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people
SPSS	Statistical Package for the Social Sciences
SQUASH	Short Questionnaire to Assess Health enhancing physical activity
SR	Satiety Responsiveness
SRMR	Standardized Root Mean Square Residuals
SSB	Sugar Sweetened Beverages
TEDS	Twins Early Development Study
TFEQ	Three Factor Eating Questionnaire
TLI	Tucker-Lewis Index
TV	Television
UCL	University College London
WC	Waist Circumference
WtHR	Waist to Height Ratio

Chapter 1
Introduction[1]

1.1 Childhood obesity

Excess adiposity in childhood is a considerable public health concern in the UK and globally (NHS, 2018). Rates of childhood obesity have escalated significantly in recent years (Boodhna, 2014; NHS, 2018). Children are developing overweight and obesity at younger ages; with 27.7% of children classified with overweight or obesity before entering primary school in the UK (NHS Digital, 2021). These figures increase to 40.9% of children (aged 10-11) developing overweight/obesity by the time they leave primary school (NHS Digital, 2021).

Evidence has shown clear socioeconomic inequalities in childhood obesity (El-Sayed et al., 2012). In the UK, children living in areas of greatest deprivation are more than twice as likely to have obesity compared to those in the least deprived areas (4-5 year olds: 20.3% vs 7.8%; 10-11 year olds: 33.8% vs 14.3%) (NHS Digital, 2021). The rising trend in obesity rates and widening inequalities in prevalence are a major concern as excess adiposity in childhood has been strongly associated with obesity in adulthood (Simmonds et al., 2016). Childhood obesity has been shown to track into adulthood, with around 55% of children with obesity, having obesity in adolescence, and about 80% of adolescents with obesity continuing to live with obesity into adulthood (A. Llewellyn et al., 2016; Simmonds et al., 2015, 2016). A 2015 systematic review and meta-analysis

---

[1] Much of the information in this chapter has now been published in a book chapter [Kininmonth, A.R. and Fildes, A. (2022). The Home Food Environment. In (Eds) C.E.L. Evans. *Transforming Food Environments.* CRC Press: Abingdon. ISBN-10: 036748966X].

revealed that children with obesity were over five times more likely to have obesity as adults compared to children with a healthy weight (Simmonds et al., 2015).

Childhood obesity is associated with negative physical and psychological health consequences (Pulgarón, 2013), both in the short (Reilly et al., 2003) and long term (Power et al., 1997; Reilly & Kelly, 2010). Adverse psychological outcomes include poorer self-esteem, depression, anxiety, body dissatisfaction and greater risk of developing psychological disorders (Puder & Munsch, 2010; Rankin et al., 2016; Reilly et al., 2003; Sagar & Gupta, 2017). For physical health, children with overweight or obesity experience musculoskeletal problems (Smith et al., 2014), high blood pressure (Brady, 2017), dyslipidaemia (Cook & Kavey, 2011), type 2 diabetes and cardiovascular complications (Di Cesare et al., 2019). In the long-term, excess adiposity in childhood is strongly associated with increased risk of complex co-morbidities such as type 2 diabetes, coronary heart disease, hypertension (Reilly & Kelly, 2010) and some cancers in adulthood (Di Cesare et al., 2019; Llewellyn et al., 2016; Simmonds et al., 2016). The consistent association between child and adult obesity, highlights the importance of early prevention strategies. However, in order to develop effective preventative methods, research is required to better understand the modifiable factors influencing the development of overweight in childhood.

1.2 Factors contributing to childhood obesity risk

Obesity is a complex multifactorial disease, influenced by behavioural, environmental, psychosocial, and genetic factors (Maes et al., 1997; Silventoinen, Jelenkovic, et al., 2016). These factors will be discussed in more detail in the next sections.

1.2.1 Environmental factors

Although variation in weight has a moderate-to-strong genetic basis (as discussed in the section 1.2.2), the increased prevalence of obesity in recent decades cannot be solely attributed to genetic factors. The human gene pool has not changed significantly over this period and there are strong data which implicate environmental factors too. Rather, it is likely that changes in the obesogenic nature of the environment such as increased availability of cheap, palatable, energy-dense convenience foods (Swinburn et al., 2019), increased exposure to food advertisements (Folkvord & Hermans, 2020), and increased access to fast food outlets (Campbell, 2015; He et al., 2012) have encouraged increases in energy intake. While other societal changes, such as an increased reliance on transportation (i.e. cars, trains, buses), and sedentary job roles have led to a reduction in energy expenditure (Booth et al., 2005; Campbell, 2015; Rahman et al., 2011), and in turn this has led to rises in obesity levels.

The environment is complex, multifaceted and acts on multiple levels. From a public health perspective this makes it challenging to identify opportunities to develop prevention strategies. Socio-ecological models provide a useful framework for understanding how environmental influences can impact children’s energy balance behaviours, and in turn their risk of developing obesity (Egger & Swinburn, 1997; Kremers et al., 2006; Swinburn et al., 1999). Such frameworks often categorise the environment into two levels of influence: ‘macro’ and ‘micro’. The macro-environment encompasses higher-level factors that influence the wider population (city or country), such as food taxes and subsidies, transportation systems, food laws and regulations, food prices, government investment in parks and recreational facilities. Whereas, the micro-environment can be defined as environments the individual directly interacts with, such as homes, schools, neighbourhoods and workplaces. Within the macro- and micro-environments, there are various types of influence including physical, socio-cultural, political and economic factors (see **Figure 1.1)**.

To date, a large body of evidence has focussed on the role of macro-level environmental factors in children's energy balance behaviours and/or weight. One micro-level environment which has been hypothesised as important for children's energy balance is the family home. The role of the home environment in children's obesity risk is the focus of this thesis. As such, it is important to understand existing evidence in the field to ascertain what is currently know and to identify existing knowledge gaps. The evidence base for the role of the home environment in children's food intake, physical activity levels and screen-based sedentary behaviours will be discussed in later sections of this Chapter. While, evidence for the role of the home environment in children's weight is systematically reviewed in **Chapter Three (Paper One).**

Although the obesogenic environment provides explanation, at least in part, for the rise in the prevalence of obesity over recent decades, it does not help to explain why some individuals develop obesity, in response to the obesogenic environment, and others are able to maintain a healthy body weight, while also being exposed to the obesogenic environment. Genetic factors, as discussed in the section 1.2.2, are proposed to help explain a large proportion of the variation in susceptibility to obesity.

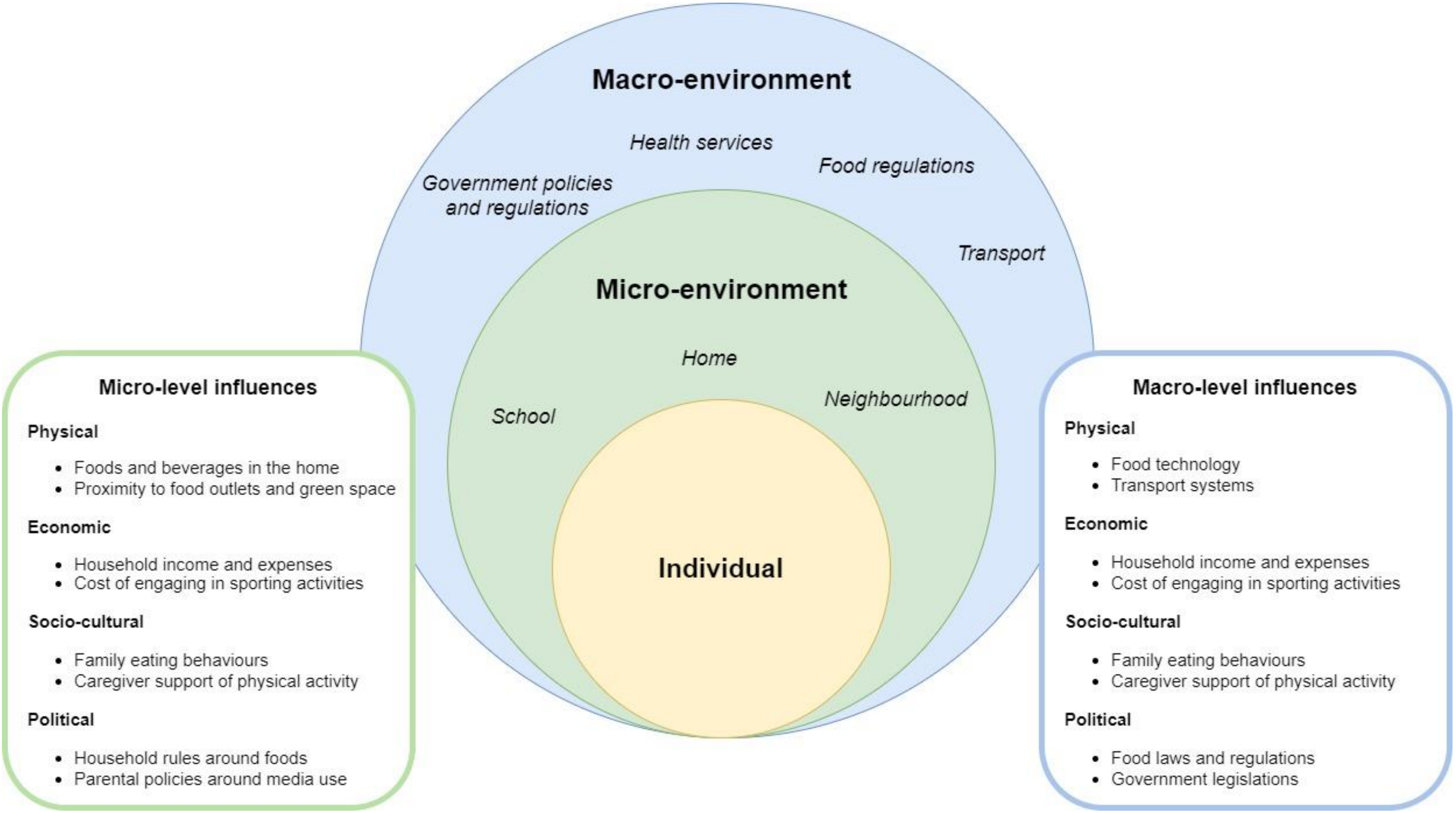


Figure 1.1. Environmental influences on energy balance behaviours and child obesity risk using the socio-ecological framework proposed by Egger & Swinburn, 1997; Swinburn et al., 1999.

1.2.2 Genetic factors

Evidence from twin and family studies have allowed researchers to quantify the contribution of genetic variation to differences in body weight (Elks et al., 2012; Maes et al., 1997). Family studies have shown a strong familial resemblance in human body weight, with parental weight status acting as a strong predictor of childhood obesity (Kral & Faith, 2009). One study demonstrated that children (n=1190; 10-12 years old) were three times more likely to have obesity if one parent had obesity, and more than 10 times as likely to have obesity if both parents had obesity (Notara et al., 2019). Findings from adoption studies have shown that adopted children's weight is significantly correlated with the weight of their biological parents, and not correlated with that of their adoptive parents (Sorensen et al., 1989; Stunkard, Foch, et al., 1986). Building on family studies, twin studies offer a powerful method for understanding the extent to which individual differences in a particular characteristic, such as body weight or appetite, are influenced by genetic and environmental influences (shared and non-shared). Identical twins (monozygotic, [MZ]) share 100% of their genome, and are natural clones of one another; whereas non-identical twins (di-zygotic, [DZ]) like regular siblings, share on average 50% of their segregating genes. Both types of twins share their environments to a very similar extent; they are gestated in the same mother at the same time, share the same age, share the same family and grow up in the same home (i.e. their shared environments are assumed to be the same). This means that the resemblance between MZ and DZ twins can be compared to estimate genetic (also known as 'heritability') and environmental contributions (partitioned into shared environment and non-shared environmental effects) to any measureable trait. One key assumption of the twin method is that if MZ pairs are more similar than DZ pairs then we assume that genetic factors must be contributing to this difference in similarity, because the only real difference between the two types of twins is that MZs are twice as similar genetically. This method will be discussed in more detail in **Chapter Two.**

Genome-wide association studies (GWAS) have enabled the detection of common genetic variants (in the form of single nucleotide polymorphisms, SNPs) associated with a phenotype. A 2018 meta-analysis of ~700,000 individuals revealed 941 SNPs associated with variation in BMI (Yengo et al., 2018). Furthermore, evidence from whole genome sequencing data indicates that genomic heritability from both rare and common variants can explain about ~50% of the variance in BMI (Wainschtein et al., 2019). Building on this, studies have used the genetic variants identified in GWAS to calculate a genetic risk score of obesity and showed that genetic risk for obesity was positively associated with BMI and waist circumference (Jacob et al., 2018).

Adiposity (i.e. Body Mass Index [BMI] Standard Deviation Scores [SDS], waist circumference) has been shown to be more closely correlated for MZ than DZ twin pairs (Wardle et al., 2008). Evidence from studies of twins reared apart has demonstrated that MZ pairs reared apart have BMIs correlated to a similar extent as MZ pairs reared together (Stunkard, Sørensen, et al., 1986), suggesting a stronger influence of genes than the environment. Twin analyses have shown heritability estimates of BMI to vary widely, ranging from 47-90% (Elks et al., 2012; Min et al., 2013a). Meta-regression of findings revealed the heritability of BMI was 0.07 higher in childhood than in adulthood (Elks et al., 2012), with estimates increasing with age from early childhood to adolescence (+0.012/year) and decreasing with age in adults (-0.002/year) from age 20 (Elks et al., 2012).

Together, these findings suggest that individual differences in weight have a moderate to strong genetic basis (Elks et al., 2012; Silventoinen, Jelenkovic, et al., 2016) – i.e. genetic differences between people help to explain population variation in adiposity. At the same time, environmental factors have also been shown to play a considerable role in weight variation (Silventoinen et al., 2009; Silventoinen, Jelenkovic, et al., 2016). A meta-analysis of the literature highlighted that environmental factors, particularly shared environmental factors (such as the family home environment) had a considerable effect in childhood, with the greatest influence observed in mid-childhood. However, the influence of the shared environment on BMI variation disappeared before adulthood (Silventoinen et al., 2009). This likely reflects that as children reach adolescence they gain greater independence from their parents, spend less time in the home environment and have greater autonomy over their food choices and behaviours.

1.2.3 Gene-environment interactions

Over recent decades, researchers have been trying to understand how genes bestow differential obesity risk in the context of the modern obesogenic environment. Evidence has highlighted that obesity develops as a consequence of a complex interaction between genetic susceptibility and exposure to the obesogenic environment. In other words, an individual's genes predispose them to developing obesity, but environmental exposure determines the outcome (Llewellyn & Fildes, 2017). The famous quote by Bray: "Genes load the gun, the environment pulls the trigger" exemplifies this complex interaction between genes and the environment (Bray, 1996).

Such gene-environment interactions occur when innate genetic factors affect susceptibility to environmental risk factors, making some people more susceptible (Knopik et al., 2017). The term gene-environment interactions in quantitative genetics means that the effect of the environment on a phenotype[2] depends on a genotype[3] or that the effect of a genotype on a phenotype depends on the environment (Knopik et al., 2017). Gene-environment interactions contribute to the complex interplay between genetic and environmental factors underlying human individual differences in a trait, such as body weight or appetite, whereby the genetic and environmental influences underlying a trait increase or decrease depending on the environmental exposure.

Previous research has found evidence for gene-environment interactions in relation to the heritability of BMI (Min et al., 2013b; Reddon et al., 2016). The majority of research has examined this in relation to macro-level influences (such as socioeconomic factors). One large twin study conducted in the Netherlands (n=33,338 children, followed from 1-20 years of age) examined the effect of SES, using parental education level as the indicator of SES, on the heritability of BMI (Silventoinen, Huppertz, et al., 2016). Their findings revealed that the heritability of BMI was significantly higher in children whose parents were less educated, compared to children of more highly educated parents (Silventoinen, Huppertz, et al., 2016). Similar findings have also been observed in countries with higher gross domestic product (GDP) (Min et al., 2013b) and in populations born after

[2] A phenotype is defined as an observed characteristic of an individual (e.g. height, weight, appetite) which results from the combined effect of genes and the environment.

[3] A genotype is an individual's combination of alleles at a particular site of a gene on a chromosome.

the onset of modern ‘obesogenic’ environment (Reddon et al., 2016; Rokholm, Silventoinen, Ängquist, et al., 2011; Rokholm, Silventoinen, Tynelius, et al., 2011; Wardle et al., 2008).

Research exploring micro-level influences on heritability of BMI has focussed on the neighbourhood and home setting. One large community-based sample of twin adults (n=2998; Mean [SD] age = 39.4 [17.6] years) revealed that neighbourhood design features such as walkability influenced genetic variance in BMI (Horn et al., 2015). The heritability of BMI was higher for those living in less walkable neighbourhoods compared to those living in more walkable neighbourhoods (Horn et al., 2015). In addition, recent findings from a large twin study of 1850 children (Mean [SD] age = 4.2 [0.4] years), which used a comprehensive measure of the home environment (the Home Environment Interview) to quantify the obesogenic quality of the food, activity, media and overall home environment, demonstrated that the heritability of BMI was significantly higher for children living in more obesogenic home environments, compared to those living in less obesogenic homes (heritability 86% vs 36%) (Schrempft et al., 2018). These findings indicate gene-environment interactions, whereby the effect of genes depends on environmental exposure. In other words, the genetic influence on weight is much more potently expressed in a more obesogenic home environment (Schrempft et al., 2018).

The role of gene-environment interactions in relation to children’s appetite will be discussed in depth in **Chapter Seven (Paper Five).**

1.2.4 A behavioural susceptibility model of weight

As discussed, both genetic and environmental factors play an influential role in human body weight (Silventoinen, Jelenkovic, et al., 2016). In western societies, the obesogenic environment is ever-present. However, despite everyone being exposed to this obesogenic environment, large variations in body weight still occur, even within the same household. Such variations provide support for the theory that susceptibility to obesity has a genetic basis and that weight gain results from an interaction between an individual's genetic risk and their environmental exposure, otherwise known as Behavioural Susceptibility Theory (BST) (Carnell et al., 2008; Llewellyn & Fildes, 2017; Llewellyn & Wardle, 2015). Central to BST is the hypothesis that inherited differences in appetite act as behavioural mediators of an individual's genetic susceptibility to the 'obesogenic' environment **(Figure 1.2)**. BST helps to explain why people interact with the obesogenic environment differently. BST proposes that inherited individual differences in appetite determine why some people overeat and others do not, in response to environmental opportunity. For example, individuals who are genetically predisposed to be more responsive to food cues (i.e. wanting to eat in response to the sight, smell, or thought of food) and less sensitive to internal satiety signals (i.e. feelings of fullness), are more likely to overeat and gain weight in response to an obesogenic environment. On the other hand, individuals who inherit genes predisposing them to a smaller appetite, who are less food responsive and less likely to be influenced by everyday environmental exposures (i.e. food advertisements, greater availability of palatable, energy-dense foods), are consequently less likely to overeat and gain weight.

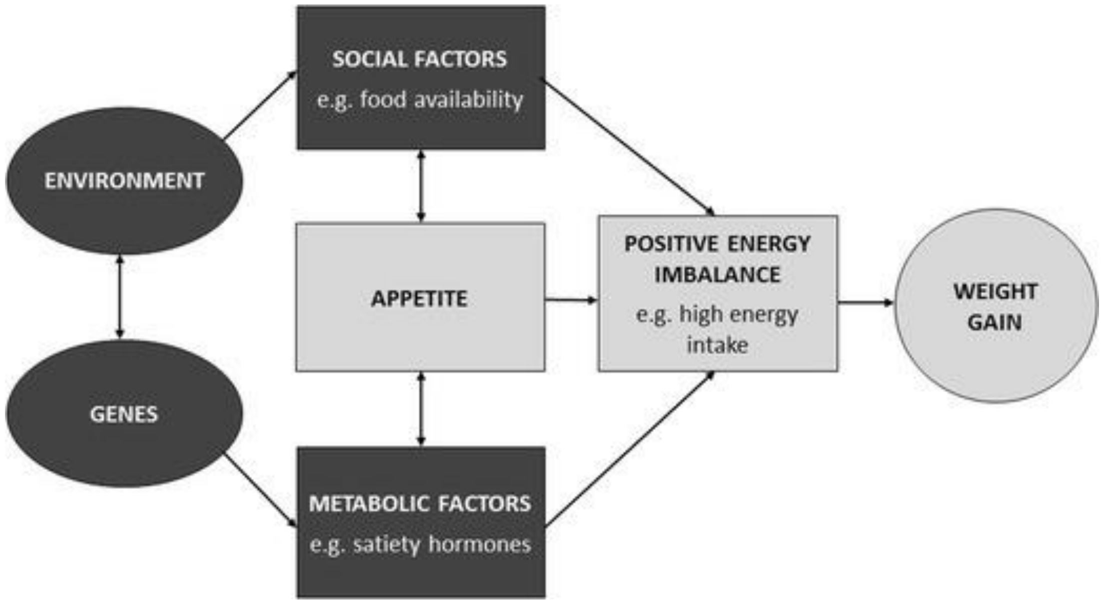


Figure 1.2. Model depicting Behavioural Susceptibility Theory. Behavioural Susceptibility Theory proposes that appetite mediates the interaction between genetic susceptibility to obesity and exposure to an obesogenic environment (Llewellyn & Fildes, 2017).

Studies using measured genetic obesity risk have provided support for BST, with results indicating that genetic susceptibility to obesity is partly mediated by appetitive traits (Jacob et al., 2018; Llewellyn et al., 2014). In children, appetite is commonly measured using the Child Eating Behaviour Questionnaire (CEBQ), a psychometric measure of eight appetitive traits in children (Wardle, Guthrie, Sanderson, & Rapoport, 2001; This measure is discussed further in **Chapter Two**). An infant version of the CEBQ, the Baby Eating Behaviour Questionnaire (BEBQ) was also developed to capture variation in appetite during the first six months of life (Llewellyn et al., 2011). Variation in these appetitive traits are evident from early childhood, influence food intake (Syrad et al., 2016) and weight gain in early life (Llewellyn et al., 2011; Quah et al., 2015, 2017; Steinsbekk et al., 2015), and are highly heritable from infancy and into childhood (Llewellyn & Fildes, 2017). Furthermore, a recent systematic review and meta-analysis highlighted appetitive traits are consistently cross-sectionally and prospectively associated with weight (Kininmonth, Smith, Carnell, et al., 2021), providing further support for a behavioural susceptibility model of weight. The evidence for associations between child adiposity and appetitive traits, as measured by the CEBQ and BEBQ, are discussed in greater depth in **Chapter Six (Paper Four)**.

1.3 The role of the home environment in childhood

As research into the aetiology of obesity has evolved beyond individual-level determinants to explore environmental influences, the home environment has become a point of focus. For younger children, the home setting is considered crucial in shaping diets, eating behaviours, activity related behaviours, and ultimately weight status. Children spend a significant amount of their early life at home and much of their food intake (around 70% for children aged 2-11) is consumed through meals and snacks eaten in the home setting (Chai & Nepper, 2015; Savage et al., 2007). It is also where children spend their free time. Unlike adolescents and adults, young children are entirely dependent on caregivers for their food, and experience fewer social and cultural interactions beyond the family. Although children gain more independence and autonomy over their eating habits and activity levels once they reach secondary school, they still spend a significant proportion of their time at home and it remains the primary place that food is consumed (Chai & Nepper, 2015). The home is also where children first learn eating- and physical activity-related behaviours, by observing and mirroring those around them (Savage et al., 2007). Dietary behaviours developed during childhood track into early adulthood (Bjelland et al., 2013). The eating behaviours, both healthy and unhealthy, that children learn at home are likely to endure long after they gain autonomy and leave this environment. This is also true for physical activity-related, and conversely sedentary, behaviours. Early childhood is an important period for the development of motor skills and this has been shown to predict time spent in physical activity in later childhood (Barnett et al., 2009). As such, the home environment plays a key role in shaping food preferences, dietary intake, physical activity levels and sedentary behaviours – key behavioural influences on children's energy intake and energy expenditure (Couch et al., 2014; Savage et al., 2007). Early childhood is a critical period for intervention and prevention in the development of overweight and obesity.

When considering the home environment, it is important to recognise that it does not exist in isolation, rather it is influenced by a range of societal, cultural, political and economic factors, as discussed in section 1.2.1. These aspects and how they pertain to children's energy balance behaviours (dietary intake, physical activity levels and sedentary behaviours) are depicted in **Figure 1.3.**

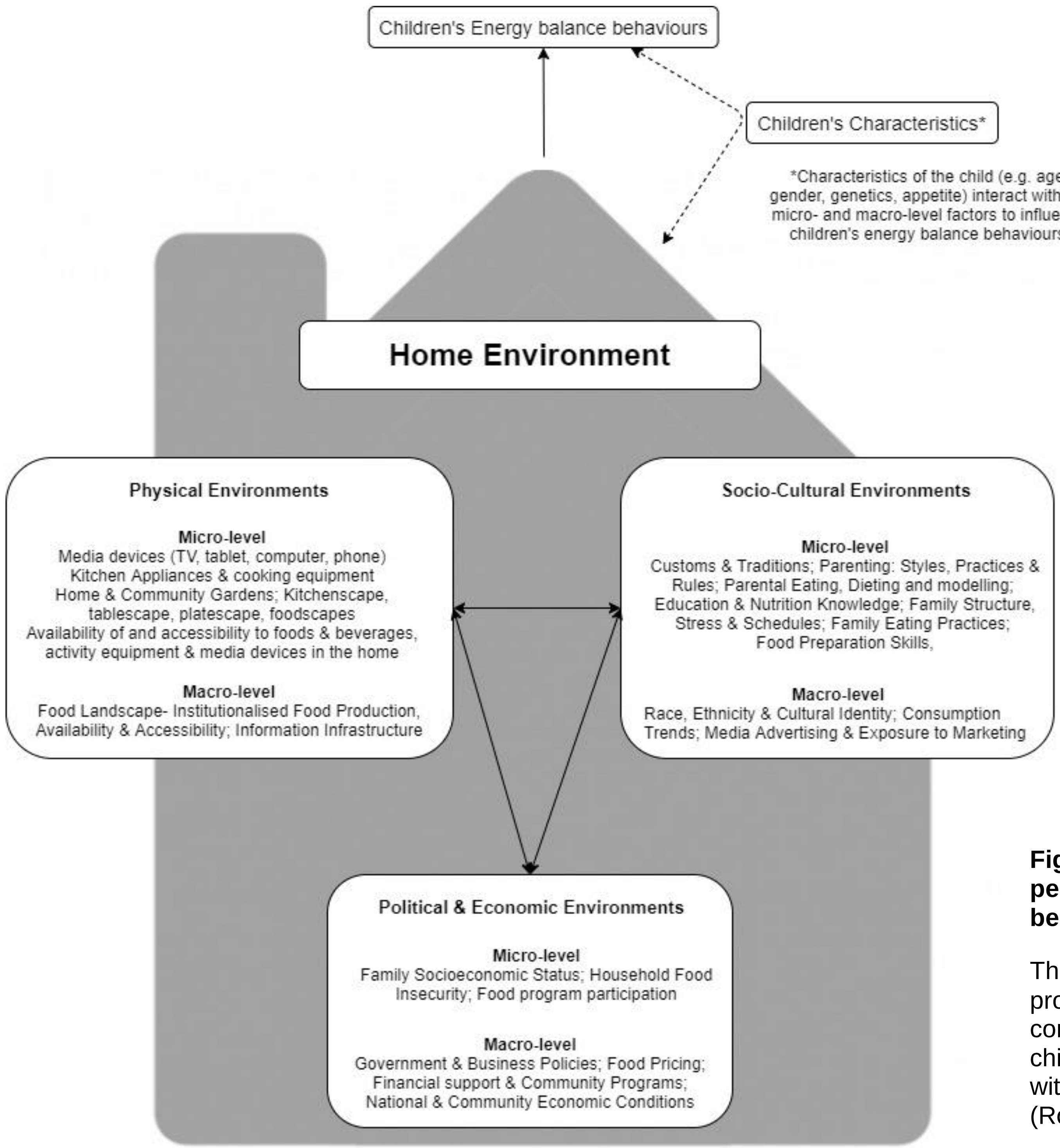


Figure 1.3 Model of the home food environment pertaining to children's energy balance behaviours.

The model comprises micro-level (defined as proximal to child's home) and macro-level (exist at community level but have potential to influence a child's home) factors (Adapted and reproduced with permission from Rosenkranz & Dzewaltowski (Rosenkranz & Dzewaltowski, 2008)).

1.3.1 Defining the obesogenic home environment

The home environment is multidimensional. Despite the wealth of research in this area, there is very little consensus about how to define and measure it (Pinard et al., 2012). The home environment has been conceptualised in a variety of ways but most commonly, and in this thesis, the home environment comprises three key domains; the food, the physical activity and the media environment (Gattshall et al., 2008; Schrempft et al., 2015). Each domain consists of physical and social factors that are hypothesised to influence a child's corresponding energy balance behaviours; food intake, activity levels and screen-based sedentary behaviours, and ultimately child weight (Gattshall et al., 2008). **Figure 1.4** provides a conceptual model of the home environment, presenting the three domains that will be examined throughout this thesis.

Caregivers are fundamental in shaping both the physical and social aspects of the home environment deemed important in children's health and development. In terms of the physical food environment, caregivers act as nutritional gatekeepers for the household, largely controlling; a) the types of foods and beverages available, b) the quantity of foods and beverages present, and c) the types and quantities of foods and beverages offered at mealtimes (Savage et al., 2007). Similarly for the physical media environment caregivers influence, a) the types of electronic devices available, b) the number of electronic devices available, and c) the location these devices are available e.g. in the child's bedroom. Within the physical activity environment caregivers also control the types of physically equipment available at home, and whether the child has access to a garden or outdoor space. However, caregivers are only able to control this to an extent as access to such activity facilities is also determined by financial and geographical factors.

From a social perspective, caregivers act as role models of eating practices and food intake, while also setting rules and structures around food within the home. Within the media domain, caregivers are role models of electronic media use, and set rules and limits around the use of electronic devices such as amount of screen time, use of devices in the bedroom, or during mealtimes. For the physical activity domain, caregivers are similarly role models of physical activity and play a pivotal role in providing the support and encouragement needed to help facilitate engagement in physical activity, whether it be as part of an informal activity e.g. a walk, bike ride, or activity in the garden, or as part of a more formal exercise or sporting activity, such as a team sport.

Throughout this thesis, the obesogenic quality of the home environment will simply be referred to as ‘the home environment’. As shown in **Figure 1.4,** these aspects of the home environment are hypothesised to play a key role in children’s energy balance behaviours and to directly influence weight status in childhood (Gattshall, Shoup, Marshall, Crane, & Estabrooks, 2008; Schrempft, van Jaarsveld, Fisher, & Wardle, 2015).

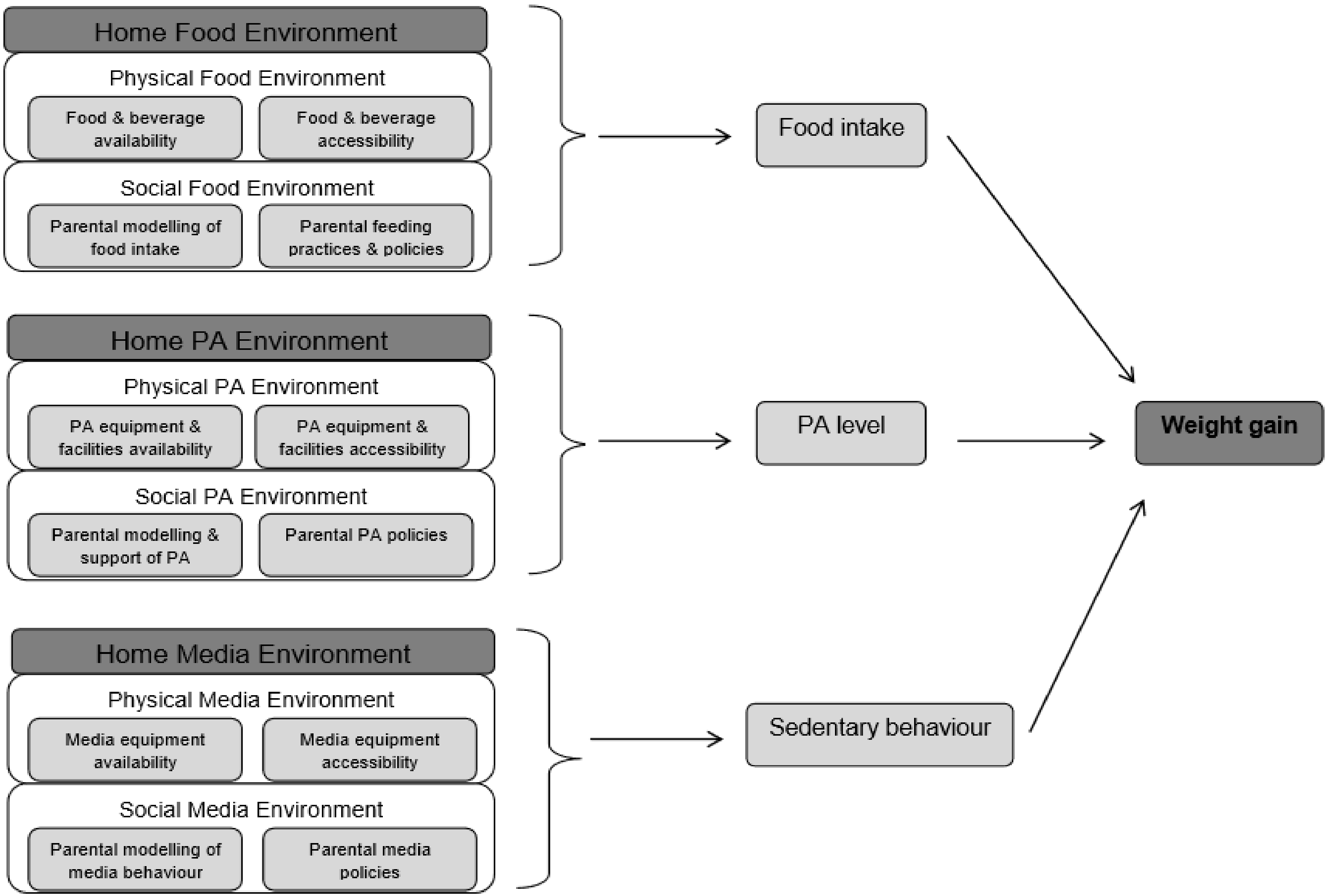


Figure 1.4. Model of home environmental factors that influence health behaviours; physical activity levels, food intake and sedentary behaviours.
Figure adapted from Gattshall et al., 2008; Schrempft et al., 2015. Abbreviations: PA, Physical activity

1.3.2 Measuring the home environment

A range of methods have been used to measure key features within the home environment deemed to play a role in children's energy balance behaviours, and weight (Pinard et al., 2012). Broadly speaking measures of the home environment can be divided into those that endeavour to capture either physical or social aspects, or both (see **Table 1.1**). Most research in this area has focussed on capturing one domain of the home environment (e.g. the home food environment), or a particular aspect within a domain (e.g. types of foods and beverages available, family meal times, caregiver modelling of television (TV) viewing or access to a garden) (Berge et al., 2015; Fulkerson et al., 2008a; Jago et al., 2014a; Palfreyman et al., 2014), to examine associations with energy balance behaviours and/or weight. Recently, researchers have taken a more inclusive and comprehensive approach to understanding the role of the home environment and have developed measures that capture two or more domains of the home environment (e.g. food and media, physical activity and media) (Bryant et al., 2008a; Hales et al., 2013; Rodenburg et al., 2013; Schrempft et al., 2015; Timperio et al., 2008; Vaughn et al., 2019). Very few studies have utilised comprehensive measures which capture both physical and social aspects of the home food, physical activity and media domains (Pinard et al., 2012). Research highlights that few studies include comprehensive evaluation of the psychometric properties of measures used, with many focussing on reliability rather than validity (Pinard et al., 2012). In the sections below, existing measures of the home food, activity and media environments are discussed in further detail.

Table 1.1. Methods commonly used to assess the home environment, based on physical and social aspects.

What is measured?	Type of measure	Advantages	Disadvantages	Examples of validated tools
Physical factors: Availability and accessibility of foods and beverages, physical activity equipment and garden/outdoor space, and electronic media devices in the home	Parent-report inventories or checklist	• Relatively low cost and easy to administer on large scale and at multiple time points	• Open inventories are time consuming to complete - high participant burden may result in reduced response rate or incomplete data • Potential for self-report biases e.g. social desirability.	• Home food Inventory (Fulkerson et al., 2008b) • Physical and Nutritional Home Environment Inventory (Spurrier et al., 2008) • Physical Activity and Media Inventory (Sirard et al., 2008)
	Parent-report questionnaires	• Relatively low cost and easy to administer on large scale and at multiple time points	• Potential for self-report biases e.g. social desirability.	• Home Food Availability: Active Where Parent-Child Survey (Couch et al., 2014) • HomeSTEAD (Vaughn et al., 2017) • HOME Inventory Describing Eating & Activity (Boles et al., 2019) • Comprehensive Home Environment Survey (Pinard et al., 2014)
	Parent-report telephone interview	• Opportunity for interviewer to prompt, probe or seek clarification to gain information. • Able to conduct at multiple time points	• Labour intensive and costly to administer • Potential for self-report biases e.g. social desirability.	• Home Environment Interview (Schrempft et al., 2015) • Healthy Home Survey (Bryant et al., 2008a)
	In home observation	• Objective measure, information gained via direct observation by researcher. • Social desirability bias reduced (but not eliminated)	• Very labour intensive and costly to administer • High participant burden, invasive and time consuming to conduct	• EATS (Coates & Thoresen, 1981; Terry & Beck, 1985)
Social aspects: Caregiver feeding practices, caregiver modelling and	Parent-report Questionnaires	• Relatively low cost and easy to administer on large scale • Range of standardized, validated, psychometric measures available.	• Potential for self-report biases e.g. social desirability.	• Parental Feeding Styles Questionnaire (Wardle et al., 2002) • Child Feeding Questionnaire (Birch et al., 2001) • Food Parenting Practices (Vereecken et al., 2004)

What is measured?	Type of measure	Advantages	Disadvantages	Examples of validated tools
support, caregiver rules & policies around eating, physical activity and media use.				• Household Food Rules (Bailey-Davis et al., 2017) • Comprehensive Feeding Practices Questionnaire (Musher-Eizenman & Holub, 2007).
	Parent-report telephone interview	• Relatively low cost and easy to administer on large scale	• Labour intensive and costly to administer • Potential for self-report biases e.g. social desirability.	• Home Environment Interview (Schrempft et al., 2015) • Healthy Home Survey (Bryant et al., 2008a)
	Behavioural observation of parent-child interactions during mealtime	• Objective measure, information gained via direct observation by researcher	• Labour intensive and costly - requires specialised equipment and trained researcher to code behaviour • Some designs have limited ecological validity • High participant burden, invasive and time consuming to conduct • Potential for unnatural behaviours and social desirability bias resulting from observation.	• BATMAN (Klesges et al., 1983) • Family Mealtime Coding Scale (Blissett et al., 2016); • Behaviors of Eating and Activity for Children's Health Evaluation System (McKenzie et al., 1991)

Abbreviations: HomeSTEAD, Home Self-administered tool for environmental assessment of activity and diet; BATMAN, Bob's and Tom's method for assessing nutrition; EATS, Eating Analysis and Treatment Schedule

1.3.2.1 Physical aspects of the home environment: availability and accessibility

Physical aspects within the home food environment include the availability and accessibility of foods and beverages. Availability is commonly measured by assessing the frequency with which foods and beverages are present in the home (e.g. *"How often do you have fruit in the home?"*) and the amount or variety of these (e.g. *"What types of fresh fruits do you have in the home?"*) (Schrempft et al., 2015). Accessibility is assessed in terms of the physical location (i.e. can the food be accessed by child, without assistance) or visibility (i.e. can be seen, out in the open) of foods and beverages in the home (e.g. *"Without opening any fridge or cupboard doors, is there any kind of confectionery in your home now displayed out in the open?"*) and the extent to which available foods are prepared or ready-to-eat (e.g. *"Do you have any ready to eat fresh vegetables on a shelf in the fridge or on the kitchen counter now?"*) (Schrempft et al., 2015).

For the physical activity environment, researchers have tended to measure availability by assessing the presence of physical activity equipment. This includes either fixed equipment, such as trampolines, basketball hoops, or moveable items, such as rackets, footballs, bikes, (e.g. *"Do you have any usable play equipment such as swings, slides, climbing or ladders in your yard?"* (Bryant et al., 2008b)) and/or the presence (e.g. *"Do you have a garden or outdoor space?"* (Schrempft et al., 2015)) and size of a garden/outdoor space (e.g. *"Would you say that your garden or outdoor space is small, medium or large?"* (Schrempft et al., 2015)). Accessibility has been measured in terms of a child's ability to use physical activity equipment or their access to a garden/outdoor space (e.g. *"To what extent would you agree that your child has adequate room to play actively inside the home?"* (Bryant et al., 2008a))

For the home media environment, availability is commonly measured by assessing the types and number of electronic media devices available within the home (e.g. *"How many working computers or laptops do you have in your home?"* (Bryant et al., 2008b)). Accessibility can be assessed in terms of the physical location or visibility of the electronic media devices in the home (e.g. *"Does your child have a working TV in their bedroom?"* (Bryant et al., 2008b)).

Researchers take a variety of approaches when measuring availability and accessibility of the home food, activity and/or media environments, including caregiver-reported checklists, questionnaires, telephone interviews, or in-home observations. Table 1.1 provides a comprehensive overview of the methodologies used, the strengths and limitations of each method and examples of validated tools. Measures vary in length; some are comprehensive, using multiple items to capture a wide range of foods and beverages or electronic devices, while others use fewer items and simply focus on one food group (e.g. energy dense foods or sugar sweetened beverages), one electronic device (e.g. television) or one physical activity feature (e.g. garden). This variation emerges from the constant need to balance the richness of data against the participant burden generated by these types of studies. Longer, more comprehensive measures are time and resource intensive, impacting participants' willingness to respond. These measures, like many in the area of children's energy balance behaviours, rely on caregiver-report and can be affected by social desirability biases (Van De Gaar et al., 2016). Caregivers' might choose responses suggestive of a ‘healthier’ home environment, because they are aware of what might be perceived as the ‘desirable’ answer. This is arguably even more problematic when the researcher asks participants direct questions, using interview-style methodologies, than when participants complete digital or paper-based questionnaires. In contrast, observational methods, whereby the researcher visits a participant’s home and visually inspects the kitchen, food storage areas (Bryant et al., 2008a; Terry & Beck, 1985), have the advantage of greater objectivity. However, such methods are labour intensive, costly, intrusive and potentially burdensome for the participant (Bryant & Stevens, 2006). Additionally, although social desirability bias is reduced when using observations, it is not eliminated. One small US study of 16 families (8 families with obesity, 8 families without obesity) with children aged 8-12 years examined food availability via in-home observations over two visits, revealing differences between the two visits. Their findings revealed that at the first home visit families with obesity stored more food items and had more energy-dense foods visible in the home than families without obesity (mean number of energy-dense foods on display 4.50 (4.84) vs 1.37 (1.50)), whereas at the second visit the availability of food items in the homes of the families with obesity had reduced significantly (Terry & Beck, 1985). This suggests participants may adapt the types of foods and beverages available within their homes in response to researcher observation.

Another key limitation across all methodologies, is the tendency to collect data at a single time-point. This may be more problematic for physical aspects of the home food environment as it fails to capture fluctuations in the types and/or amount of foods and beverages available in the home over the course of weeks and months, or due to seasonal variation or special occasions. It may be less of an issue for physical aspects of the home physical activity and media environments as these are likely to be more stable over time. For example, availability and access to garden/outdoor space is unlikely to change unless the family moves house.

1.3.2.2 Social aspects of the home environment: caregiver modelling and support, caregiver feeding practices, caregiver policies and rules

Social aspects of the home environment include caregiver feeding practices, caregiver modelling, caregiver support, and caregiver policies and rules around eating, activity and use of electronic devices in the home. Of these, caregiver feeding practices (also referred to as parent feeding practices) have received the most attention in the literature. Caregiver feeding practices are specific goal-oriented behaviours, not exclusively restricted to the home setting. They comprise feeding behaviours used to influence *what*, *when* and *how much* a child eats, including constructs such as; 1) pressure to eat (e.g. *"My child has to finish his/her plate"*), 2) use of food as reward (e.g. *"I reward my child with something to eat when s/he is well behaved"*), 3) restriction of food (e.g. *"I have to be sure that my child does not eat too many sweets"*), and 4) emotional feeding[1] (e.g. *"I give my child something to eat to make him/her feel better when he/she has been hurt"*). Over the past decade, there has been a rapid increase in the development of tools designed to measure caregiver feeding practices. This has resulted in inconsistent definitions of constructs and terminology being used interchangeably (e.g. feeding styles, parenting styles, feeding behaviours, feeding practices), despite having different meanings (Vaughn et al., 2013; Wood et al., 2020). For

[1] Otherwise known as using food to control negative emotions. Examples include parent using food to manage or calm the child when he/she is upset, angry, fussy, hurt or bored.

example, there is clear overlap between constructs such as feeding styles and feeding behaviours[2], which can be confusing (Vaughn et al., 2013, 2016).

Caregiver modelling, like caregiver feeding practices, are not restricted to the home setting. Caregiver modelling is a mechanism by which children learn their own behaviours (i.e. what to eat and what not to eat) by observing the behaviours of their parents. As such, caregivers may model eating behaviours, physical activity or sedentary behaviour intentionally (i.e. consciously eating certain foods in front of their child) or unintentionally (i.e. a child simply observing their caregivers' natural eating behaviour). Modelling has been measured in a variety of ways, ranging from asking caregivers to report their own dietary intake (Yee et al., 2017), activity levels, or sedentary behaviours (Schoeppe et al., 2017) to asking about intentionality of behaviours exhibited in front of the child (e.g. *"I model healthy eating for my child by eating healthy foods myself"* (Musher-Eizenman & Holub, 2007)). Simply measuring parents' dietary intakes, activity levels and/or sedentary behaviours alone is problematic as it fails to capture a key feature of the modelling process - whether the behaviour is actually observed by the child.

Like modelling, caregiver support is key in facilitating behaviour, especially among infants and young children. Caregiver support can be separated into two forms; a) practical support (e.g. *"How often in the past 7 days did you or another*

---

[2] Feeding styles capture the overall emotional climate of meals and are measured along 2 dimensions: responsiveness (represented by warmth, acceptance, and involvement during feeding) and demandingness (represented by parental control and supervision of feeding). Feeding behaviours can be categorised into four feeding styles: authoritarian, authoritative, indulgent, and uninvolved, which the extent to which a caregiver's overall feeding behaviours reflect responsiveness to the child within the context of boundary setting around food (Wood et al., 2020).

adult in the household take your child to practice, lessons, classes or other programs that involved moderate or vigorous physical activity?" (Vaughn et al., 2019)); and b) emotional support (e.g. *"I encourage my child to eat a variety of foods?*"(Musher-Eizenman & Holub, 2007)). Support, particularly emotional support, is a subjective concept and therefore difficult to measure accurately. In contrast, caregiver policies and rules around eating, activity levels and sedentary behaviours in the home are more specific and easier to conceptualise. Again, measures used to capture these factors vary in their scope but they most commonly examine caregiver rules and limit setting in relation to food, activity levels and/or sedentary behaviours (e.g. *"No snacking while watching TV/DVDs"* (Birch et al., 2001)).

Measurement of all the social aspects of the home environment most commonly rely on caregiver report, as naturalistic observation of these constructs can be difficult to capture. Observational measurement can be labour intensive and costly to administer, and carries the risk that caregivers may alter their behaviours in response to being observed (Gardner, 2000; Hughes et al., 2011). This may be a particular issue when observations take place in artificial locations such as a clinic or laboratory setting, rather than in a participants' own homes (Gardner, 2000). However, observational techniques offer a way to capture caregiver-child interactions that may be difficult to assess through self-report, either due to lack of awareness of own behaviour or socially desirable responding (Gardner, 2000).

1.3.2.3 Multi-component measures of the home environment

Over the past decade, researchers have endeavoured to develop more comprehensive measures of the home environment. One of the earliest multi-component measure of the home environment, The Family Activity and Eating Habits Questionnaire was developed by Golan & Weizman (1998). This measure examined physical and social aspects of the food environment, such as availability and accessibility of energy-dense snacks, caregiver limit setting around energy-dense snacks, caregiver feeding practices and eating behaviours. It also incorporated measures of parental activity levels and parental sedentary behaviours. Items for this measure were developed based on a review of the literature and via consultation with experts to identify factors that affect obesity and weight loss and evaluate the questionnaires content validity (such as completeness of criteria, clarity and suitability of scoring, and rate the relevant and importance of each item). Test-retest reliability was excellent for individual items (r=0.78-0.90) and internal consistency of the measure was excellent. Criterion validity was not assessed. Criterion validity could have been assessed using more objective measures such as in-home observations or wearable cameras.

Another comprehensive measure of the home environment, the Healthy Home Survey (HHS) was developed for administration via telephone interview with parents of children aged 3-8 years old living in the US (Bryant et al., 2008a). This measure captures both physical and social features within the home food, activity and media environment. Items were developed based on a literature review and experts were consulted to gain feedback on item relevance. A key strength of the development and psychometric evaluation of the HHS is that home visits were utilised to examine criterion validity of the measure. Home visits were carried out on average 7.9 (SD 3.6) days after the first telephone interview. Criterion validity values were poor to excellent (ICC ranged from 0.30 – 0.82), with lowest estimates observed for availability of sweet snacks and salty snack foods. Test-retest reliability of the measure over a 2-week period varied from low to high (ICC = 0.22-0.91).

Building on the work by Bryant et al., (2008), Schrempft et al., (2015) made adaptations to the HHS to make the language specific to the UK population. Additional scales were included to more comprehensively assess caregiver support of physical activity, caregiver media use, and neighbourhood satisfaction. Caregiver feeding practices were also examined using an additional validated questionnaire. The Home Environment Interview (HEI) was developed for administration via computer-assisted telephone interview by trained researchers with parents of pre-school aged children. Test-retest reliability (n=44) of the measure was moderate to excellent over a two-week period (ICC = 0.71-0.92). Construct validity of the HEI was also good, with findings indicating cross-sectional associations between the home environment composites (food, activity, media and overall) and children's energy balance behaviours such as food intake, physical activity levels and sedentary behaviours in pre-school children (Schrempft et al., 2015). Criterion validity, measured via wearable cameras over a four-day period (n=15), was good or excellent (ICC or kappa ≥0.60) for most HEI variables captured. Validity was poor (ICC or kappa <0.40) for tinned and frozen vegetable availability and variety, and sweet snack availability (Schrempft et al., 2017).

Other researchers have developed shorter measures which aim to act as a 'screening' tool and provide a snapshot of the home environment. One example of this type of measure is the Family Nutrition and Physical Activity (FNPA) tool, a 21-item questionnaire capturing ten constructs identified as associated with overweight and obesity. The FNPA captures information about family mealtimes, caregiver modelling of food intake, physical activity, household rules (i.e. eating while watching TV) and children's energy balance behaviours (Ihmels, Welk, Eisenmann, & Nusser, 2009). The constructs included in the FNPA are used to create a total score, whereby higher scores represent a more favourable family environment. There was limited evaluation of the psychometric properties of the FNPA; test-retest reliability, inter-rater reliability and criterion validity were not assessed. However, construct validity revealed positive associations between the total FNPA score and child BMI, both cross-sectionally and prospectively (n=704) over a one year period (Ihmels, Welk, Eisenmann, & Nusser, 2009; Ihmels, Welk, Eisenmann, Nusser, et al., 2009). Screening tools such as the FNPA, offer a valuable opportunity for studies with limited time, resources, or money to capture a snapshot of the home environment. However, such methods are limited and may overlook important features, such as availability or access to foods and beverages, electronic devices, and physical activity equipment, within the home environment. In contrast to screening tools, more comprehensive measures (as discussed above) yield a larger amount of information and may offer greater insight into the influence of the environment as a whole.

1.4 Associations between the obesogenic home environment and children's energy balance behaviours

In sections 1.4.1-1.4.3, the current evidence base for associations between the home environment and children's food intake, physical activity levels and screen-based sedentary behaviours – key behavioural influences on energy balance -

will be discussed in detail. A systematic review of the evidence for associations between the home environment and child weight was conducted (Kininmonth, Smith, Llewellyn, et al., 2021) and is presented in **Chapter Three (Paper One).**

1.4.1 The home food environment

1.4.1.1 Physical aspects: availability and accessibility

Observational and experimental studies have consistently demonstrated that the types of foods and beverages present in the home are important correlates of children's dietary intake (Cook et al., 2015; Dave et al., 2010; Hanson et al., 2005). This is unsurprising, as foods need to be both available and accessible for a child to consume them. Evidence is most consistent for fruits and vegetables, with availability identified as the strongest predictor of consumption, even among individuals with lower preference for those foods (Campbell & Crawford, 2001; Neumark-Sztainer, Wall, Perry, & Story, 2003). Research also suggests that availability of fruits and vegetables in the home may shape children's liking for these foods (Campbell & Crawford, 2001). Repeated exposure to a food has been consistently shown to positively influence food preference (Cooke, 2007). Familiarity is a key determinant of a child's liking for a particular food and liking is a strong predictor of intake; in other words, children 'like what they know and eat what they like' (Cooke, 2007; Savage et al., 2007). The relationship between home availability and intake has not only been observed for nutrient dense foods, such as fruits and vegetables; various experimental and observational studies have demonstrated similar associations for energy-dense snack foods (n=167, 11-16 year olds) (Watts et al., 2018), dairy products (n=347, 12-13 year olds) (Campbell et al., 2007), fruit juice (n=225, 9-12 year olds) (Cullen et al., 2003), and sugar-sweetened beverages (n=187, 10-14 year olds) (Santiago-Torres et al., 2014). These findings have been reported in children of disparate ages and backgrounds, including rural, low income, culturally and ethnically diverse families (Boles et al., 2019; Santiago-Torres et al., 2014).

Beyond availability in the home, experimental and observational research has shown children's consumption of certain food groups increases further when those foods are accessible (Hearn et al., 1998). For children with lower preference for fruits and vegetables, increasing the visibility of these foods within the home by placing them in easy-to-reach locations and in forms that encourage consumption (e.g. pre-prepared, ready to eat), may be particularly important to encourage intake (Pearson et al., 2011). Similar findings have been observed for foods and beverages high in fat, sugar and salt. A cross-sectional study of 521 UK children aged 11-12 years reported greater availability of, and access to, energy-dense foods was associated with higher consumption of these foods and lower consumption of fruits and vegetables (Pearson et al., 2017). While greater availability of fruits and vegetables and lower accessibility of energy-dense snacks in the home predicted greater consumption of fruits and vegetables and lower consumption of energy dense foods (Pearson et al., 2017). These findings suggest making simple environmental modifications within the home, such as putting fruits and vegetables in an easy-to-reach location (e.g. a fruit bowl on the kitchen counter) and making energy dense snack foods harder to obtain (Larson et al., 2017; Pearson et al., 2011) (e.g. on the top shelf, inside a cupboard), could help to improve the quality of children's diets. Further to this, covert restriction – not having the food available or accessible within the home – has been suggested to be an effective way to limit intake of certain foods (Ogden et al., 2006).

However, the majority of research in this field is cross-sectional meaning we cannot be sure about the direction of these associations, or determine causality. Limited data from randomised controlled trials (n=343, 3-5 year olds; n=103, 9-12 year olds) suggest modifications to the home food environment, such as reduced access to energy-dense snack foods or increasing accessibility of vegetables, are associated with improvements in dietary intake (Fletcher et al., 2013; Overcash et al., 2019). Yet, more longitudinal and experimental research is required to establish the extent to which availability and accessibility of foods and beverages in the home causally influences children's food preferences and dietary intake. Or the extent to which children's preferences shape their home food environment, with caregivers providing the foods and beverages their children most enjoy.

1.4.1.2 Social aspects

Alongside providing the physical food environment within the home, caregivers play a key role in shaping the social home food environment. Experimental and observational studies have shown that caregiver behaviours, such as caregiver feeding practices, modelling and support, are strong predictors of children's food intake (Yee et al., 2017).

1.4.1.2.1 Caregiver feeding practices

In the context of increasing concern about child obesity, caregiver feeding practices have received substantial attention as a potentially important influence on children's eating behaviours, i.e. the what, when and how much of children's diets. Although certain practices are likely a reflection of caregivers' well-intentioned attempts to improve their children's diets, observational research has suggested the use of certain non-responsive or controlling feeding practices (including restriction and pressure to eat) may disrupt a child's ability to self-regulate their appetite and negatively impact on diet quality. 'Pressure to eat', when a parent urges their child to consume a food they do not want to eat, or a greater quantity of food than they wish to, has been linked with increased selective or fussy eating behaviours in children (Jansen et al., 2017; Ventura & Birch, 2008). It is hypothesised that stressful feeding encounters may negatively impact preferences for certain foods, or impair a child's ability to self-regulate and respond to their internal satiety signals (Ventura & Birch, 2008). Similarly, openly restricting a child's access to certain types of foods may cause a 'forbidden fruit' effect, whereby the desirability of the 'forbidden fruit' increases, making the child more likely to seek out and potentially overeat when they eventually have access to it (Bauer et al., 2017; Fisher & Birch, 1999). However, the majority of research into caregiver feeding practices within the home is cross-sectional and survey-based, making it extremely difficult to fully adjust for confounding influences such as socioeconomic status or cultural differences, or to tease apart causation.

It is also important to highlight that parenting is in part reactionary; parents respond to and are influenced by their child's characteristics and behaviours. For example, parents may restrict certain types or amounts of food in response to their child's weight status or dietary preferences. Or, a parent may use more pressuring practices because their child expresses fussiness around food. Several sibling studies have found support for a child responsive model of caregiver feeding, demonstrating that caregivers vary their feeding practices for children who differ in their eating behaviours or weight status. Caregivers appear to use more pressure to eat with their fussier or lighter child, and more restriction with their food responsive or heavier child (Berge, Meyer, et al., 2016; Berge, Tate, et al., 2016; Harris et al., 2016). Similar findings were also observed in a large twin study (n=10,346, age 10) using genome-wide polygenic scores (GPS), which found that caregivers of children with genetic predisposition to higher BMI used more restriction, and caregivers of children with predisposition to lower BMI used pressuring practices more (Selzam et al., 2018).The limited longitudinal research in this area supports both directionality from child characteristics to parent's use of controlling feeding practices, as well as the reverse (Farrow & Blissett, 2008; Jansen et al., 2017; Rodgers et al., 2013).

1.4.1.2.2 Caregiver modelling and support

Caregivers also shape their children's eating through intentional and unintentional modelling of behaviours in the home (Palfreyman et al., 2013). Existing research has shown that simply observing a caregiver passively eating a particular food is not always enough to encourage a reluctant child to eat it too (Blissett, 2018). Infants and children are more likely to try and accept new food, or eat more of a food, when it is presented in a positive social context and the model is enthusiastic (Blissett et al., 2016; Hendy & Raudenbush, 2000; Savage et al., 2007). Positive modelling of 'healthy eating' has been consistently associated with greater consumption of fruits and vegetables in pre-school (2 to 6-year olds) and school aged (7 to 11-year olds) children (Yee et al., 2017). Less positively, higher intakes of energy-dense and high sugar foods have also been observed among children whose caregivers model eating these foods (Yee et al., 2017).

Like modelling, caregiver verbal support of ‘healthy eating’ has been associated with higher preference for and consumption of fruits and vegetables, as well as lower liking and consumption of energy dense foods (Vollmer & Baietto, 2017; Young et al., 2004). However, research into both caregiver modelling and support has again been largely cross-sectional and focussed predominantly on children from higher income and less ethnically-diverse backgrounds, limiting generalisability to the most vulnerable populations.

1.4.1.2.3 Caregiver practices and rules

Mealtimes are a key social feature within the home and a major component of the home food environment. Family mealtime practices, in terms of both the types of foods offered and the rules enforced, have been linked with dietary intake and obesity risk in both caregivers and children (Berge et al., 2015; Jones & Fiese, 2014; Lytle et al., 2011). Eating meals together as a family has been associated with increased consumption of fruits and vegetables, and lower consumption of sugar sweetened beverages (Neumark-Sztainer, Hannan, et al., 2003), but the setting may also be important. Family meals consumed in front of the TV have been found to contain fewer vegetables, grains and calcium rich foods, and more fried foods, than those eaten without the TV on (Avery et al., 2017). A recent review emphasised that children, regardless of age group, who ate while watching television had poorer quality diets, consuming more energy-dense foods, more sugar-sweetened beverages, and fewer fruits and vegetables (Avery et al., 2017). Eating in front of the TV has also been associated with increases in the amount of food consumed, as well as overall energy intake at meals (Temple et al., 2007). This effect has been partly attributed to TV acting as a distraction which shifts a child’s attention away from eating, inhibiting awareness of food intake and internal satiety cues. In addition, the presence of technology can also inhibit social interactions, and positive feeding interactions (e.g. positive modelling, responsiveness) that may occur at mealtimes.

Socioeconomic status (SES) and ethnicity (Neumark-Sztainer, Hannan, et al., 2003) have been linked to variation in the structure of family mealtimes. Children from lower SES backgrounds have been reported to eat fewer family meals and to be more likely to have the TV on while eating. Qualitative evidence has helped shine light on the barriers to traditional family mealtimes experienced by many (Jarrett et al., 2016). Time pressures, conflicting schedules, shift work and lack of space and/or a dining table all impact on a family's ability to schedule and structure mealtimes together (Jarrett et al., 2016).

1.4.2 The role of physical activity environment

1.4.2.1 Physical aspects: availability and accessibility

A systematic review of the 43 peer-reviewed studies revealed that availability of and access to non-fixed physical activity equipment (such as balls, wheeled toys), access to open space, and having a large garden or outdoor space, were correlates of higher levels of physical activity in pre-school aged children (De Craemer et al., 2012). Similar findings were also observed in an earlier review of 108 peer-reviewed studies which examined correlates of physical activity in children (ages 3-12) and adolescents (ages 13-18) (Sallis et al., 2000). Findings from cross-sectional studies examining associations between availability and access to physical activity equipment and children's physical activity have been mixed (Ferreira et al., 2007; Verloigne, Lippevelde, et al., 2012), with some studies demonstrating positive associations (Tandon et al., 2014) but the majority of studies revealing no association. The limited longitudinal research (n=301, children aged 10-12, followed over a 5 year period) in this area suggests availability of, and access to, physical activity equipment at home may not be a predictor of physical activity over time (Crawford et al., 2010). It may be that the physical aspects of the home physical activity environment play a role in children's activity levels by acting as an environmental facilitator but availability/access to activity equipment alone is insufficient to predict behaviour. Furthermore, there may be age-related variation in relationships between the home activity environment and children's activity levels, such that the home setting is more important for younger children, who spend greater time there. Whereas, for older children, school and neighbourhood environments may be more important for shaping activity levels.

1.4.2.2 Social aspects: caregiver modelling and support of activity

Caregivers influence children's physical activity behaviours through various mechanisms including role modelling, encouragement, and support, such as transportation to a sports club or activity (Sallis et al., 2000). Existing literature indicates that caregiver support and modelling of physical activity are positively correlated with children's physical activity levels (Pearson et al., 2009; Sallis et al., 2000; Sleddens et al., 2012; Tandon et al., 2014), although not all studies have found an association and the findings may vary by children's age, gender, ethnicity (Dolinsky et al., 2011; Eichinger et al., 2017; Sallis et al., 2000; Sleddens et al., 2012; Verloigne, Van Lippevelde, et al., 2012). Research conducted in children aged 6-16 years (n=889) old demonstrated that caregivers physical activity levels were a key correlate of children's physical activity levels (Bringolf-Isler et al., 2018), in particular when engaging in physical activity with their child and by providing logistical support, such as transportation to activity venues (Verloigne, Van Lippevelde, et al., 2012).

The relationship between parental and child physical activity has also been observed when activity levels are measured using accelerometers (Bringolf-Isler et al., 2018; Moore et al., 1991), rather than self-report questionnaires. Accelerometers are small wearable devices that detect accelerations or changes in velocity produced by the body over a given time (Ridgers & Fairclough, 2011). Accelerometers provide an objective measure of the frequency, duration and intensity of physical activity with minimal burden to participant (Welk et al., 2000). One US study of families (n=99 mothers and n=92 fathers) and their children (n=100, aged 4-7 years) who wore accelerometers for 8.6 days revealed that children with two physically active parents were 5.8 times more likely to be physically active compared to children with two inactive parents (Moore et al., 1991). The association between caregiver-child physical activity levels may in part reflect that parents who are more physically active, are also more likely to create an environment that is conducive to physical activity by encouraging their child to engage in activity, ensuring there is adequate equipment for activity and by supporting them to engage in activities.

1.4.3 The home media environment

1.4.3.1 Physical aspects: availability and access

Technology is a key feature within the home. Over the past decade, availability and access to a wide range of electronic devices such as mobile phones, tablets, laptop computers and games consoles have risen dramatically (Ofcom, 2019). Such devices are now a common feature in the home and are often present when food is eaten, whether children eat alone or with family. A 2017 systematic review revealed the negative impact of television on children's dietary behaviours, with children who watched TV while eating consuming more energy-dense snack foods, sugar sweetened beverages and fast foods, and fewer fruits and vegetables compared to those who did not watch TV while eating (Avery et al., 2017). These findings were observed in children (2-6 year olds [n=135]; 4-5 year olds [n=1540]; 8-10 year olds [n=697], 10-11 year olds [n=4966]; 2-9 year olds [n=15144]) and adolescents (12-17 year olds [n=1231];11-18 year olds [n=4064]; 14-16 year olds [n=495], 12-15 year olds [n=15973]). Much of the existing literature focussing on availability of and access to electronic devices in the home has focussed on TV, with a large number of studies demonstrating significant associations between access to TV in the child's bedroom and greater time spent watching TV. What is more, these findings have been observed in both cross-sectional (Bassul et al., 2021; Jago et al., 2012; Lo et al., 2015; Wethington et al., 2013) and longitudinal studies (Atkin et al., 2013), which allows us to elucidate the directionality of association over time.

Technological advances in recent years has necessitated broadening research focus to encompass a wider range of devices (Chahal et al., 2013; Ofcom, 2020). A cross-sectional study of 502 9-11 year olds revealed that children with 2-3 screens in their bedroom engaged in significantly more screen time overall (4 hours/day) compared to children with no devices in the bedroom (2.5 hours per day) (Chaput et al., 2014). These findings are supported by research conducted in pre-school aged children (Spurrier et al., 2008) and children aged 6-11 years (Tandon et al., 2012a, 2014). No association was observed between number of devices in bedroom and physical activity levels or sleep duration (Chaput et al., 2014). However, other studies have reported significant reductions in sleep duration and physical activity levels among children with devices in their bedrooms (Chahal et al., 2013; Ferrari et al., 2015). Furthermore, a large cross-sectional study of 9-11 year old children (n=5,844) which pooled data from 12 countries revealed having a TV or computer in the bedroom were key correlates of not meeting the physical activity guidelines and engaging in more screen-based sedentary behaviours (LeBlanc et al., 2015).

Although an understudied area, SES has been linked to variations in availability and access to electronic devices in the home (Tandon et al., 2012b). One study conducted in children from the US aged 6-11 (n=715) revealed greater access to electronic media devices in the bedroom among children from lower income households compared to children from higher income households (TV 52% vs 14%, video games 21% vs 9%, respectively) (Tandon et al., 2012b). Similar findings were reported in US children aged 0-8 years, with 64% of children living in low income households having access to TV in the bedroom compared with 20% of children living in high income households (Common Sense Media, 2011). The paradoxical association between low SES and greater access to expensive electronic devices seems counter-intuitive, however, a lack of time to supervise children (Stenhammar et al., 2007), less access to alternate activities (Fairclough et al., 2009) and greater concerns about neighbourhood safety (Burdette & Whitaker, 2005; Weir et al., 2006) may make indoor screen-based entertainment more appealing than outdoor activities for lower SES households (Tester et al., 2020).

1.4.3.2 Social aspects

1.4.3.2.1 Caregiver rules and limit setting around media use

This rise in technology over the past decade has led to changes in consumption habits; children aged between 5 and 15 years now spend far more time online than they do watching TV (Ofcom, 2019, 2020). As a result, companies have modified the way they advertise to children - with a rise in digital marketing to children through social media sites such as YouTube and Instagram. Such ways of advertising have the potential to influence children, through peer-to-peer promotions (e.g. tagging friends, sharing posts), the use of “influencers”, and personalised advertisements (Boyland et al., 2018; Kelly et al., 2019). Irrespective of the medium through which food is advertised, studies have demonstrated advertisements are effective at influencing children’s brand loyalty and food choices (Story & French, 2004). In addition, children who are exposed to food advertisements are more likely to either pester their parents to purchase energy-dense food products or purchase energy-dense snack foods and beverages themselves (Boyland et al., 2018). As previously discussed, the types of foods available in the home are associated with children’s consumption, therefore, reducing a child’s exposure to TV and online food advertising, via limit setting, may help to minimise the influence on the home food environment, and subsequently children’s diet.

Increased screen-time and poorer diet quality are behaviours that tend to co-occur (Pearson et al., 2018). This clustering of behaviours has been observed in cross-sectional studies of 5-6 year olds (Pearson et al., 2018) and 11-12 year olds (Seghers & Rutten, 2010) and longitudinally in children from aged 5 to 8 years (Gubbels et al., 2012). Experimental studies suggests caregiver behaviours, such as enforcing rules and limit setting around media, may help to uncouple these behaviours and encourage healthier eating habits (Epstein et al., 2008). Two reviews revealed that studies examining rules and limit setting tended to focus on rules around TV and not the wide variety of devices (e.g. phones, tablets, laptops) that are now common features within the home (Aftosmes-Tobio et al., 2016b; Jago, Edwards, et al., 2013). Technological advances have led to a rapid rise in the popularity of these devices, making it difficult for research to catch up. With regard to TV rules, consistent associations have been observed between caregiver rules around TV viewing (e.g. time limits, content restriction, parental supervision etc.) and children's TV viewing, with caregiver rules and limit setting associated with less time engaged in TV viewing (Aftosmes-Tobio et al., 2016a; Spurrier et al., 2008; Vandewater et al., 2007). Additionally, data from a large study of parents with children aged 6-17 years (n=63,145) reported that children from households without TV rules were 74% more likely to engage in more than two hours of screen time each day compared to children from households with rules (Gingold et al., 2013).

More recent research with parents of children aged 6-8 years (n=735) aimed to capture data on caregiver rules and limit setting around a wider range of devices, such as TV, computer, video games and smartphones (Kesten et al., 2015). Contrary to previous findings, results revealed that 'always' setting limits around media devices was associated with higher TV viewing, computer use, smartphone use and game console use. The cross-sectional nature of this study precludes our ability to understand the directionality of association. Caregivers may have enforced more rules around devices in response to their child already spending significant amounts of time using media devices. Longitudinal research is required to understand the directions of these relationships. In contrast to these findings, a cross-sectional study of parents with 3-12 year olds (n=129) revealed children living in households with stricter limits and greater supervision of screen media spent less time engaged in TV viewing and video game use (Vaughn et al., 2019). The evidence surrounding TV rules is more consistent but greater research is needed to understand the role of caregiver rules/limit setting around a wider range of screen-devices to understand relationships with children's screen-time behaviours, particularly as consumption habits evolve from traditional viewing to multiscreen viewing behaviour (i.e. using multiple devices simultaneously).

1.4.3.2.2 Caregiver modelling of media use

Similar to modelling of food intake and physical activity, studies have shown positive associations between caregiver and child screen-viewing time (Schoeppe et al., 2017). Data from 2965 families with 3-10 year olds revealed children with parents that watched >2 hours of TV per day were also more likely watch >2 hours of TV per day (Jago et al., 2012). These findings are supported by another cross-sectional study of UK families with 5-6 year old children (n=1078), which found if both parents spent >2 hours watching TV on a weekday, their children were 3.4 times more likely to spend >2 hours watching TV (Jago et al., 2014b). The influence of maternal and paternal modelling may differ based on the gender of the child, with strongest associations observed between fathers and daughters (Jago et al., 2014b; Totland et al., 2013). Recent changes in media consumption have led to increases in multi-screen viewing (Jago et al., 2011). One of the few studies that has attempted to capture the use of multiple devices concurrently revealed children (aged 6-8 years; n=750) of parents who spent ≥

one hour multiscreen viewing were 34 times more likely to also spent more than one hour per day multiscreen viewing (Jago, Sebire, et al., 2013).

1.5 Summary and aims of present thesis

As discussed in this chapter, extensive research has explored relationships between the home food, activity and media environments and children's food intake, activity levels and screen-based sedentary behaviours. However, existing evidence has tended to focus on one domain of the home environment (e.g. availability of media equipment or home food availability or caregiver modelling of physical activity, etc.), rather than capturing the complexity of the overall home environment (Kininmonth, Smith, Llewellyn, et al., 2021; Pinard et al., 2012). This approach fails to consider the combined effect of the multiple factors within the home, or how these different factors interact to influence children's energy balance behaviours. Additionally, there is a lack of clarity around the role of the home environment in child weight development. To address this gap, evidence examining associations between the home environment and child adiposity will be explored in **Chapter Three**.

The lack of comprehensive measures of the home environment will also be addressed in this thesis. Previously, Schrempft et al. (2015) developed a comprehensive psychometric measure of the early home environment, known as the Home Environment Interview (HEI). The HEI was shown to be valid and reliable in the Gemini twin cohort when the children were ~four-year olds (discussed in detail in **Chapter Two**). Findings indicated clear cross-sectional associations between the three home environment domains (food, physical activity and media) and health related behaviours such as food intake, physical activity levels and sedentary behaviours (Schrempft et al., 2015). However, Schrempft et al. (2015) did not find significant associations between the home environment and weight at age four. It was hypothesised that the children were too young, and the relationship between the home environment and body weight is not fully expressed by this age. Alternatively, the finding may have resulted from characteristics of the Gemini sample; twins have been shown to have lower BMI at age five compared to the average singleton population (Estourgie-van Burk, Bartels, van Beijsterveldt, Delemarre-van de Waal, & Boomsma, 2006). Despite the strengths of the study methodology, it was cross-sectional precluding understanding of how the environment changes over time, or the directionality of associations between the home environment and children's energy balance behaviours, and ultimately adiposity. This thesis will build on the work of Schrempft et al. and attempt to address the gaps in the current evidence base.

As discussed previously, BST posits that appetite plays a causal role in obesity. However, no previous studies have synthesised peer-reviewed literature examining associations between appetite and adiposity in infancy and childhood. This lack of synthesis limits our ability to understand whether appetitive traits relate to adiposity in childhood, and to establish the size and direction of association between appetite and adiposity. Such investigation into the relationships between appetite and adiposity across childhood is needed to evaluate BST. This thesis aims to address this gap in the evidence base. Building on this, BST helps to provide a possible explanation for why people interact with the obesogenic environment differently and proposes that individuals who inherit genes promoting a more avid appetite are more vulnerable to overeating and developing obesity, in response to exposure to the ‘obesogenic’ environment. This theory suggests gene-environment interactions, whereby the genetic and environmental influence underlying a trait (such as appetite or weight) increase or decrease depending on environmental exposure. Considering this in relation to the obesogenic home environment may help us to understand a child’s risk for weight gain and develop preventative strategies that take into account genetic susceptibility. Previous research in Gemini examining gene-environment interactions revealed that the heritability of BMI is higher among children living in higher-risk (86%) home environments compared to those living in lower-risk (39%) home environments (Schrempft et al., 2018). These findings suggest the more obesogenic the environment, the stronger the genetic effect on body weight. As appetitive traits have a moderate-to-strong heritable component it would be informative to examine this in relation to appetitive traits. However, to our knowledge no research has explored gene-environment interactions in relation to child appetitive traits. The overall aim of this thesis is to address the gaps in the current evidence base by examining the obesogenic quality of the home environment and its role in children’s appetite and weight development. Specifically, the thesis aims to answer the following research questions:

i) Can the obesogenic quality of the home environment be measured comprehensively in childhood?

ii) To what extent is the home environment associated with weight in childhood?

iii) In accordance with BST, are appetitive traits associated with weight in childhood and does the heritability of appetite vary by the obesogenic quality of the home environment?

1.6 My contributions to the research in this thesis

The data used in this thesis are from the Gemini twin birth cohort. For the duration of my PhD, I was primarily based in the School of Psychology at the University of Leeds, while collaborating closely with researchers from the Department of Behavioural Science and Health at University College London, which hosts the Gemini twin cohort study. During my PhD I contributed to the design and management of the cohort contacts database and datasets, the day-to-day management of correspondence with Gemini families, as well as redesigning, developing and maintaining the Gemini study website (www.geministudy.co.uk). This website hosts the main portals with which participants submit data e.g. weights and heights every three months and questionnaires for data collection waves. The Gemini cohort, measures used and rounds of data collection are discussed in detail in **Chapter Two.**

For Paper One in **Chapter Three**, in collaboration with my supervisions, I was responsible for the conceptualisation and design of the systematic review, and the generation of the review search terms. With input from my primary supervisor, Dr Alison Fildes, I developed the protocol for the review and pre-registered this on PROSPERO (CRD42018115139). I conducted the literature search, reviewed all articles and trained two researchers to assist with the screening and data extraction process. I was responsible for drafting the first draft of the manuscript, and in collaboration with the other authors contributed to all subsequent version. I submitted this for publication in the International Journal of Behavioral Nutrition and Physical Activity and led the process of responding to reviewer comments, with input from my supervision team and co-authors. Upon acceptance, I also worked with the University of Leeds Library services to ensure the open access charges were covered.

For **Chapter Four,** alongside my supervision team, I led the work involved in updating and validating the HEI for use in school-aged children. I was responsible for communicating with the experts during consultation and incorporating their insights into the update. I developed the procedures and was in charge of creating the resources (e.g. recruitment material, participant information sheet, consent form, script for interview) for the pilot work and conducted all of the cognitive interviews with participants. The interviews were recorded and transcribed by an external company, the transcriptions were used to inform the update. I also designed the online questionnaire (using Qualtrics) which was sent to a panel of experts in the field of childhood obesity to gain their input about the constructs that should be included in the composite score. Following the update of the HEI, I was responsible for creating the online data collection resources via REDCap, used when administering the interview. I contacted Gemini families to invite them to take part and carried out the home environment telephone interviews using the computer-assisted method. I also trained two masters students to be able to administer the HEI, however, due to the Covid-19 pandemic interviews had to be halted prior to their commencing support of the data collection. As a result, all completed interviews were conducted by myself. I led the cleaning of the home environment data, and carried out all of the subsequent analyses (**Chapter Four, Five and Seven**) and I also took primary responsibility for writing up these studies for publication and inclusion in this thesis. I submitted the publication presented in Paper Two, **Chapter Four** to the International Journal of Behavioral Nutrition and Physical Activity and led the process of responding to reviewer comments, with input from my supervision team and co-authors.

For the analysis conducted in **Chapter Five**, I attended a 3.5 day course by the Psychometrics Centre at the University of Cambridge in December 2020 (https://www.psychometrics.cam.ac.uk/trainingworkshops/structural-equation-modelling-in-r-course). This course was incredibly valuable and provided me with a solid background in structural equation modelling. Following the course, I built on the knowledge gained using a book entitled *Longitudinal Structural Equation Modeling: a comprehensive introduction* and supporting online materials. This enabled me to confidently undertake the analyses presented in Paper Three; Chapter Five.

For **Chapter 6**, in collaboration with members of my supervision team (Dr Alison Fildes and Dr Clare Llewellyn) and external collaborator (Dr Susan Carnell), we planned the scope of the review and I subsequently drafted the protocol for this to allow pre-registration via PROSPERO (CRD42017081218). Together, we developed the search strategy and I conducted the search and carried out the screening process in full, with assistance from two MSc students (Shauna Farrell and Lewis Cox). I was responsible for conducting data extraction and due to heterogeneity of findings, ascertained the need to contact authors to request additional data for the purpose of meta-analysis. I contacted 45 authors to request additional information and collated information received. In collaboration with another of my supervisors, Dr Andrea Smith, I narratively synthesised the extracted data that could not be included in meta-analysis and analysed the pooled data included in meta-analysis using random effects models. I was responsible for drafting the first draft of the manuscript, and in collaboration with the other authors contributed to all subsequent versions. I submitted this for publication in Obesity Reviews and led the process of responding to reviewer comments, with input from my supervision team and co-authors.

For the analyses conducted in **Chapter Seven**, I attended a week long course at the Social Genetic and Developmental Psychiatry Centre, Kings College London, in June 2019 (https://www.kcl.ac.uk/events/twin-model-fitting-open-mx-course). This course was intellectually challenging but extremely beneficial as it introduced me to important statistical methods integral to twin research. Following the course, I used the materials provided to develop my abilities further which enabled me to write and modify scripts and interpret the output produced. This was invaluable in enabling me to complete the twin analyses and interpret and utilise them in a meaningful way.

Introduction to Chapter 2

This chapter provides a comprehensive overview of the cohort and methodology used in this thesis. Information is provided about the recruitment and sampling of the cohort, the measures used, and analytical approaches taken. This chapter aims to supplement the separate methods sections included in each of the chapters that follow.

Chapter 2
Methods

2.1 Overview of the Gemini cohort

The data used in this thesis are from the Gemini cohort. Gemini is a large population-based birth cohort of 2402 families with identical (monozygotic) and non-identical (dizygotic) twins (n = 4804 children) born in England and Wales between March and December 2007. The Gemini cohort study was established by Professor Jane Wardle at the Health Behaviour Research Centre, Department of Epidemiology and Public Health (renamed the Research Department of Behavioural Science and Health in 2016), University College London, in 2007. The main aims of the Gemini Study are to: i) examine the genetic and environmental influences on appetite, energy balance behaviours and weight development during childhood, ii) identify modifiable risk factors for excessive early weight gain, and iii) establish a database of early developmental exposures to assess contributors to long-term health.

Gemini is the ideal dataset with which to investigate the obesogenic home environment and its role in children’s appetite and weight development. The cohort have been followed since birth, with repeated measures of appetite, weight and a comprehensive measure of the home environment was administered when the children were aged 4 which will be discussed in this chapter. The use of repeated measures provides a solid basis to build on and examine the longitudinal impact of the obesogenic home environment. In addition, the twin nature of the cohort will allow investigation of the relative environmental and genetic influences on children's appetite and examine this in relation to the obesogenic risk in the home environment.

2.2 Methods

2.2.1 Recruitment, attrition and representativeness of the Gemini sample

All families with twins born in England and Wales between March and December 2007 (N = 6754) were contacted by the Office of National Statistics in January 2008 and asked whether they would consent to having their details sent to the Gemini research team. Data from the National Health Service Central Registry was used to verify that the mother and both twins were alive. Half of the families (n=3435 families; 51%) agreed to be contacted by the research team. These families were sent a consent form, a leaflet explaining the study and the baseline questionnaires between February and April 2008. Of those contacted, 2402 (70%) returned completed consent forms and baseline questionnaires. The response rate of families was considered acceptable given they had been approached when their twins were on average 8 months old and they were asked to complete two long questionnaires. The distribution of families across England and Wales roughly mirrored the population density, as shown in **Figure 2.1***.* Parents provided informed consent for their family to participate in the study and ethical approval was granted by the University College London Committee for the Ethics of non-National Health Service Human Research (Project ID/Title: 1126/004: Gemini – health and development in twins). In 2018, ethical approval for the continuation of the study until 2023 was again granted by the UCL

Research Ethics Committee (Project ID/Title: 1624/004: Gemini - Phase 2; **Appendix A.1**).

The baseline characteristics for the Gemini cohort are compared with the national twin statistics and national health statistics in **Table 2.1.** The Gemini cohort are representative for sex, zygosity, birth weight, and gestational age at birth. However, mothers in the Gemini cohort were on average slightly older (33.6 vs 29.5 years), had a lower body mass index (25.10 vs 26.8 for mothers, 26.40 vs 27.10 for fathers) and a higher education level when compared to the general population (33.8% vs 7.3% educated to University degree level), compared with national statistics. There was also an overrepresentation of White-British families in Gemini, as has been observed in other cohort studies (Atherton et al., 2008; Trouton et al., 2002). Married or cohabiting couples were also overrepresented, but this is perhaps expected as the target sample was families with young children while the national statistics refer to all adults aged 16 and over.

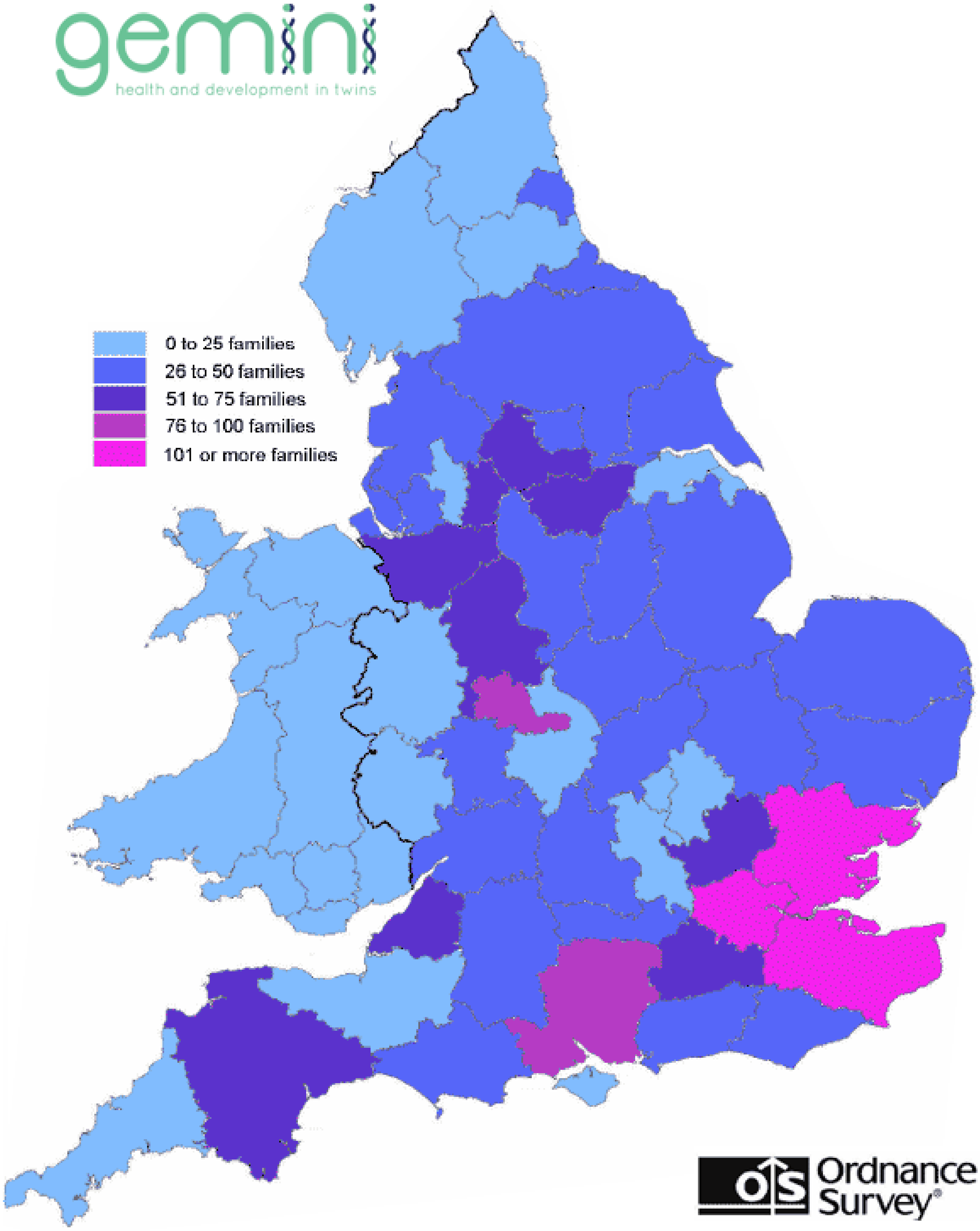


Figure 2.1. Distribution of Gemini Twins across the United Kingdom (adapted from van Jaarsveld et al., 2010).

Table 2.1. Characteristics of total Gemini sample at baseline compared to national statistics.

Characteristic	Gemini cohort baseline *(N = 2402 families; 4804 twins)*	National twin statistics
	Mean (±SD) or N (%)	**Mean or %**
Twin characteristics		
Gestational age	36.2 (±2.48)	37 [a]
Birth weight (kg)	2.46 (±0.54)	2.50 [a]
Sex of twin pair		
Both male	785 (32.7%)	32.1%[a]
Both female	801 (33.3%)	32.8% [a]
Male-female	816 (34%)	35.1% [a]
Parental characteristics		
		National Statistics Mean or %
Age at twins' birth		
Mother	33.6 (± 5.2)	29.5[a]
Father	36.4 (± 6.2)	
BMI in kg/m^2		
Mother	25.10 (±4.76)	26.8[b]
Father	26.40 (±3.73)	27.1[b]
Maternal educational qualifications[c]		
Low	518 (21.6%)	51.9%
Middle	878 (36.5%)	41.2%
High	1006 (41.9%)	6.9%
Paternal educational qualifications[c]		
Low	722 (31.7%)	47.4%
Middle	742 (36.5%)	45.3%
High	812 (33.8%)	7.3%
Ethnicity[d]		
White	2231 (92.9%)	72.8%
Non-White	169 (7.0%)	27.4%
Not known	2 (0.1%)	-

[a] Office for National Statistics (2006). Birth Statistics Series FM1 no.35. Review of the Registrar General on births and patterns of family building in England and Wales. Newport. (Numbers are for twin births in 2006).(Office for National Statistics, 2006)
[b]BMI calculated from self-reported height and weight.
[c]Education level categorised as: low (no qualifications or high school education e.g. CSE, GCSE, O level), intermediate (vocational qualification or advanced high school education), and high (University-level education)
[d]Ethnicity was collapsed into 'White' and 'Non-White' (and 'Unknown' in the cases of missing data). Ethnicity was collapsed as there was insufficient numbers across the 'Non-White' categories to enable subgroup analyses among specific ethnic groups. Within the 'White' category the majority (87%) identified as 'White British'
Table adapted from (van Jaarsveld et al., 2010)

Table 2.2. presents the characteristics of the Gemini sample at baseline and the other data collection time points relevant for this thesis (T0, T6, T7, and T10). As with other longitudinal cohorts, there has been participant attrition over time (shown in **Figure 2.2**).

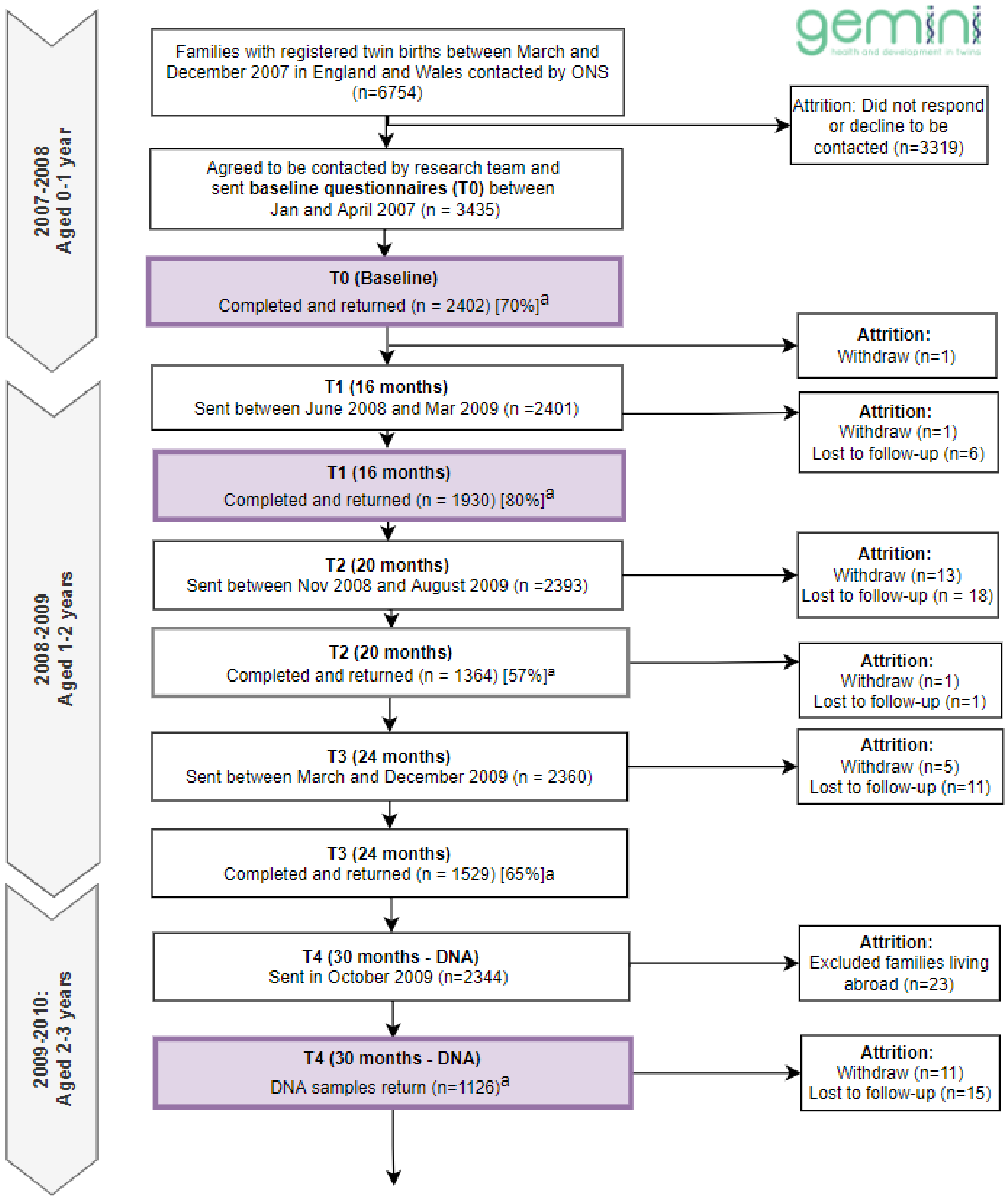


Figure 2.2. An overview of the flow of families through the Gemini study from 2007 to 2020.

[a]Response rates are given in square brackets.
[b]Only a sub-sample of families were invited to take part in this wave of data collection. Therefore, the response rates are relative to the invited sub-sample. For T8 the sub-sample included families who were considered 'actively engaged' – i.e. they had not withdrawn or been lost to follow up and had completed the latest questionnaire when the twins were approximately five years old. For T10, the sub-sample included families who participated in T6 and T9.
The purple boxes represent the waves of data collection relevant to the current thesis.

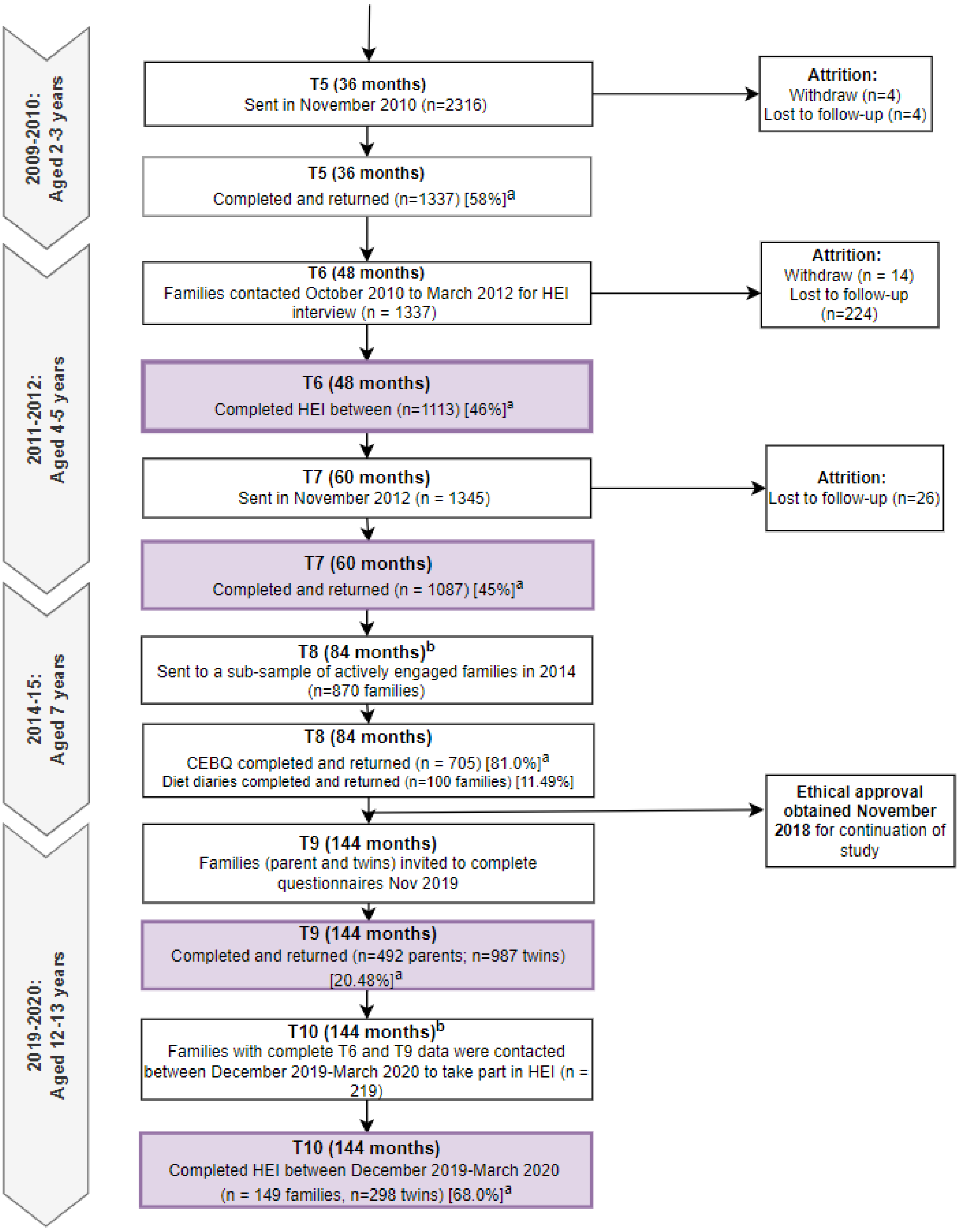


Figure 2.2 (Continued) An overview of the flow of families through the Gemini study from 2007 to 2020.

[a]Response rates are given in square brackets.
[b]Only a sub-sample of families were invited to take part in this wave of data collection. Therefore, the response rates are relative to the invited sub-sample. For T8 the sub-sample included families who were considered ‘actively engaged’ – i.e. they had not withdrawn or been lost to follow up and had completed the latest questionnaire when the twins were approximately five years old. For T10, the sub-sample included families who participated in T6 and T9.
The purple boxes represent the waves of data collection relevant to the current thesis.

Descriptive statistics were compared between the different time points using Paired samples t-test or McNemar's test to test for significant changes in the demographics of participating families across the duration of the study. Compared to the baseline Gemini sample (n=2402 families), the caregiver sample providing home environment interview data when the twins were age 4 (n=1113 families) were more highly educated (41.9% vs 48.2% with university degree; $\chi^2(2) = 55.01$, $p<0.001$), slightly older (32.16 vs 33.86 age at twins birth; $t=8.05$, $p<0.001$) had lower average maternal BMI (25.10 vs 24.8; $t=-2.501$, $p=0.01$) and were of higher socioeconomic status[6] (SES) (4.31 vs 4.55; $t=8.18$, $p<0.001$). Similarly compared with the baseline sample (n=2402 families), the caregiver sample providing home environment interview data when the twins were aged 12 (n=149 families), were older (32.16 vs 35.1 age at twins birth; $t=5.25$, $p<0.001$), had a lower maternal BMI (25.10 vs 24.33, $t=-2.08$, $p=0.038$), were more highly educated (41.9% vs 51.2% with a university degree; $\chi^2(2) = 33.55$, $p<0.001$) and were of higher SES (4.31 vs 5.03; $t=6.43$, $p<0.001$).

[6] SES is based on a weighted composite score using seven indicators of socioeconomic position. These include maternal educational qualifications, household NS-SEC score, home ownership status, annual household income, index of multiple deprivation, household composition e.g. bedrooms and cars. Higher scores represent higher SES (Kininmonth et al., 2020). Full details of this measure are described later in this chapter.

Table 2.2. Characteristics of sample at T0, T6, T7 and T10 compared with National statistics.

Characteristic	Gemini cohort baseline (T0) ***(N = 2402 families; 4804 twins)***	Gemini HEI cohort at 4 years (T6) ***(N = 1113 families; 2226 twins)***	Gemini cohort at 5 years (T7) [a] ***(N = 803 families; 1606 twins)***	Gemini HEI cohort at 12 years (T10) ***(N = 149 families, 298 twins)***	**National statistics**
	Mean (±SD) or N (%)	Mean (±SD) or N (%)	Mean (±SD) or N (%)	Mean (±SD) or N (%)	% or mean
Twin age (months or years)	8.17 month (±2.18)	4.17 (±0.40)	5.15 (±0.13)	12.50 (±0.28)	
Sex (% male)	2386 (49.7%)	1099 (49.4%)	788 (49.1%)	145 (48.7%)	
Weight at birth (kg)	2.46 (±0.54)	2.46 (±0.54)	2.48 (± 0.53)	2.43 (±0.56)	2.50
BMI-SDS at HEI at age 4	-	-0.05 (±0.96)[i]	-0.06 (± 0.95)	0.01 (±0.84)	
BMI-SDS at HEI at age 12	-	-	-	-0.06 (±1.14)	
Combined sex of twin pair					
Both Male	1570 (32.7%)	750 (33.7%)	546 (34%)	98 (32.9%)	32.1%[b]
Both Female	1602 (33.3%)	778 (35.0%)	576 (35.9%)	106 (35.6%)	32.8% [b]
Opposite sex (male and female)	1632 (34%)	698 (31.4%)	484 (30.1%)	94 (31.5%)	35.1% [b]
Zygosity[c]					
Monozygotic	749 (31.2%)	375 (33.7%)	272 (33.9%)	43 (28.9%)	
Di-zygotic	1616 (67.3%)	726 (65.2%)	524 (65.3%)	105 (70.5%)	
Unknown	37 (1.5%)	12 (1.1%)	7 (0.9%)	1 (0.7%)	
Maternal age (in years) at twins' birth[d]	33.6 (± 5.2)	33.86 (±4.75)	34.10 (±4.52)	35.1 (±4.22)	29.5
Maternal BMI	25.10 (±4.76)	24.84 (±4.58)	24.7 (±4.61)	24.33 (±4.20)	26.8
Paternal BMI	26.40 (±3.73)	26.3 (±3.63)	26.25 (±3.41)	26.19 (±3.24)	27.1
Maternal educational qualifications[e]					
Low	518 (21.6%)	173 (15.5%)	113 (14.1%)	10 (7.4)	51.9%
Middle	878 (36.6%)	403 (36.3%)	279 (34.8%)	37 (24.9%)	41.2%
High	1006 (41.9%)	537 (48.2%)	411 (51.2%)	102 (68.5%)	6.9%
Paternal educational qualifications[e]					
Low	722 (31.7%)	297 (19.6%)	200 (24.9%)	11 (7.8%)	47.4%
Middle	742 (36.5%)	332 (29.8%)	232 (28.9%)	40 (28.6%)	45.3%

High	812 (33.8%)	445 (41.4%)	342 (42.6%)	87 (63.5%)	7.3%
Ethnicity[f]					
White	2231 (92.9%)	1055 (94.7%)	768 (95.6%)	141 (94.6%)	
Non-White	169 (7.0%)	108 (5.3%)	35 (4.4%)	8 (5.4%)	
Not known	2 (0.1%)	-	-	-	
NS-SEC classification[g]					
Lower	472 (19.7%)	163 (14.6%)	107 (13.3%)	8 (5.4%)	33%
Intermediate	407 (16.9%)	173 (15.5%)	117(14.7%)	11 (7.4%)	18%
Higher	1515 (63.1%)	649 (60.1%)	577 (71.9%)	130 (87.2%)	49%
Unknown	-	-	2	-	
SES composite score[h]	4.31 (1.36)	4.55 (±1.26)	4.65 (±1.24)	5.03 (±1.01)[j]	

[a] Only includes families with complete data at baseline and home environment interview at age 4 (T6).

[b] Office for National Statistics (2006). Birth Statistics Series FM1 no.35. Review of the Registrar General on births and patterns of family building in England and Wales. Newport. (Numbers are for live twin births in 2006). (Office for National Statistics, 2006)

[c]Zygosity was unknown for 37 pairs, due to inconsistent questionnaire results and no DNA available.

[d] Maternal age (in years) only available for n=2396 families.

[e]Education level categorised as: low (no qualifications or high school education e.g. CSE, GCSE, O level), intermediate (vocational qualification or advanced high school education), and high (University-level education)

[f] Ethnicity was collapsed into ‘White’ and ‘Non-White’ (and ‘Unknown’ in the cases of missing data). Ethnicity was collapsed as there was insufficient numbers across the ‘Non-White’ categories to enable subgroup analyses among specific ethnic groups. Within the ‘White’ category the majority (87%) identified as ‘White British’

[g]Classified based on the Office for National Statistics Socioeconomic Classification (NS-SEC) and grouped into high (higher and lower managerial and professional occupations), middle (intermediate occupations, small employers and own account workers) and low (lower supervisory and technical occupations, (semi)routine occupations, never worked and long-term unemployed). In comparison to the average statistics for the UK population, Gemini has a higher percentage of high SES families, (63.1% vs 49%) and less low SES families (19.7% vs 33%). Figures on National Statistics from Health Survey for England 2007 (The Health and Social Care Information Centre, 2008)

[h]SES-composite score is based on a weighted score using seven indicators of socioeconomic position. These include maternal educational qualifications, household NS-SEC score, home ownership status, annual household income, index of multiple deprivation, household composition e.g. bedrooms and cars. Higher scores represent higher SES (N = 1055 available cases, 58 missing) (Kininmonth et al., 2020)

[i] BMI-SDS at age 4 only available for n=1858 children (929 families)

[j]Based on the SES information collected from families at baseline.

2.2.2 Data collection

At the time data collection was completed for this thesis, the primary method of data collection in the Gemini cohort was via caregiver-reported questionnaire measures (either paper-based or online), along with two caregiver completed telephone interviews. To date, there have been ten waves of data collection involving either the full Gemini cohort or subsamples. Figure 2.2 provides an overview of the data collection waves and response rates at each time-point. A summary of the data collection waves that are relevant for this thesis are shown in **Table 2.3**. The current thesis uses data from questionnaire and interview administered measures collected when the twins were on average eight months (T0), 16 months (T1), 30 months (T4), four years (T6), five years (T7) and 12 years (T9 and T10). All measures used in this thesis are described in detail in this chapter.

The baseline questionnaire (T0) was completed when the twins were approximately eight months old. The second wave of data collection (T1) was completed when the twins were around 16 months, with a focus on parental feeding practices, and the children's appetite. The fifth wave of data collection (T4), which commenced in October 2009 provided Gemini families with materials and instructions for collecting DNA samples from their twins which could be returned through the post and used to determine zygosity (T4). The seventh wave of data collection (T6), comprised the telephone-administered Home Environment Interviews which were conducted between November 2010 and March 2012. The focus of this wave was to collect detailed information about the food, physical activity and media environments in the home. In November 2012, when the twins were approximately five years old, the families were sent questionnaires asking about caregivers' health behaviours, their children's appetite, growth and sleep (T7). The most recent waves of data collection (T9 and T10) commenced when the twins were 12 years old. The tenth wave comprised three questionnaires (T9), which were completed by the primary caregiver and each of the twins. Data included measures of the children's appetite, health behaviours, growth, and parental feeding practices. The eleventh wave of data collection (T10), which is discussed in depth in **Chapters Four and Five**, took the form of another telephone interview about the home food, activity and media environments and was conducted with the families who participated in T5 and T9. All measures from the data collection waves utilised in the current thesis are described below and the relevant sections from the questionnaires are included in **Appendix A.2-A.7**.

Table 2.3. Overview of measures and children's ages at time of data collection within Gemini relevant to this thesis.

Data collection wave	T0	T1	T4	T6	T7	T9	T10
	Child age (months; years)						
	8	16	30	4 yrs	5 yrs	12-13 yrs	12-13 yrs
Child variables							
Birth weight	X						
Anthropometrics [a]	X	X		X	X	X	X
Eating behaviours/Appetite – CEBQ (childhood: Wardle et al 2001).	X	X			X	X	
DNA collection cheek swab & zygosity questionnaire	X		X				
Family variables							
Demographics, anthropometrics, health behaviours of both parents [b]	X				X		X
Home environment [b] (Schrempft et al., 2015)				X			X
Parental feeding practices[c]	X	X			X	X	
Socioeconomic variables (SES-composite)							
Household ownership	X		X				X
Maternal educational qualification	X				X		X
Current occupation (both parents)	X	X	X		X		X
Annual household income	X						X
Number of bedrooms	X						X
Number of cars	X						X

[a]Anthropometrics collected at baseline and 16 months include weight, length and head circumference as recorded by health professional in red book from birth. Electronic weighing scales and height charts with detailed instructions were sent at age 2 years for parents to measure their twins' growth in 3-month intervals.
[b] Measures that were modified or newly designed for Gemini. These were all intensively piloted in parents of young children (both singletons and twins). All other measures are based on validated questionnaires.
[c] Measures used to assess parental feeding practices include; 1) Parental Feeding Style Questionnaire (PFSQ; Wardle et al., 2002), 2) Child Feeding Questionnaire (CFQ; Birch et al., 2001), and 3) Pre-schooler Feeding Questionnaire (PFQ; (Baughcum et al., 2001), and 4) the Infant Feeding Questionnaire.

2.2.3 Measures

Measures described below that were specifically developed or modified for use in the Gemini sample were piloted in parents of young children (singletons and twins). All other measures were based on validated questionnaires.

2.2.3.1 Anthropometric

At baseline (eight months), parents were asked to provide all anthropometric measurements taken by health professionals that were recorded in the child's personal health record (red book) up to that point. The same procedure was used to gain measurements taken prior to 16 months (T2). When the twins were ~24 months, electronic weighing scales, height charts and detailed instructions were sent to all families to allow them to weigh and measure their twins at home. Parents were asked to provide weight (kg) and height (m) information for each twin at 3-month intervals using the weighing scales and height charts provided. When the twins turned 10 years old, updated height charts were subsequently send to all parents to allow them to continue to collect accurate measurements at 3-month intervals. Weight and height information can be submitted online via the website (www.geministudy.co.uk), by email, by post or over the phone. Weights and heights at baseline, 5 years and 12 years were used to calculate body mass index (BMI) standard deviation scores (SDS). If weight data were missing then available weight data from the nearest 3 months was used, e.g. missing data at 60 months was replaced with corresponding data collected at 57 months or 63 months. BMI-SDS were calculated based on the British Growth reference data, using the LMSgrowth macro for Microsoft Excel, adjusting for age, sex and gestational age (Freeman et al., 1995). It is important to use SDS because body composition fluctuates throughout childhood and therefore, standard weight or BMI measurements can be misleading. Using SDS means it is possible to compare a child's weight or BMI status against other children of a similar age and sex (Cole, 1989, 1996; Freeman et al., 1995). A BMI-SDS of 0 indicates average BMI, whereas a SDS < 0 indicates lower BMI, and SDS >0 indicates higher BMI compared to the British 1990 growth reference data (Freeman et al., 1995).

Parents were also asked to provide weight (kg) and height (m) information for themselves at baseline. Paternal and maternal heights (m) and weights (kg) at baseline were used to calculate BMIs using the following equation: weight (kg)/ height $(m)^2$.

2.2.3.2 Demographic information

2.2.3.2.1 Age

Parents were asked to report the number of weeks the mother had been pregnant at the time of delivery and this was used to calculate gestational age. Parents' age at their twins' birth was calculated (in years) using the twins' date of birth and each parent's date of birth. Twin age at the time of each data collection wave was calculated using the twins' date of birth and the date that the questionnaire/interview was completed.

2.2.3.2.2 Ethnicity

At baseline, parents were asked to provide information about their own and their partner's ethnicity. Categories were taken from the Office for National Statistics interim standard classifications for ethnic and national groups data. The categories were; ‘White British’, ‘White Irish’ ‘Other White background’, ‘Caribbean’, ‘African’, ‘Other Black background’, ‘Indian’, ‘Pakistani’, ‘Bangladeshi’, ‘Other Asian background’, ‘White and Black Caribbean’, ‘White and Black African’, ‘White and Asian’, ‘Other Mixed background’, ‘Chinese’, ‘Any other’. If ‘other’ was selected parents were asked to provide additional information for clarity. The original 16 categories were collapsed into two categories; ‘White-British’ and ‘Non White-British’ as there were insufficient numbers across the ‘Non White-British’ categories to enable subgroup analyses.

The ethnicity of the twins was classified from the ethnicity of the parent using the following approach: in cases where parents selected the same category the twins’ ethnicity was classified using that category; where parents selected different categories the twins were classified as ‘mixed ethnicity’, and in cases where only one parent’s ethnicity was available, twin ethnicity was classified using the ethnicity of the parent with available data.

2.2.3.2.3 Marital status

Parents were also asked to provide information about their marital status in the baseline questionnaires (8 months), T3 (2 years), T7 (5 years) and again at T10 (age 12). Parents were able to select from one of the following categories: ‘married or cohabiting’, ‘divorced’, ‘widowed’, ‘separated’ or ‘single’. These were then collapsed into three categories ‘Married or cohabiting’, ‘Divorced or separated’ and ‘Single’.

2.2.3.3 Socioeconomic information

At baseline (8 months) and age 12, parents provided information about multiple indicators of socioeconomic status (SES) including; highest maternal educational qualifications, current occupation (both parents), postcode, home ownership status, number of bedrooms, number of cars owned, and total annual household income.

2.2.3.3.1 Maternal education

Mothers were asked to report their highest educational qualification achieved. The response options were ‘No qualifications’, ‘GCSE, O level, CSE’, ‘Vocational qualification (GNVQ, BTEC)’, ‘A or AS level’, ‘Higher National Certificate (HNC) or Higher National Diploma (HND)’, ‘Undergraduate degree’, ‘Postgraduate qualification (Masters or PhD)’. Each response option was coded with a numerical value from 1 to 7 (1 = No qualifications to 7 = Postgraduate degree), with the higher scores representing higher maternal education (and representing higher SES).

2.2.3.3.2 National Statistics Socioeconomic Class (NS-SEC) index

Occupation was used to calculate each household’s National Statistics Socioeconomic Class (NS-SEC) using the simplified method in which occupation is attributed a four-digit Standard Occupation Classification 2000 (SOC2000) code, using the Computer Assisted Structured Coding tool (Cascot) (Office for National Statistics, 2000; Warwick Institute for Employment Research, 2020). For individuals with two jobs, the highest NS-SEC score was used. The parent or carer with the highest NS-SEC score was defined as the household reference person (HRP) and their score was used to represent the household NS-SEC score. In accordance with the NS-SEC scoring, NS-SEC scores were organised in 8 categories: 1 = ‘Large employers and higher managerial and higher professional occupations’, 2 = ‘Lower managerial and professional occupations’, 3 = ‘Intermediate occupations’, 4 = ‘Small employers and own account workers’, 5 = ‘Lower supervisory/technical occupation’, 6 = ‘Semi-routine’, 7 = ‘Routine occupation’, 8 = ‘Never worked or long-term unemployed’. The NS-SEC scores were then reverse coded so that higher scores represented higher SES: 1 = ‘Never worked or long-term unemployed’, 2 = ‘Routine occupation’, 3 = ‘Semi-routine’, 4 = ‘Lower supervisory/technical occupation’, 5 = ‘Small employers and own account workers’, 6 = ‘Intermediate occupations’, 7 = ‘Lower managerial and professional occupations’, 8 = ‘Large employers and higher managerial and higher professional occupations’. Further information about the classification of occupations with the NS-SEC are published elsewhere (Office for National Statistics, 2019). It was possible to attribute an NS-SEC score to 2394 (99.7% of cohort) households. Higher scores represented a household with higher SES.

2.2.3.3.3 Average annual household income

Annual household income was calculated based on the total combined income of each member of the household. Parents were asked to answer the following question ‘What is the total household income (before tax deduction)?’. Household incomes were categorised into the following; 1 = ‘Up to £15k’, 2 = ‘£15-22.5k’, 3 = ‘£22.5-30k’, 4 = ‘£30-37.5k’, 5 = ‘£37.5-45k’, 6 = ‘£45-52.5k’, 7 = ‘£52.5-60k’, 8 = ‘£60-67.5k’, 9 = ‘£67.5-75k’, 10 = ‘£75-82.5k’, 11 = ‘£82.5-90k’, 12= ‘More than 90k’.

2.2.3.3.4 Home ownership status

Parents were asked to provide information about their home ownership status via the following question: ‘Do you own or rent the accommodation you live in?’. Household tenure was classified according to the Census 2001 and was used as an indicator of SES. Families were asked to state their home ownership status based on the following categories; 4 = ‘Rent from local authority’, 3 = ‘Rent privately’, 2 = ‘Own with mortgage’, or 1 = ‘Own without mortgage’. The numerical codes for these categories were later reverse scored; so that the scoring was equivalent to the other SES variables, with higher scores indicating higher SES: 1 = ‘Rented from local authority’, 2 = ‘Rent privately’, 3 = ‘Own with mortgage’, 4 = ‘Own without mortgage’.

2.2.3.3.5 Index of Multiple Deprivation

Postcodes at baseline were used to assign each household with an Index of Multiple Deprivation (IMD) score. IMD is commonly used to measure the level of deprivation in each local area in England and Wales. IMD is calculated based on seven different measures of local deprivation, including employment, education, living environment, income, crime, health deprivation, disability, and barriers to housing and services. These domains are then used to attribute a weighted overall IMD score for each local area, known as Lower-layer Super Output Areas (LSOAs) (Communities and Local Government, 2007). A higher IMD scores represents higher level of deprivation. An IMD score was assigned to each household based on their postal code. At baseline, IMD scores could be assigned to 2,378 households based on their postcode. The mean IMD score across the Gemini cohort was 18.07 (±13.54), scores ranged from 0.93 – 73.73. The IMD scores were subsequently categorised into 5 quintiles of deprivation (NPEU Tools, 2010). Quintiles were classified as follows: 1 = ‘score ≤8.49 (least deprived quintile)’, 2 = ‘8.5 -13.79’, 3= ‘13.8 - 21.35’, 4 = ‘21.36 - 34.17’, 5= ‘≥ 34.18 (most deprived quintile)’. These were then reverse scored so that 1 = ‘most deprived’ and 5 = ‘least deprived’ to reflect the other SES variables i.e. so higher scores represent higher SES.

2.2.3.3.6 Household composition

Less commonly used as indicators of social class are the number of bedrooms and cars per household. This information was collected via the baseline questionnaire (8 months) and T10 (12 years) and used as an indicator of social status. Parents were asked to provide information about ‘how many bedrooms does your household have?’ and ‘How many cars does your household have?’. Responses were provided numerically e.g. 1, 2, 3. Total number of bedrooms within each household and the number of cars owned were used to provide an indication of the quality of living within the household. A higher overall numerical score indicated higher SES.

2.2.3.3.7 SES composite measure[7]

Principal component analysis (PCA) was used to create the SES composite score, which incorporated the seven individual indicators of SES discussed above (see **Figure 2.3**). Correlations between the individual indicators of social class were low to moderate in size, ranged from r = 0.16 (maternal education and number of cars) and r = 0.57 (NS-SEC and gross annual income), indicating that each indicator was tapping into a separate component of SES. The Kaiser-Meyer-

[7] Much of the information about the measurement of SES and full details of this composite measure are published in the following paper: Kininmonth et al., 2020. Socioeconomic status and changes in appetite from toddlerhood to early childhood. *Appetite, 146.* DOI: 10.1016/j.appet.2019.104517

Olkin (KMO) revealed that the sample was adequate to run the PCA (KMO = 0.82). PCA revealed all seven SES indicators loaded well onto a single factor (all had factor loadings >0.4). Therefore, all were retained in the final composite measure. Household annual income (0.77) and household NS-SEC (0.75) loaded highest and were given the highest weightings in the composite measure. These were followed by maternal education (0.56), home ownership status (0.54), IMD score (0.49), number of bedrooms (0.46) and number of cars (0.43). Weightings were attributed to individual components of the composite based on their factor loadings. These weightings were combined with the raw values and used to calculate the weighted SES composite using the following equation: SES composite = (household annual income*.22) + (household NS-SEC*0.22) + (maternal education*.18) + (home ownership status*.18) + (IMD score*.08) + (number of bedrooms*.06) + (number of cars*.06). Internal reliability for the composite measure was high (Cronbach α = 0.72) and was not improved by removing any individual indicator (Kininmonth et al., 2020). The composite SES score was defined as a continuous variable, with higher composite scores reflecting higher SES.

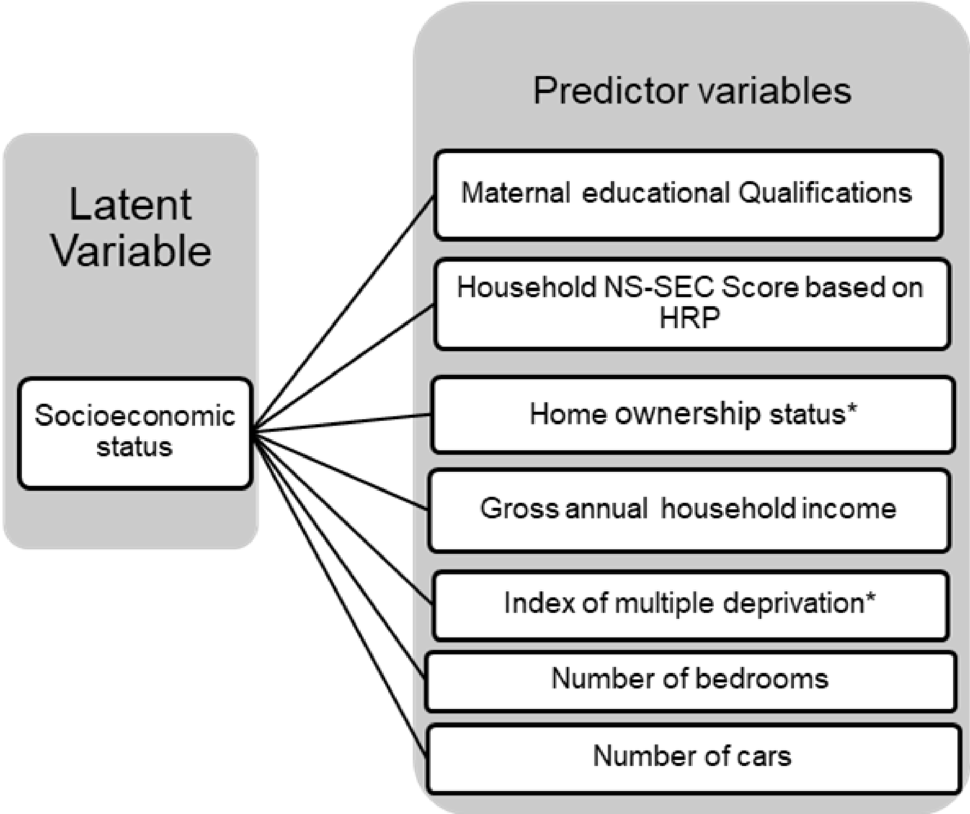


Figure 2.3. Composite measure of SES with the key aspects of social class (*item reverse scored) (Kininmonth et al., 2020)**.**

2.2.3.4 Twin Zygosity

In the baseline questionnaires (T0), parents were asked to provide information about whether their twins were the same sex or mixed-sex. All mixed-sex twins were classified as DZ. Parents of same-sex twins were asked to complete a 20-item zygosity questionnaire, when their twins were 8 months (T0) and 30 months (T4). The zygosity questionnaire was originally developed and validated in the Twins Early Development Study (TEDS) (Price et al., 2000). The items in the zygosity questionnaire relate to the twins physical resemblance, for example, general similarity, similarity of features e.g. facial, eye colour, etc., ease of being able to distinguish between the twins, and other items about blood type, health professionals opinions and the parents own opinions about zygosity. As described by Price et al. (Price et al., 2000), certain individual items were used as definite markers of zygosity. Twins described as ‘two peas in a pod’ were classified as MZ. Whereas, twin pairs described as ‘not looking much alike at all’ or described as having differences in eye colour, hair colour or texture were classified as DZ, unless they were also described as ‘two peas in a pod’, in which case they were left unclassified (Price et al., 2000). In all other instances, the zygosity questionnaire is scored by adding up the scores obtained for each question and dividing the total by the maximum possible score based upon the number of questions answered to create a value between 0 and 1. In accordance with Price et al., higher scores closer to 1 represent maximal dissimilarity and lower scores closer to zero represent maximal similarity. Scores <0.64 were classified as MZ, scores >0.70 were classified as DZ, and scores between 0.64 and 0.70 were coded as ‘uncertain’ zygosity (Price et al., 2000). Further information about the development and validation of the zygosity questionnaire is published elsewhere (Price et al., 2000). Twin pairs with missing data for 50% of the items or more were classified as having ‘uncertain’ zygosity. A total of 934 families answered the questionnaires at both time points and zygosity results were compared in these to assess the test-retest correlation and percentage agreement of the questionnaire. Zygosity was deemed to be ‘unclear’ for 66 twin pairs, leaving 868 pairs with results on both occasions. Of these, 827 (95.3%) were assigned the same zygosity on both occasions. The Spearman correlation coefficient was 0.80 (p<0.001) and Kappa statistic was 0.80 (p<0.001), indicating good test-retest reliability.

When the twins were 30 months of age, all families were invited to provide DNA. DNA was collected by the parents using cheek swabs that were sent and returned by post. A total of 1127 families provided DNA samples for both twins. Of these, a random sample of 10% of the Gemini families who returned the DNA (n=81 pairs; 43 MZ, 38 DZ) were zygosity-tested using the twins' DNA. This DNA testing was carried out to assess the validity of the zygosity questionnaire. The DNA results from the random sample (n=81 pairs; 43 MZ, 38 DZ) exactly matched the results of the questionnaires with 100% agreement (Herle et al., 2016). An additional 117 families elected to have DNA-based zygosity testing and the zygosity of 112 pairs who could not be classified using questionnaire data but who had provided DNA samples were also tested. The results from the zygosity questionnaire and DNA testing were combined to provide the most accurate zygosity assignment for the Gemini sample. A total of 749 twin pairs (31.2 %) were classified as MZ and 1616 (67.3%) twin pairs were classified as DZ (including 816 opposite sex DZ twins), based on the questionnaire and DNA results. Zygosity could not be established for 37 pairs (1.5% of the baseline sample), as questionnaire results were unclear and no DNA was provided. The numbers of MZ, DZ and unknown zygosity twin pairs in the Gemini cohort at each time point are presented in Table 2.2.

2.2.3.5 Child appetite

As shown in **Table 2.3,** children's appetitive traits were assessed at 16 months, 5 years and 12 years using the Child Eating behaviour Questionnaire (CEBQ) (Wardle et al., 2001). The CEBQ examines eight appetitive traits via a 35-item questionnaire. Items are rated using a 5 point Likert-Scale (1=Never to 5=Always; See **Appendix A.7**; Wardle et al., 2001). Each of the eight CEBQ scales examines a different aspect of appetite. Food Responsiveness measures a child's drive to eat in response to external food cues (FR; 5 items e.g. 'Given the chioce, my child would eat most of the time'). Satiety Responsiveness measures a child's sensitivity to internal cues of 'fullness' (SR; 5 items e.g. 'My child gets full up easily'). Enjoyment of Food assesses a child's subjective pleasure from eating (EF; 4 items, e.g. 'My child loves food'). Desire to Drink measures a child's wanting for beverages (DD; 3 items, e.g. 'My child is always asking for a drink'). Emotional Overeating (EOE; 4 items, e.g. 'My child eats more when worried') and Emotional Undereating (EUE; 4 items, e.g. 'My child eats less when s/he is tired') assess the extent to which a child eats (more or less) in response to emotional stressors. Slowness in Eating refers to the speed of consumption (SE; 4 items, e.g. 'My child eats slowly'). Finally, Food Fussiness examines a child's pickiness about the flavour and texture of foods they are willing to eat (FF; 6 items, e.g. 'My child refuses new foods at first'). Further details of the questionnaire development and validation is available elsewhere (Wardle et al., 2001).

2.2.3.6 Home Environment Interview (HEI)

Primary caregivers completed the Home Environment Interview (HEI) by telephone with a trained researcher when their children were 4 years of age, and again when they were 12 years of age. The HEI is a comprehensive measure of the home environment which assesses a range of physical (availability and accessibility) and social (caregiver support, caregiver limit setting) aspects of the home food, physical activity and media environments. The HEI was originally adapted from the Healthy Home Survey (Bryant et al., 2008), which was one of the most comprehensive measures of the home environment available at the time of development. Amendments were made to make the language UK-specific and additional scales were included to assess parental support of physical activity, parental TV viewing (Schrempft et al., 2015). The HEI was administered as a computer-assisted telephone interview by trained researchers and the original version for pre-school aged children took on average 30 minutes to complete (see full interview in **Appendix A.3)**. Primary caregivers were asked to complete the interview at home and were prompted to check the foods and beverages in their home, to ensure accurate responding. Alongside the HEI, caregiver feeding practices were assessed using validated questionnaires, these are detailed in section 2.2.3.7.

The obesogenic quality of the home environment was determined by creating four composite scores which captured the food, physical activity, and media home environments, as well as the overall home environment. A total of 32 constructs were included in the composite scores; the food (21 constructs), physical activity (6 constructs), and the media environment (5 constructs). The creation of the composite scores was guided by feedback from an expert panel of child obesity researchers (n = 28). Constructs identified as being associated with decreased risk for excess childhood weight gain were reverse-scored so that a higher total score would reflect 'higher-risk' for excess weight gain. The constructs included in the composite score include a mixture of categorical, ordinal and continuous variables, therefore, it was necessary to define a common metric to allow these variables to be aggregated. The identified variables were standardised using Z-scores, this procedure transforms all variables to a common scale with an average of 0 and a standard deviation of 1. The resultant Z-scores are the number of standard deviation units an individual's score is above or below the average score. This process of standardisation was chosen over other methods such as rescaling as such approaches may lead to extreme values (minimum and maximum), creating a distortion effect on the transformed variables. For example, extreme values can arise in open-ended questions, such as food availability questions in the HEI.

To create the composite scores, each variable was standardised using z-scores. Missing values were recoded to 0 (the mean value for a standardised variable). The standardized variables were summed to create three composite scores: the home food environment (21 variables), the physical activity environment (6 variables) and the media environment (5 variables). The food, activity and media composites were then summed to create an overall home environment composite score, dividing by the number of variables per composite so that each composite contributed equally to the overall score (food composite/21 + activity composite/6 + media composite/5). Higher scores on each composite reflect 'higher-risk' environments. The HEI was shown to have acceptable to high test-retest reliability over a two-week period at four years. Intraclass correlation coefficient (ICC); 95% confidence interval (CI) at age four was: food (ICC; 95% CI = 0.71; 0.52–0.83), activity (0.83; 0.72–0.91), media (0.92; 0.85–0.95), overall (0.92; 0.86–0.96) (Schrempft et al., 2015). In addition, objective measures, in the form of wearable cameras, were used to examine criterion validity of the HEI at four years. Wearable cameras were worn over a 4-day period around 12 days after the initial interview. Criterion validity was good or excellent (ICC or kappa ≥0.60) for most HEI variables captured. Validity was poor (ICC or kappa <0.40) for tinned and frozen vegetable availability and variety, and sweet snack availability (Schrempft et al., 2017).

When the twins were aged 12, an updated HEI was administered with parents who completed the original HEI at age four and who also completed the parental feeding practices questionnaire at T9 (questionnaires detailed in section 2.2.3.7). As discussed in **Chapter Four**, the HEI needed updating because the original measure was developed in 2010 for use in parents with pre-school aged children. Therefore, it was necessary to modify the wording in the interview to ensure that it was appropriate to be administered with parents of school-aged children. Consultation with an expert panel further identified the need to update questions relating to the media environment. The modification of the original HEI for use in parents with school-aged children and the evaluation of the psychometric properties of the updated measure is detailed in **Paper Two; Chapter Four**. The updated version of the HEI, the decision tracking document detailing the changes made to the original measure, and other relevant documents (e.g. online survey for the expert panel, recruitment poster, participant information sheets and consent form) from the work involved in the update of the HEI are included in **Appendix A.6, A.8-A.15**.

2.2.3.7 Parental feeding practices

Parental feeding practices were assessed at baseline (8 months), T2 (16 months), T7 (5 years) and T10 (12 years) using adapted scales from existing validated questionnaires; a shortened version of the Parental Feeding Style Questionnaire (PFSQ)(Wardle et al., 2002), and scales from the Child Feeding Questionnaire (CFQ) (Birch et al., 2001), the Comprehensive Feeding Practices Questionnaire (CFPQ (Musher-Eizenman & Holub, 2007)), Poppets (Cooke, 2008; Sweetman et al., 2011), and Over-Covert Control (Ogden et al., 2006). All items were rated on a five point Likert-Scale by the parents who chose from the following options ‘never’, ‘rarely’, ‘sometimes’, ‘often’, ‘always’. A full list of items included at 16 months, 5 years and 12 years and adaptations made to the measures at each time point are detailed in **Table 2.4.**

Four scales from the PFSQ were included to examine the following parental feeding practices: ‘encouragement to eat’ (five items; e.g., ‘I encourage my child to eat a wide variety of foods’), ‘instrumental feeding’ (four items; e.g. ‘I reward my child with something to eat when he/she is well-behaved’), ‘emotional feeding’ (five items; e.g. ‘I give my child something to eat to make him/her feel better when he/she is feeling upset’); and ‘control’ (five items; e.g. ‘I decide how many snacks my child should have’). Each item was rated on a five point Likert-scale, ranging from ‘never’ to ‘always’. The items were used to calculate mean scores for the scale. Each of the original scales have demonstrated adequate internal consistency (Cronbach’s α = 0.65 – 0.85) and test-retest reliability (Pearson’s r = 0.76 – 0.83) (Wardle et al., 2002). The PFSQ was adapted, with input from the original author of this questionnaire (Professor Jane Wardle), so that it focused on the encouraging fruit and vegetable consumption rather than general food consumption. Modifications were made to wording of items included in the ‘instrumental feeding’ and ‘emotional feeding’ scales to ensure they were appropriate for 16-month-old children. For the emotional feeding subscale, adjectives or phrases used to describe the child’s mood state were adapted to be appropriate for 16-month-olds. The original wording was adapted in four out of five items in the emotional feeding scale (the adapted wording used is followed by the original wording in brackets): ‘when s/he has hurt him/herself’ (when s/he has been hurt); “to occupy him/her, e.g. when in company, shopping, or travelling” (If s/he is feeling bored); “when s/he is feeling irritable” (when s/he is worried); ‘when s/he is grumpy’ (when s/he is feeling angry). One item (‘In order to get my child to behave him/herself I promise him/her something to eat') was removed from the instrumental feeding scale as it was considered unlikely that children of this age group would be able to understand action-consequence formulae sufficiently to have implications for their behaviour.

Two scales from the CFQ were included to assess the following parental feeding practices: 'pressure to eat' (five items; e.g. 'my child should always eat all of the food I give him/her') and 'monitoring' (three items; e.g. 'I keep track of the sugary foods that my child eats') (Birch et al., 2001). Each item was rated on a 5 point Likert-scale, ranging from 'never' to 'always'. The items were used to calculate mean scores for the scale. The factor structure of these scales has been confirmed previously (Anderson et al., 2005; Birch et al., 2001; Corsini et al., 2008); and each factor has shown adequate internal consistency (Cronbach's alpha = 0.70 for Pressure; 0.92 for monitoring) (Birch et al., 2001).

The CFQ also assesses the feeding practice parental restriction; however, the measure is limited in several ways. Firstly, there is evidence that restriction is a separate construct from using food as a reward for behaviour (Anderson et al., 2005; Birch et al., 2001). Secondly, the measure refers to restriction of the child's favourite foods, which could be healthy or unhealthy. Thirdly, the measure does not capture portion sizes. 'Restriction' was therefore assessed using a four-item scale from the Poppets study (Cooke, 2008) which was designed to measure restricted access to, and portion sizes of, sugary and high-fat foods e.g. 'I limit the portion sizes of high fat foods that I give to my child'. Each item on the scale is rated using a 5 point Likert-scale, ranging from 'never' to 'always'. Feedback from parents during piloting of the measure led to a modification to one of the original Poppets items – "I limit the portion sizes of high fat and sugary foods that I give to my child". This item was split into two separate items to measure portion sizes of high fat and sugary foods separately, as parents highlighted that they viewed the two food types slightly differently.

In accordance with emerging evidence at the time on the effectiveness of parental modelling of healthy eating, the 'Modelling' scale from the Comprehensive Feeding Practices Questionnaire (Musher-Eizenman & Holub, 2007) was included (4 items; e.g. 'I model healthy eating for my child by eating healthy food myself'). Each item is rated using a 5 point Likert-Scale, ranging from 'never' to 'always'. The items were used to calculate mean scores for the scale.

One scale from the Overt/Covert Control (Ogden et al., 2006) was used to assess the parental feeding practice 'Covert control'. The original scale includes 4 items (e.g. "I avoid buying foods that I would like because I don't want my child(ren) to have them") and was modified in the following ways for use in the Gemini sample. Firstly, all items were changed into statements to keep the items in line with the rest of the questionnaire. For example, "I avoid buying foods that I would like because I don't want my child(ren) to have them" was changed to "I avoid buying unhealthy foods and bringing them into the house". Secondly, the response scale was changed from "yes/no" to a five point Likert-scale, "never, rarely, sometimes, often, always" to keep it in line with the response scale from the PFSQ, and to create more variance among the responses. Thirdly, two items ('I avoid buying sweets and crisps and bringing them into the house' and 'I avoid buying biscuits and cakes and bringing them into the house') were combined into one ('I avoid buying unhealthy foods and bringing them into the house') to shorten the scale.

One item was added to the scale to capture an additional behaviour considered to relate to covert control ('I ask other people not to feed my child unhealthy foods'). The items were used to calculate mean scores for the scale. Additional modifications were made to wording of items to make them age-appropriate for subsequent waves of data collection at 5 years and 12 years. **Table 2.4** provides a comprehensive overview of all items included in the scales used to assess parental feeding practices and any modifications that were made to scales at each time point.

Table 2.4. Parental feeding practice measures included at 16 months, 5 years and 12 years, and any deletions (shown as strikethrough) and/or modifications (shown in red text) made at each time point.

	Original items	Items[a] included at 16 months	Item modifications at 5 years	Item modifications at 12 years
Encouragement to eat (5 items; PFSQ) (Wardle et al., 2002)	**1.** I encourage my child to eat a wide variety of foods **2.** I praise my child if s/he eats a new food **3.** I praise my child if s/he eats what I give him/her **4.** I encourage my child to enjoy his/her food **5.** I present food in an attractive way to my child - I encourage my child to taste each of the foods I serve at mealtimes - I encourage my child to try foods that s/he hasn't tasted before - I encourage my child to look forward to the meal	**1.** I encourage my child to eat a wide variety of foods **2.** I praise my child if s/he eats a new food **3.** I praise my child if he/she eats fruit or vegetables **4.** I encourage my child to eat fruit or vegetables **5.** I present fruit and vegetables in an attractive way to my child	No modifications (items same as 15 months).	No modifications (items same as 15 months and 5 years).
Instrumental feeding (4 items; PFSQ) (Wardle et al., 2002)	**6.** If my child misbehaves I withhold his/her favourite food **7.** I use puddings as a bribe to get my child to eat his/her main course **8.** I reward my child with something to eat when s/he is well-behaved **9.** I use foods my child likes as a way to get him/her to eat "healthy" foods - In order to get my child to behave him/herself I promise him/her something to eat	**6.** If my child misbehaves, I withhold his/her favourite food **7.** I use puddings as a bribe to get my child to eat his/her main course **8.** I reward my child with something to eat when s/he is well behaved **9.** I use foods my child likes as a way to get him/her to eat 'healthy' foods.	No modifications (items same as 15 months).	No modifications (items same as 15 months and 5 years).

	Original items	Items[a] included at 16 months	Item modifications at 5 years	Item modifications at 12 years
Emotional feeding (5 items; PFSQ) (Wardle et al., 2002)	**10.** I give my child something to eat to make him/her feel better when s/he is feeling upset. **11.** I give my child something to eat to make him/her feel better when s/he has been hurt. **12.** I give my child something to eat if s/he is feeling bored. **13.** I give my child something to eat to make him/her feel better when s/he is feeling angry **14.** I give my child something to eat to make him/her feel better when s/he is worried	**10.** I give my child something to eat to make him/her feel better when s/he is feeling upset **11.** I give my child something to eat to make him/her feel better when s/he has hurt him/herself **12.** I give my child something to eat to occupy him/her, e.g. when in company, shopping, or travelling. **13.** I give my child something to eat to make him/her feel better when s/he is feeling grumpy **14.** I give my child something to eat to make him/her feel better when s/he is feeling irritable	**10.** No change. **11.** I give my child something to eat to make him/her feel better when s/he has been hurt **12.** I give my child something to eat when s/he is feeling bored **13.** I give my child something to eat to make him/her feel better when s/he is feeling angry **14.** I give my child something to eat to make him/her feel better when s/he is worried	No modifications (items same as 5 years).
Control (5 items; PFSQ) (Wardle et al., 2002)	**15.** I allow my child to choose which foods to have for meals **16.** I decide how many snacks my child should have **17.** I let my child decide when s/he would like to have her meal **18.** I let my child eat between meals whenever s/he wants **19.** I decide what my child eats between meals - I decide when it is time for my child to have a snack	**15.** I allow my child to choose which foods to have for meals **16.** I decide how many snacks my child should have **17.** I let my child decide when s/he would like to have his/her meal **18.** I let my child eat between meals whenever s/he wants **19.** I decide what my child eats between meals	No modifications (items same as 15 months).	~~**16.** 'I decide how many snacks my child should have' (~~ Item 16 removed) **19.** 'I decide what my child eats between meals as far as possible'

	Original items	Items[a] included at 16 months	Item modifications at 5 years	Item modifications at 12 years
	- I decide the times when my child eats his/her meals - I insist my child eats meals at the table - I allow my child to decide when s/he has had enough snacks to eat - I allow my child to wander around at meals			
Pressure to eat (5 items; CFQ) (Birch et al., 2001)	**20.** My child should always eat all of the food on her plate **21.** I have to be especially careful to make sure my child eats enough **22.** If my child says "I'm not hungry", I try to get her to eat anyway - If I did not guide or regulate my child's eating, she would eat much less than she should.	**20.** My child should always eat all of the food I give him/her **21.** I have to be especially careful to make sure my child eats enough **22.** If my child thinks he/she isn't hungry, I try to get him/her to eat anyway **23.** If I did not guide or regulate my child's eating, s/he would eat much less than s/he should **24.** I insist my child eat some fruit or vegetables, even if s/he doesn't want	No modifications (items same as 15 months).	No modifications (items same as 15 months and 5 years).
Monitoring (3 items; CFQ) (Birch et al., 2001)	**25.** How much do you keep track of the sweets (candy, ice cream, cake, pies, pastries) that your child eats? **26.** How much do you keep track of the snack food (potato chips, Doritos, cheese puffs) that your child eats? **27.** How much do you keep track of the high-fat foods that your child eats?	**25.** I keep track of the sugary foods that my child eats **26.** I keep track of the high fat foods that my child eats **27.** I keep track of the foods my child's been eating when he/she is not with me (e.g. with a childminder or family member)	No modifications (items same as 15 months).	~~**27.** 'I keep track of the foods my child's been eating when he/she is not with me (e.g. with a childminder or family member).~~ (Item 27 removed)

	Original items	Items[a] included at 16 months	Item modifications at 5 years	Item modifications at 12 years
Modelling (4 items; CFPQ) (Musher-Eizenman & Holub, 2007)	**28.** I model healthy eating for my child by eating healthy foods myself **29.** I try to eat healthy foods in front of my child, even if they are not my favourite **30.** I try to show enthusiasm about eating healthy foods **31.** I show my child how much I enjoy eating healthy foods	**28.** I model healthy eating for my child by eating healthy foods myself **29.** I try to eat healthy foods in front of my child, even if they are not my favourite **30.** I try to show enthusiasm about eating healthy foods **31.** I show my child how much I enjoy eating healthy foods	No modifications (items same as 15 months).	**31.** ~~'I show my child how much I enjoy eating healthy foods'~~. (Item 31 removed)
Restriction[b] (4 items; Poppets) (Cooke, 2008)	**32.** I limit my child's access to sugary foods **33.** I limit my child's access to high fat foods **34.** I limit the portion sizes of high fat foods that I give to my child **35.** I limit the portion sizes of sugary foods that I give to my child	**32.** I limit my child's access to sugary foods **33.** I limit my child's access to high fat foods **34.** I limit the portion sizes of high fat foods that I give to my child **35.** I limit the portion sizes of sugary foods that I give to my child	No modifications (items same as 15 months).	**32.** I limit my child's access to sugary foods as far as possible **33.** I limit my child's access to high fat foods as far as possible **34.** I limit the portion sizes of high fat foods that I give to my child as far as possible **35.** I limit the portion sizes of sugary foods that I give to my child as far as possible
Covert restriction (4 items; Overt-Covert Control) (Ogden et al., 2006)	How often do you **36.** Avoid going to cafes or restaurants with your children which sell unhealthy foods **37.** Not buy foods that you would like to because you don't want your children to have them **38.** Try not to eat unhealthy foods when your children are around	**36.** I avoid going to cafes or restaurants with my child which sell unhealthy foods **37.** I avoid buying unhealthy foods and bringing them into the house **38.** I try not to eat unhealthy when my child is around	No modifications (items same as 15 months).	~~**39.** I ask other people not to feed my child unhealthy foods~~. (Item 39 removed)

Original items	Items[a] included at 16 months	Item modifications at 5 years	Item modifications at 12 years
39. Avoid buying biscuits and cakes and bringing them into the house	**39.** I ask other people not to feed my child unhealthy foods		

[a]All items (except Restriction; Poppets) are rated using a 5 point Likert-Scale, 1=‘never’, 2=‘rarely’, 3=‘sometimes’, 4=‘often’, 5=‘always’.
[b]Items are rated using a 7 point Likert-Scale, ranging from 1=’Not at all’ to 7=’Strictly’

2.3 Analytical methods

2.3.1 Complex samples analyses

Complex Samples Logistic Regression (CSLR) was used to examine associations between domain-specific home environment composites (IVs), and corresponding diet, physical activity and sedentary behaviours dichotomised into binary outcomes (DVs) (see Paper Two; **Chapter Four**). Complex Samples General Linear Models (CSGLM) were used to examine associations between the home environment composites scores (media environment and overall home environment composite) (DVs) and corresponding screen-based sedentary behaviours and BMI-SDS (DVs) (see Paper Two; **Chapter Four**). Complex samples analysis enables the analysis of data from related individuals, in which variables are likely to be correlated within family members (e.g. twin pairs). Complex samples analyses adjust for clustering of twins in families by widening the standard errors to account for the reduced variation in the sample (Hahs-Vaughn, 2005; Hahs-Vaughn, 2006; Korn & Graubard, 1995; Xue et al., 1998), due to correlation between twins, which thereby produces smaller test statistic values. By using these methods the full dataset can be analysed, allowing the sample size to be maximised, thus increasing the power to detect effects. Analyses were conducted in Statistical Package for Social Sciences (SPSS) version 26.0 (IBM Corp., 2019), with a p-value <0.05 considered statistically significant.

2.3.2 Structural equation modelling

Structural Equation Modelling (SEM) in the form of cross-lagged panel models were used to examine bi-directional prospective associations between the obesogenic quality of the home environment and child BMI-SDS (see **Paper Three**; **Chapter Five**). The benefit of this analytic approach is that it allows both directional hypotheses to be tested in the same model, rather than running separate regression analyses, and thus enables more meaningful interpretation of the output and increases statistical power (Newsom, 2015). Additionally, another advantage of this approach over standard regression analysis is that SEM provides indices of the overall fit of the model to the data. Analyses were conducted in the statistical software R version 4.0.3 using with the statistical package 'lavaan' (Rosseel, 2012) and the add-on 'lavaan.survey' (Oberski, 2014). This add-on allows for adjustment for clustering within families and means that the data from both twins in a pair can be included in the analyses, which maximises the sample size, thus increasing the power to detect effects. Evidence has suggested that an SEM model should include a minimum of 200 participants (Weston & Gore, 2006), the sample size used in Paper Four (**Chapter Five**) included 298 participants.

2.3.3 Heritability analyses using twins

Twin studies offer a powerful method for understanding the extent to which individual differences in a particular trait, such as body weight or appetitive traits, are influenced by genes and environmental influences (shared and non-shared). Identical twins (MZ) share 100% of their genome, and are natural clones of one another; whereas non-identical twins (DZ) like regular siblings, share on average 50% of their segregating genes (Knopik et al., 2017a). Additionally, both MZ and DZ twins (if reared together) share their environments to a very similar extent; they are gestated in the same mother at the same time, share the same age, share the same family and grow up in the same home. Therefore, the resemblance between MZ and DZ twins can be compared to estimate genetic and environmental contributions to any measureable trait. A key assumption of the twin method is that if MZ pairs are more similar than DZ pairs then we can assume that genetic factors must be contributing to this difference, because the only real difference between the two types of twins is that MZs are twice as similar genetically. The extent to which environmental factors are shared is assumed to be equal for both MZ and DZ twins.

The statistic derived to estimate genetic effects is commonly referred to as 'heritability'. Heritability is the proportion of phenotypic variation attributable to genetic variation, and can be thought of as an index of the genetic effect size; it ranges from 0% (genes do not contribute at all to trait variation) to 100% (genes entirely explain trait variation). Heritability, otherwise known as additive genetic effects, can be roughly estimated by doubling the difference between the MZ and DZ correlations (Knopik et al., 2017a). Resemblance not attributed to additive genetic effects can be attributed to environmental effects. Environmental effects are also estimated, and separated out into those that are completely shared between twin siblings (those factors that contribute to their similarity), and non-shared (those that contribute to sibling differences) which includes measurement error (Rijsdijk & Sham, 2002). This approach allows for variation (V) in a trait to be broken down into three latent factors: the proportion attributable to: additive genetic effects (A); shared environmental influences such as the shared family environment (C); and non-shared environmental influences (E), which also captures random measurement error (Knopik et al., 2017a).

The simple ‘univariate’ twin model described above can be extended to interaction models whereby the effects of A, C and E can be estimated separately and compared for twins exposed to different environments, for example, those living in higher-risk home environments compared to those living in lower risk home environments. This approach is termed the ‘heterogeneity model’ and will be described in more detail in **Paper Five; Chapter Seven**.

Maximum Likelihood Structural Equation Modelling (MLSEM) is commonly used to analyse twin data as it provides more reliable estimates of A, C, and E with 95% confidence intervals and goodness-of-fit statistics. Analyses were carried out in R version 4.0.3. (Wilson & Norden, 2015) using the statistical package OpenMX (Boker et al., 2011).

2.3.3.1 Limitations of the twin method

There are a number of limitations of the twin method that should be addressed. Firstly, a key assumption of the twin method is the ‘equal environments assumption’ (EEA), which states that environmental exposure influencing similarity is the same for both MZ and DZ twins reared in the same family (Knopik et al., 2017b). The EEA is a critical aspect of the twin method; we assume that greater similarity between MZ than DZ pairs is only a result of greater genetic similarity, and no other reason. However, if MZ twins share their environments more closely than DZs, this is a violation of the EEA and would lead to an overestimation of the genetic contribution to variation. The reason being is that in this scenario, the higher MZ correlation would reflect greater shared environmental influences as well as greater genetic relatedness compared to DZ correlation; not just a greater genetic relatedness of MZs. It has been argued that

MZ twins may share their environments more closely than DZ twins because MZ twins are the same sex and look identical (Guo, 2001; Hettema et al., 1995), and thus may be treated more similarly by parents than DZ twins (Felson, 2014). Violation of the EEA has been suggested to be a fundamental flaw of the twin method (Richardson & Norgate, 2005). However, the EEA has been tested using methods such as examining twins that have been misclassified as DZ twins when they are in fact MZs. The design compares the correlation of a trait for MZ pairs who correctly identify as MZs and MZs who have been misclassified as DZs. If the correlation matches for MZ twins who have been correctly classified and those who are misclassified, then this is seen to provide support for the EEA. This design has been used to provide support for the validity of the EEA for a number of traits as MZ twins have been found to correlate to the same extent regardless of believed zygosity (Conley et al., 2013; Herle et al., 2016; Kendler et al., 1993; Scarr & Carter-Saltzman, 1979). A review of the evidence revealed that the EEA is valid for most traits and controlling for environmental similarity only resulted in a reduction of ~10% for heritability estimates, these findings indicate that if the EEA is violated it would only result in a minor inflation of heritability estimates (Felson, 2014).

Another limitation of the twin method is the generalisability of twins to the general population of singletons. Compared to singletons, twins generally have a lower birth weight, are born earlier and are at increased risk for perinatal complications than singletons (Grumbach et al., 1986; Van Dommelen et al., 2008). For these reasons, the twin method has received criticism with researchers arguing that twins are not generalizable to singleton research. However, research has shown that twins do not differ from singletons on various physical and behavioural traits

(Andrew et al., 2001), and can thus be deemed representative. In addition, although twins have a lower birth weight they grow at a faster rate after birth, experiencing ‘catch up’ growth over the first 2 years of life, and achieve the same height and weight as singletons by about 2.5 years (Van Dommelen et al., 2008).

Introduction to Chapter Three

As outlined in Chapter One, there has been extensive research examining relationships between the home food, physical activity and media environments and children's food intake, activity levels and screen-based sedentary behaviours. However, there is a lack of clarity around the role of the home environment in child weight development. Therefore, Chapter Three aimed to address this gap through a systematic review of peer-reviewed literature examining relationships between physical and social aspects of the home environment and measures of adiposity in children ≤12 years. The findings of this systematic review were used to inform the approach taken in Paper Two (detailed in Chapter Four).

Chapter 3
The relationship between the home environment and child adiposity: A systematic review.

Chapter type:	Journal Article
Journal:	*International Journal of Behavioral Nutrition and Physical Activity*
Submission date:	November 2020
Submission status:	Published 06 January 2021
Reference:	Kininmonth, A.R., Smith, A.D., Llewellyn, C.H., Dye, L., Lawton, C.L. & Fildes, A. (2021). The relationship between the home environment and child adiposity: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, 18, 4 (2021). https://doi.org/10.1186/s12966-020-01073-9

Note. *As this paper is accepted and published, the formatting and layout are consistent with the requirements for International Journal of Behavioral Nutrition and Physical Activity, references will not follow the APA style and will be placed at the end of the chapter rather than at the end of the thesis.*

3.1 Abstract

Background: Extensive research has demonstrated the role of the Home Environment (HE) in shaping children's energy balance behaviours. Less is known about direct relationships with bodyweight. This review examines associations between the social and physical aspects of three pre-defined Home Environment domains (food, physical activity and media) and adiposity measures in children ≤12 years.

Methods: Six electronic databases (PubMed, Medline, EBSCO CINAHL, EMBASE, Web of Science, PsycInfo) were systematically searched up to October 2020. Studies reporting at least one physical and/or social aspect of the food, physical activity and/or media domains of the Home Environment in relation to child adiposity outcomes were included (n=62).

Results: Most studies examined one (n=41) or two domains (n=16). Only five studies assessed all three domains of the Home Environment. Most consistent relationships were observed for physical aspects of the home media environment; with greater availability of electronic devices associated with higher child adiposity (21/29 studies). Findings were less consistent for the smaller number of studies examining physical aspects of the home food or physical activity environments. 8/15 studies examining physical food environments reported null associations with adiposity. Findings were similarly mixed for physical activity environments; with 4/7 reporting null associations, 2/7 reporting negative associations and 1/7 reporting positive associations between access to physical activity equipment/garden space and adiposity. Fewer studies assessed social aspects (e.g. caregiver modelling or limit setting) of the Home Environment in relation to child adiposity and findings were again mixed; 9/16 media environment, 7/11 food environment and 9/13 physical activity environment studies reported null associations with child adiposity outcomes.

Conclusions: The home media environment was most consistently associated with adiposity in childhood. Findings were less consistent for the home food and physical activity environments. Greater agreement on definitions and the measurement of the obesogenic home environment is required in order to clarify the strength and direction of relationships with child adiposity. Robust longitudinal research using comprehensive measures of the holistic home environment is needed to better identify which aspects contribute to excess weight gain in childhood.

3.2 Introduction

Excess adiposity in childhood is a major public health issue, it is associated with a wide range of negative physical and psychological health outcomes (1,2). Socio-ecological models provide a useful framework for understanding the different factors contributing to childhood obesity risk (3), theorizing that children are shaped by the environments they interact with most often. The home environment and family context are where children spend a significant proportion of their time during key developmental years (4). Around 70% of a child’s food (for children <12 years old) is consumed at home and importantly, it is where children observe and learn from others’ behaviour (5–8). Consequently, it is hypothesised that the home environment is a major factor in shaping children’s weight trajectories.

Numerous models have been developed to conceptualise how different aspects of the home environment may influence children’s growth and development (5,9,10). Yet the multifaceted and complex nature of the home environment (HE) complicates attempts to characterise and measure its contribution to excess weight development in childhood. A variety of measures have been developed to capture different aspects of the obesogenic HE, such as the types and frequency of foods available in the home (11) or the availability of electronic devices in a child’s bedroom (12). Relationships have been observed between these measures and children’s energy-balance behaviours, including dietary intake(13,14), activity levels(15), and screen-based sedentary behaviours(16,17). However, the extent to which the HE is directly associated with child adiposity is less clear and no previous systematic reviews have examined this.

For the purpose of this review, the obesogenic HE has been partitioned into three domains hypothesised to influence children's food intake, activity levels and sedentary behaviours (10,18–20); the food (e.g. availability of sugar sweetened beverages [SSB]), physical activity (e.g. access to a garden) and media-related (e.g. caregiver rules around electronic devices) domains within the home. As shown in **Figure 3.1**, each domain of the HE can be sub-divided into both physical aspects and social aspects that can either deter or promote health behaviours. These are all hypothesised to influence child energy balance and, ultimately, body weight.

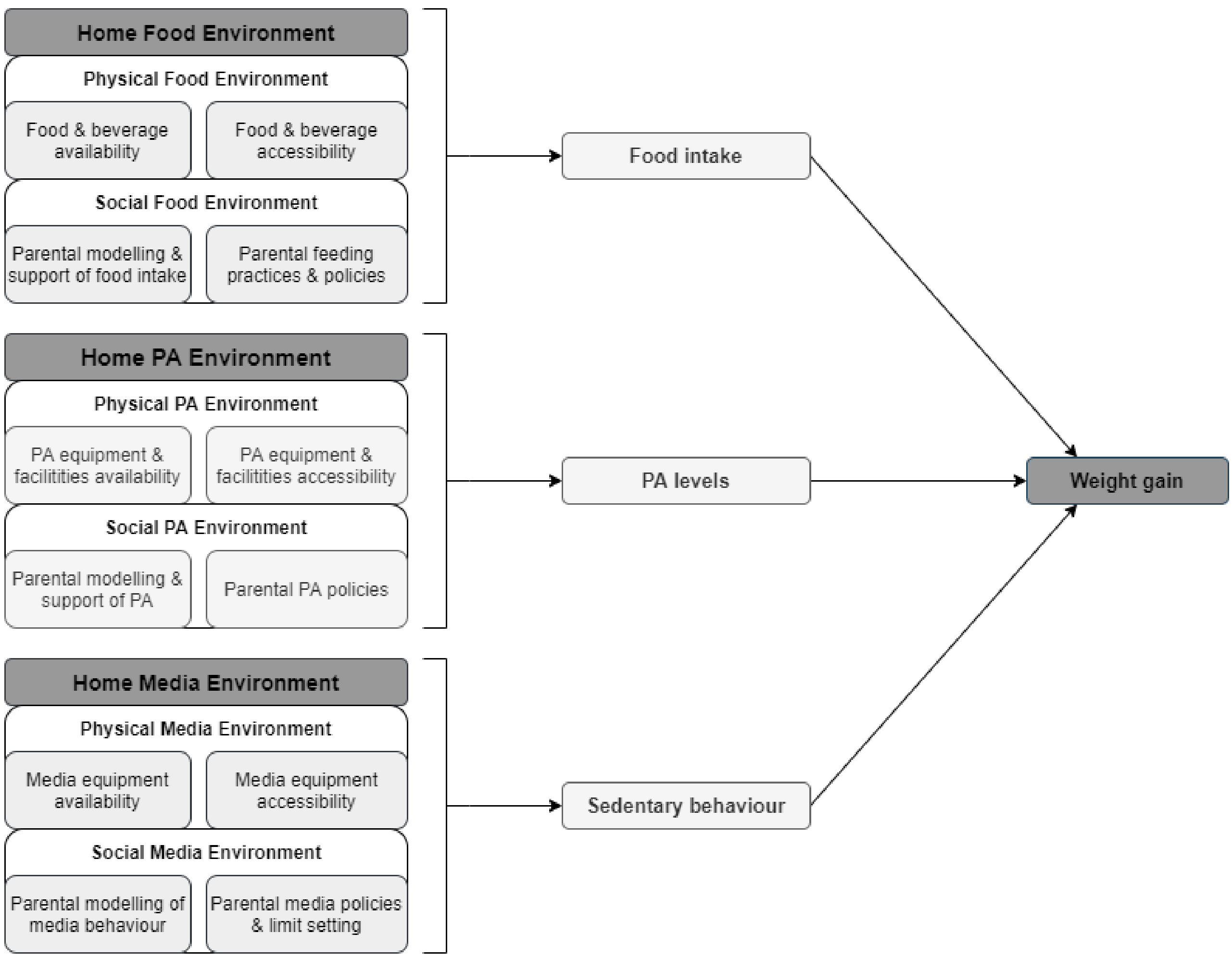


Figure 3.1. Conceptual model used to define the 'obesogenic' home environment (10).

Despite the wealth of literature in this field, previous reviews have largely focussed on only one domain of the HE, for example, the home food environment (21,22), the home media environment (23), or the home physical activity environment (24). Most of these reviews also explored relationships between the HE and behavioural outcomes such as children's diet, activity and/or sedentary behaviour, meaning direct associations with adiposity have not been established. Only one review from a decade ago included all three HE domains, but it primarily explored the psychometric properties of existing measures, rather than evaluating relationships with child weight (18). No previous review has synthesised the evidence to investigate relationships between the obesogenic HE in its entirety, and child adiposity outcomes.

It is important to understand how the different aspects of the home environment relate to excess weight gain in childhood in order to inform effective targeted child obesity prevention and intervention strategies. Therefore, the purpose of this review is to examine associations between physical and social aspects of the food, activity and media domains of the HE with measures of adiposity in childhood (≤12 years).

3.3 Methods

This review followed the PRISMA guidelines **(Appendix B.1)** and was registered on PROSPERO (CRD42018115139).

3.3.1 Eligibility Criteria

Manuscripts were included if they reported on at least one of the three domains of the HE (food, activity and/or media). Each domain was required to be assessed in terms of either the physical (availability of, and access to; foods, media or PA equipment) and/or social aspects (caregiver modelling/support or caregiver policies and rules around energy balance behaviours). Studies were also required to provide a quantitative estimate of the association between the chosen HE domain(s) and a measure of adiposity (e.g. BMI z-score). Studies were eligible for inclusion if they were peer-reviewed original observational research studies and recruited from non-clinical, non-intervention populations. The population of interest was children aged ≤12 years. This age range was chosen to broadly capture the upper age of primary school children, which can vary both between and within countries (for example children in the U.K. and Australia typically start secondary school at age 11, whereas in Singapore and the Netherlands children tend to start secondary school at age 12). Additionally, the upper limit of 12 years was selected to focus this review on pre-teenage years, before children's autonomy over their environment increases and they spend more time outside the home. Studies were excluded if they were not published in English and no translation was available (n=41).

Family mealtimes were excluded from the definition of the social home food environment as a recently published review examined the relationship between family mealtimes and child weight (25). This meta-analysis found higher family meal frequency was associated with better overall diet quality, greater consumption of nutrient dense foods and fewer energy-dense foods and lower child BMI.

3.3.2 Literature search strategy

Six electronic databases were searched up until October 2020: Medline (OVID from 1946 to Oct 2020), EBSCO CINAHL, EMBASE (OVID), Web of Science, PubMed, and PsycInfo (OVID). The search strategy (see **Appendix B.2**) was informed by search terms from a relevant review (18). Database searches were supplemented by reading the reference list of eligible studies and relevant reviews in the area (18).

3.3.3 Identification of relevant studies and data extraction

Study eligibility was assessed independently by two reviewers; with 5% of title and abstracts and 10% of full texts screened in duplicate. There was 96% agreement between the reviewers, with any disagreement resolved via discussion. A standardised format for extraction was developed to ensure detailed data were obtained from each included study. Data extracted included key study and sample characteristics (e.g. study design, sample size, demographics), aspects of the HE examined (e.g. availability of physical activity equipment, caregiver modelling, etc.) and details of the child weight-related outcomes (e.g. measures used, population reference data, obesity cut-off criteria). The strength and direction of relationships between HE aspects and adiposity measures were also extracted.

3.3.4 Assessment of study quality

Risk of bias was completed for each included study using an adapted version of the validated Newcastle Ottawa Scale (NOS) for cohort studies (26). The tool was used to evaluate studies based on the research design, representativeness of the sample, appropriateness of the statistical analysis, recruitment strategy, measurement of exposure, and use of power calculation. A NOS score ≥7 was considered indicative of high study quality. The maximum score that could be awarded for study quality was 10. Full details are described in **Appendix B.3.**

3.4 Results

Overall, the search strategy identified 21,747 independent publications. Following title and abstract review, 12,257 were excluded and a further 367 papers were excluded after assessment of the full texts. An additional seven papers were identified through searching relevant manuscript reference lists during the screening stage. In total, 62 studies met the inclusion criteria. **Figure 3.2** outlines each stage of the study selection process.

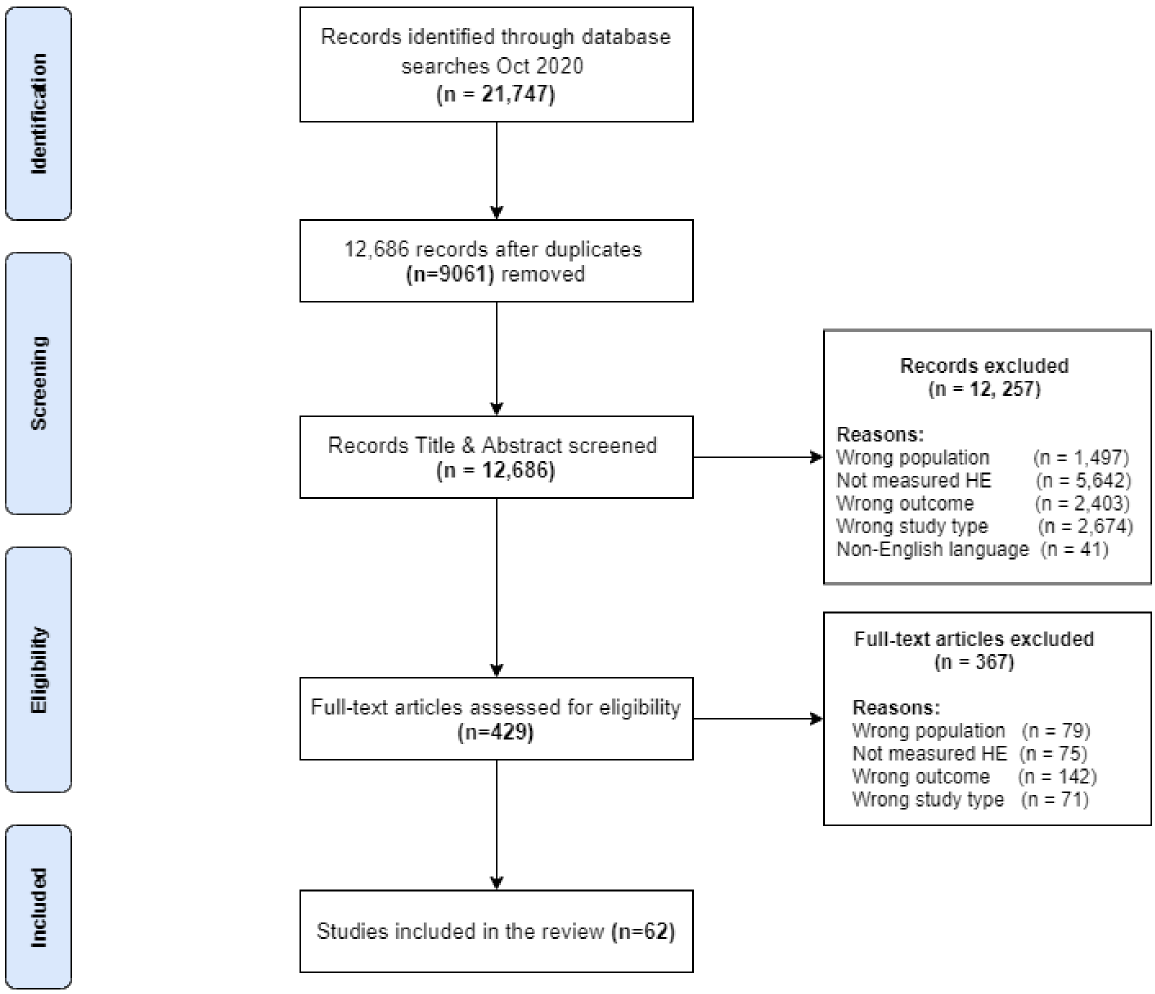


Figure 3.2. PRISMA Flow Diagram of the systematic review literature search.

3.4.1 Characteristics of included studies

Table 3.1 summarises the key characteristics and findings from the 62 included studies. Overall, most studies were undertaken in North America (n=20), Europe (n=17) or Australia (n=8), with only few studies undertaken in Asia (n=7). Across the 62 included studies, there were a total of 105,268 children ranging in age from 18 months to 12 years, but the majority of studies (n=45) focused on primary school aged children aged between 5 and 12 years. Seven studies were exclusively in pre-school aged children (<5 years) (27–31), while ten studies involved children spanning a broader age range (from pre-school up to 12 years) (32–39). Most studies examined associations between home environments and child body weight cross-sectionally (n=51), with fewer prospective studies (n=11). Most studies examined a single domain (n=41) or two domains (n=16), with only five studies assessing all three pre-defined domains of the HE (29,30,34,40,41).

Most studies were published in the 5 years (n=23; 37.1%) or 5-10 years (n=30; 48.4%) prior to this review. Fewer studies had been published before 2009 (n=9; 14.5%), with the earliest study published in 1985. A summary of the association between the food, PA and media domains and child adiposity are presented in **Table 3.2** and **Appendix B.4.-B.6.**

3.4.2 Characteristics of HE and adiposity measures

There was substantial heterogeneity in the measurement tools used to examine the HE. Measurement methods varied, including comprehensive measures of all three domains of the HE such as the Home Environment Interview (30) and Family Nutrition & Physical Activity Screening Tool (40), and measures of one or two domains of the HE such as the Family Eating and Activity Habits

Questionnaire (35), the Family Food Environment Questionnaire (42), and The Home Self-Administered Tool for Environmental Assessment of Activity and Diet (HomeSTEAD) (38). Other measures were less comprehensive, using single items or a limited number of items to measure only one aspect of the HE (e.g. availability of television in the bedroom). Most studies exclusively used caregiver and/or child self-completed (n=49) or interviewer-delivered (n=4) questionnaire methodology. Few studies (n=4) used in-home observation, and this was generally used in addition to questionnaire-based measures.

Measures of adiposity were taken via trained researcher (n=48), parent-report (n=5) or a combination of both (n=2). Most studies (n=61) used height and weight measurements to derive BMI, BMI z-score or BMI percentile. These measurements were taken using a calibrated weighing scales and stadiometer (n=53) or with parents own scale and measuring tape (n=9). Only nine studies supplemented height and weights with additional adiposity measures, such as body fat percentage (BF%) (n=1), skinfold thickness (n=1), Fat Mass Index (n=1), waist circumference (n=3), waist-to-height ratio (WtHR) (n=1), or a combination of these (n=2). Only one study used BF% as the primary outcome (n=1).

Table 3.1. Characteristics and results table for included studies (n=62).

Author, year	Study design	Country	Sample N (% male), age	HE Constructs assessed	HE measure (items, method of administration)	Adiposity Outcome	Key finding: Relationship with adiposity
MEDIA ENVIRONMENT ONLY (STUDIES N = 23)							
Adachi-Mejia et al. 2007 (16)	Cross	USA	2343 (50%), 9-12 y	Physical - TV in bedroom. TVs in household	2 items; PR	BMI z-scores[1]	TV in bedroom associated with OW (OR =1.32).
Anderson et al., 2010 (27)	Cross	USA	8550 (51%), 4 y	Social - Caregiver limits around screen-time (<2 hrs/day)	1 item; PR.	BMI z-scores[1]	Limits on screen-viewing duration associated with lower odds of OB (OR = 0.85, p = 0.002).
Atkin et al. 2013 (59)	Prosp	UK	2064, (T0) 9-10 y (45%); (T1) 10-11 y (41%)	Physical - Media equipment (TV, computer) in bedroom and household (assessed T0, T1y)	2 items; PR	BMI, weight status (NW/OW)[4]	Children with OW more likely to have a TV in bedroom (T0 and T1) compared to children with NW. No effect of computer in bedroom. Higher total bedroom media score in children with OW compared to NW (T1y).
Borghese et al. 2015 (46)	Cross	USA, Canada	1201 (43%), 10 y.	Physical - TV in bedroom	ISCOLE HNEQ; 1 item; PR.	Body Fat %	Canadian sample: TV in bedroom associated with higher BF% compared to no TV (boys: 21.8% vs 18.1%; girls: 24.9% vs 21.3%). American sample: TV in bedroom associated with higher BF% compared to no TV in boys (21.4% vs 18.9%) only.
Cameron et al. 2013 (45)	Cross	7 European Countries[b]	7234 (48%), 10-12 y.	Physical - TV in bedroom	1 item; PR.	BMI & WC[4]	TV in bedroom associated with higher BMI and waist circumference (in 4/7 European countries).
Chahal et al. 2013. (44)	Cross	Canada	3398 (50%), 10-11 y	Physical - Media equipment in bedroom (TV, DVD player, computer, video game console, phone)	Project EAT-III questionnaire, (5 items), PR and CR	BMI and weight status (NW, OW, OB)[4]	Electronic media devices (3+) in bedroom associated with greater odds of OW (OR = 2.57) or OB (OR = 2.23, p<.05) compared to no devices. Increased odds of OB for children with TV in bedroom (OR = 1.64), or computer in bedroom (OR = 1.47). Increased odds of OW for children with phone in bedroom (OR = 1.42).
Chaput et al. 2014 (43)	Cross	Canada	502 (41%), 9-11 y	Physical – Media equipment in bedroom (TV, computer, video games)	ISCOLE HNEQ; 3 items; PR.	BMI z-scores, BMI centile, BF% [5]	2-3 screens in bedroom associated with higher BF% compared to no screen. TV in bedroom associated with higher BF% compared to no TV. Computer in bedroom not associated with BF%.
Dube et al. 2017 (58)	Cross	Canada	2334 (47%), 10-11 y.	Physical - Media equipment in bedroom (TV, computer, video game, tablet, mobile phone)	Project EAT-III Q; 5 items; PR.	BMI[4]	≥1 device in bedroom associated with increased odds of OB (OR = 1.82). Increased odds of OB for those with

							mobile phone (OR = 1.56, 95% CI: 1.24, 1.98), TV (OR = 2.56), and/or computer (OR = 2.79) in bedroom.
Farajian et al. 2014 (57)	Cross	Greece	4552 (49%), 10-12 y	Physical - Media equipment in bedroom (TV, computer, video game)	2 items; CR	BMI[4]	Having both TV and PC/video game console in bedroom associated with increased odds of OW/OB (OR = 1.41).
Ferrari et al. 2015 (49)	Cross	Brazil	441 (49%), 9-11 y.	Physical - Media equipment in bedroom (TV, computer, video games)	ISCOLE HNEQ;3 items; PR.	BMI [5]	Video games in bedroom associated with higher BMI (β = 0.94). 2-3 electronic devices in bedroom associated with higher BMI (β = 0.51). No association with BMI for TV and computer.
Ferrari et al. 2017 (62)	Cross	Brazil	328 (52%), 9-11 y	Physical - Media equipment in bedroom (TV)	ISCOLE HNEQ; 3 items; PR.	BMI, BF %, WC [5]	No associations with BMI.
Hardy et al. 2012 (32)	Cross	Australia	1141 (50%), 5-12 y	Physical – TV in bedroom. Social - Caregiver rules around screen-time duration.	ASAQ; 4 items; PR; validated.	BMI, weight status (HW, OW/OB[4]	Girls with OW more likely to have a TV in bedroom compared to girls with NW (OR=2.00) (no association for boys). No association between caregiver media rules and weight status.
Heilmann et al. 2017 (50)	Prosp	UK	12,556 (51%), 7-11 y.	Physical - Media equipment in bedroom (TV)	1 item; PR	BMI, body fat, weight status[4]	TV in bedroom (at age 7) associated with greater RR of having OW at age 11 (RR for boys = 1.21; RR for girls = 1.31) compared to no TV.
Gomes et al. 2015 (53)	Cross	Portugal	580 (58.1%), 9-11 y.	Physical - Media equipment in bedroom (TV, computer, video games)	ISCOLE HNEQ; 3 items, PR.	BMI [5]	Media in bedroom associated with higher BMI (β= 0.26).
Lane et al. 2014 (54)	Cross	Ireland	8568 (48.7%), 9 y	Physical - Media equipment in bedroom (TV, computer, video games, phone)	4 items; PR.	BMI[4]	TV in bedroom (OR = 1.38) and owning a mobile phone (OR = 1.41) associated with increased odds for OW or OB. No association for computer and games console in bedroom.
Li et al. 2014 (55)	Cross	China	497 (51.7%), 8-10 y	Physical - Media equipment in home (games console, computer, DVD)	3 items; PR.	BMI-SDS[2]	No media equipment in home associated with lower risk of OB compared to 1-2 devices, specifically DVD players (OR = 0.68) and games consoles (OR = 0.60). No association for computer.
Lehto et al. 2011 (56)	Cross	Finland	604 (48.3%), 9-11 y.	Physical - Media equipment in bedroom (TV, computer, video games)	2 items; CR	BMI, WC, WHtR[11]	TV in bedroom associated with higher WC (β=2.30). Computer/video games in bedroom associated with higher WC (β=1.33)
Sijtsma et al. 2015 (28)	Cross	Netherlands	1670 (53%), 3-4 y	Physical – TV in bedroom. Number of TVs in home.	LRBQ; 2 items; PR.	BMI z-score[9]	TV in bedroom associated with higher BMI. No association between number of televisions in home on and BMI.
Tiberio et al. 2014 (65)	Prosp	USA	213 (45%), 5-9 y	Social - Caregiver monitoring and limit setting around media use	3 items[14]; PR	BMI z-scores[1]	Less maternal monitoring associated with higher BMI z-scores at age 7 (β = -.23, p<0.01) and steeper increases in BMI z-scores from ages 5 to 9 y (β = -.058, p<0.01).

Rutherford et al. 2015 (33)	Prosp	Australia	4983 (51.4%) 4-9 y	Physical – TV in bedroom and computer in home. Social - Caregiver rules around TV viewing duration	3 items; PR	BMI[4]	No associations with BMI and weight status.
Lin et al 2019 (67)	Cross	Taiwan	1031 (50%), 7-12 y	**Media:** Social – Caregiver modelling and limit setting around screen-viewing	6 items; PR.	BMI	No association with weight status.
Paduano et al 2020 (52)	Cross	Italy	588 (53.2%), 6-7 y	**Media:** Physical – TV in bedroom	1 item; PR.	BMI z-score	TV in bedroom associated with higher odds of OW/OB (OR=1.1)
Park et al 2019 (63)	Cross	USA	129 (48.1%) 2-5y	**Media:** Physical - TV in bedroom	FNPA[16]; 20 items; PR; validated.		No association with weight status.
FOOD ENVIRONMENT ONLY (n = 13)							
Cassimos et al. 2011 (70)	Cross	Greece	335 (54.03%), 9-12 y.	Physical - Availability of and access to sweets and juice in the home.	21 items; PR.	BMI[4]	Availability of sweets associated with increased odds of OW/OB (OR = 0.357).
Chen et al. 2018 (35)	Cross	China	222 (51.5%), 3-6 y	Physical - Energy dense foods at home	FEAHQ; 29 items; PR, validated.	BMI [5]	Availability of energy dense foods associated with higher BMI (β coefficient = 0.30, p<.01)
Couch et al. 2014 (13)	Cross	USA	699 (50.2%), 6-11 y	Physical – Availability of energy dense foods and nutrient-dense foods Social – Caregiver modelling positive eating behaviours. Caregiver rules around child eating.	EMS (7 items); FEAHQ (3 items); AWQ (12 items); PR; validated	BMI z-scores[1]	Encouragement/modelling of 'healthy eating' negatively associated with BMI z- scores (β coefficient = -0.17). No association between food availability and BMI z-scores. No association between caregiver rules around child eating and BMI z-scores.
Downs et al. 2009 (74)	Cross	Canada	225 (NP), 9-12 y	Physical - Food and beverages in the home.	FAQ; NP; CR interview.	BMI[4]	No associations with BMI.
Humenikova et al. 2008 (71)	Cross	Czech and USA	US: 45 (33%) Czech: 97 (43%), 10-11 y	Physical - 'healthful' foods (e.g. fruits, vegetables, low-fat dairy) in home	Shelf Inventory; 80 items; PR, validated.	BMI percentiles [1]	America: No association with BMI z-score. Czech: Greater availability of 'healthful' foods associated with lower BMI z-scores (r =-.203, p<.05).
Gable et al. 2000 (75)	Cross	USA	65 (43%), 6-10 y	Physical aspects - Food and beverages in the home.	FAQ; NP; PR.	BMI[13]	No associations with BMI.
Lopez-Barron et al. 2015 (72)	Cross	Mexico	684 (45.5%), 10-11 y	Physical - Food and beverages in the home.	Food inventory; 13 items; CR.	BMI z-scores, Height z-scores, WC[2]	OW/OB associated with increased odds of availability of fruits and vegetables (OR = 1.10, p = 0.035). OW/OB associated with lower availability of energy-dense foods at home (OR 0.56, p<.001)
MacFarlane et al. 2009 (42)	Prosp	Australia	T0=161 (50%) 5-6 y	Physical - Energy-dense foods at home Social - Caregiver policies around energy-dense snacks and fast foods.	Family food environment; 7 items; PR.	BMI z-scores[1]	No associations with BMI z-scores.

			T1=132 (50%) 10-12				
Terry and Beck, 1985 (76)	Cross	USA	16 (56%) 8-12 y	Physical - Foods in the home (foods traffic lighted based on caloric value; number of red, yellow and green foods visible in home)	In-home observation of food environment x 2.	BMI[12]	**Observation 1:** No difference between OB and NW in availability of energy-dense foods. **Observation 2:** No difference between OB and NW in availability of energy-dense foods.
Palfreyman et al. 2014 (80)	Cross	UK	484 (51%), 1-8 y	Social - Caregiver modelling of healthy eating behaviour	PARM; 18 items; PR.	BMI z-scores[10]	No association with BMI.
Van Lippevelde et al. 2013 (77)	Cross	7 European Countries[1,5]	6374 (47%), 10-12-y.	Physical – Breakfast type foods (milk, cereal, breads) in home	1 item; PR.	BMI z-score[8]	No association with BMI.
Vaughn et al. 2017 (36)	Cross	USA	129 (51%), 3-12 y.	Physical - Food and drinks in the home. Social - Caregiver modelling of eating and limit setting around unhealthy food intake	CAFPP; 124 items; PR; validated	BMI centiles and z-scores[11]	No associations between availability with BMI. No association between caregiver modelling or limit setting around unhealthy eating with BMI.
Quah et al 2018 (81)	Cross	Singapore	511 (52.1%), 5y	Social – Caregiver modelling and support for healthy eating.	CFPQ; 8 items; PR; validated.	BMI z-score	No association with BMI z-score.
PHYSICAL ACTIVITY ENVIRONMENT ONLY (n = 5)							
Chivers et al., 2012 (83)	Prosp	Australia	2868 (NP%), 1-10 y.	Physical – PA equipment at home. Social - Caregiver support of PA by visiting park or playground with child.	NP; PR.	BMI[4]	Cross-sectional: No associations with weight status. Prospective: No associations with weight status.
Sijtsma et al. 2015 (85)	Cross	Netherlands	1554 (50%), 3-4 y	Social - Caregiver modelling of PA behaviour	SQUASH; 11 items; PR.	BMI z-score and WC[9]	No association between caregiver modelling of PA and BMI or waist circumference. Caregiver modelling of PA commuting (e.g. walking) associated with lower BMI Z-score (r = −0.062).
Liszewska et al. 2018 (84)	Prosp	Poland	879 (48%), 6-11 y	Social - Caregiver modelling and support of PA	ARPQ (7 items); Modified CFPQ for PA (31 items); PR; validated	BMI z-scores[2]	Caregiver modelling and support of PA associated with lower BMI z-scores (r = -.070, p<.05).
Schalkwijk et al. 2018 (37)	Prosp	UK	6467 (51%), 3-7 y	Physical - Access to garden at home	1 item; PR.	BMI[4]	No access to garden associated with increased odds for OW/OB (OR = 1.35).

Umstattd Meyer et al. 2013 (82)	Cross	US/ Mexico	94 (42%), 6-11 y	Physical - PA equipment at home	16 items; interview PR.	BMI percentiles	No associations with BMI.
STUDIES ASSESSING TWO DOMAINS OF THE HOME ENVIRONMENT (n = 16)							
Hales et al. 2013 (38)	Cross	USA	129 (51%), 3–12 y	**Media:** Physical – Media equipment in home (TV, computer, video games) **PA:** Physical - Availability and access to PA equipment	HomeSTEAD; 1015 items; PR; validated.	BMI percentiles [1]	**Media:** No associations with BMI. **PA:** Greater PA equipment associated with lower BMI (‘adult exercise equipment’; r = −0.26, and ‘child fixed play equipment’; r = −0.25 and ‘child portable play equipment’; −0.23).
Jones, et al. 2009 (39)	Cross	Australia	140 (51%), 2-6 y	**Media:** Physical- TV in bedroom. Social aspects - Caregiver rules around TV **PA:** Social - Caregiver rules around PA	Parenting Styles Q; 9 items; PR	BMI[4]	**Media:** No associations with weight status. **PA:** No associations with weight status.
Sleddens et al. 2017 (15)	Prosp	Netherlands	1694 (51.2%), 5-7 y	**Media:** Social – Caregiver limit setting around screen-based activities **PA:** Social – Caregiver support of child PA	ARPQ; 7 items; PR; validated.	BMI z-score[9]	**Media:** Caregiver policy ‘restriction of sedentary behaviour’ associated with greater increases in BMI z-scores from ages 5 to 7. **PA:** No association with BMI.
Taylor et al. 2011 (66)	Cross	Australia	175 (44%), 7-12 y	**Media:** Social– Caregiver modelling and limit setting around of media use. **PA:** Social - caregiver modelling of PA	Parent Physical Activity Practices Q; 11 items; PR.	BMI z-score[4]	**Media:** No association with BMI. **PA:** No association with BMI.
Mathialagan et al. 2018 (64)	Cross	Malaysia	802 (NP%), 10-12 y	**Media:** Social - Caregiver limit setting around electronic media equipment use. **PA:** Social - Caregiver PA levels	42 items; CR; validated.	BMI[2]	**PA:** No association with weight status. **Media:** Caregiver limits on media use associated with lower child weight status.
Rosenberg et al. 2010 (51)	Cross	USA	116 (52.2%), 5-11 y	**Media:** Physical – Media equipment in bedroom and home (TV, computer, games console) **PA:** Physical - PA equipment at home	Home PA equipment scale (21 items); HEES (14 items); PR.	BMI z-score[1]	**Media:** Electronics in bedroom associated with higher BMI z-score (β coefficient = .17, p<.05). TV in bedroom not associated with BMI. **PA:** No association with BMI.
Mihrshahi et al. 2017 (48)	Cross	Australia	3884 (49%), 6-10 y	**Media:** Physical - TV in bedroom. Social - Caregiver rules around screen-time **Food:** Physical – Sugar-sweetened beverages (SSB) at home. Social - Caregiver policies around sweet snacks	5 items; PR.	BMI, WHtR - abdominal obesity[11]	**Media**: TV in bedroom associated with higher odds of OW/OB (OR = 1.74) and abdominal OB (OR = 1.96). No limits on screen-time associated with higher odds of abdominal OB (OR = 1.66). **Food:** Availability of SSB associated with higher risk of OW/OB (OR = 1.51) and higher abdominal OB (OR = 1.50) in unadjusted models. No association with adiposity in fully adjusted models.

Keihner et al. 2009 (61)	Cross	USA	299 (47.8%), 9-11 y	**Media:** Physical - TV in bedroom. Social – caregiver limit setting around screen-time **Food:** Social - Caregiver modelling of energy-dense foods	Food and activity diary, FMTS; 4 items; CR and PR.	BMI z-scores, BMI %tiles[1]	**Media:** No associations with BMI. **Food:** No associations with BMI.
Huynh, et al. 2011 (31)	Prosp	Vietnam	670 (49%), 4-5 y	**Media:** Physical - Media equipment in home (TV, computer, video games, portable devices) **Food:** Physical - Food and beverages in the home.	HOME-SF; validated.	BMI, skinfold thickness[7]	**Media**: No associations with changes in BMI or skinfold thickness over 1 year. **Food:** Availability of 'healthy foods' negatively associated BMI (girls only) and skinfold thickness (boys and girls) over 1 year.
Serene et al. 2011 (78)	Cross	Kuala Lumpur	1430 (41.5%), 9-12 y	**Food:** Physical – Foods in home. Social - Caregiver encouragement of healthy eating. **PA:** Social - Caregiver support of PA	Q developed based on CFQ and DASH.	BMI[5]	**Food:** No associations with BMI. **PA:** No associations with BMI
Serrano et al. 2014 (79)	Cross	Puerto Rico	114 (42.1%), 12 y	**Food:** Social - Caregiver encouragement of healthy eating **PA:** Social - caregiver encouragement of PA	Team COOL Survey; 76 items; PR; validated.	BMI[1]	**Food:** No association with weight status. **PA:** No association with weight status.
Moreno et al. 2011 (87)	Cross	USA	233 (47%), 5-12 y	**Food:** Social - Caregiver modelling of healthy eating **PA:** Social - Caregiver modelling of PA	FHBS; 27 items; PR; validated.	BMI z-score[1]	**Composite score:** No association between 'Parent behaviour' (caregiver modelling of healthy eating and PA) and child BMI z-scores.
Sirikulchayanonta et al. 2011 (86)	Cross	Thailand	280 children (50%), 8-12 y.	**Food:** Physical - Foods available in home **PA:** Physical – Access to PA equipment/garden	11 items; CR. Composite score of 'home environment'	BMI age- and sex-specific[6]	**Composite score:** Higher risk 'home environment' associated with increased odds of OB (OR = 2.8).
Torres et al. 2014 (73)	Cross	Puerto Rico	114 (43%), 12 y	**Food:** Physical - Foods in home. **PA:** Physical - PA equipment at home	Home Physical Environment; 10 items; CR	BMI percentiles [1]	**Food:** Availability of 'unhealthy' foods associated with higher BMI (r = −0.25). No association between availability of healthy foods with BMI. **PA:** Access to PA equipment associated with higher BMI (r=0.25).
Crawford et al. 2012 (47)	Cross	Australia	491 (47%), 5-12 y	**Media:** Physical - TV in bedroom and home. Social - Caregiver limit setting around electronic media **PA:** Physical - PA equipment at home. Social - Caregiver support of PA	Home environment questionnaire; 46 items; PR; validated.	BMI z-scores[1]	**Media:** TV in bedroom associated with higher BMI z-scores (B coefficient = 0.24). No association between caregiver limit setting and BMI. **PA:** No associations with BM
Vaughn et al 2019 (68)	Cross	USA	129 (51%), 3-12 y	**Media:** Social – Caregiver modelling and limit setting around electronic media use.	HomeSTEAD; 196 items; PR; validated.	BMI percentile	**Media:** No association with BMI percentile. Caregiver modelling of video games and computer associated with higher BMI percentile (r=0.15).

				PA: Social - Caregiver modelling and support of PA			**PA:** Caregiver encouragement of PA associated with lower BMI percentile (r=-0.25). Lack of caregiver support for PA associated with higher BMI percentile (r=.17). No association for modelling of PA.
STUDIES MEASURING ALL THREE DOMAINS OF HOME ENVIRONMENT (n = 5)							
Rodenburg, G., et al. 2013 (41)	Cross	Netherlands	1480 (50.5%), 8–12 y	**Food:** Physical - Food and beverages in the home. Social - Caregiver modelling and support for healthy eating **Media:** Physical – Media equipment (TV, computer) in bedroom. Social – Caregiver modelling of TV viewing. Caregiver rules around screen viewing. **PA:** Physical - PA equipment at home. Social - Caregiver modelling of PA	Home Environment Survey (HES); 84 items; PR; validated. Five composite scores created.	BMI z-score[9]	**Composite score:** 'Diet- and activity-related positive modelling' (caregiver modelling of healthy eating, modelling of sedentary behaviour, caregiver snack intake and access to PA equipment) was positively associated with child BMI z-scores (B coefficient = 0.08, p<0.05). No association between 'High visibility and accessibility to screens and unhealthy food' and BMI z-scores.
Ihmels et al. 2009 (40)	Cross	USA	854 (51.3%), 6-7 y	**Food:** Social - Caregiver modelling of healthy eating behaviour **Media:** Physical - TV in bedroom. Social - Caregiver monitoring of TV **PA:** Social - Caregiver modelling and support of PA	FNPA; 21 items; PR; validated.	BMI, BMI percentiles [1]	**Food:** Caregiver modelling of healthy eating associated with lower BMI (r = -.132). **PA:** Caregiver modelling of PA associated with lower BMI (r = -.086, p<.01). **Media:** TV in bedroom associated with higher BMI (r = -.156, p<.001). No association between caregiver monitoring and child BMI.
Kim et al. 2014 (29)	Cross	South Korea	241 (47.7%), 2-5 y	**Food:** Social - Caregiver modelling of healthy eating **Media:** Social - Caregiver modelling of media use and limit setting **PA:** Social - Caregiver modelling and support for PA	ACTS; 7 items; PA and healthy eating barriers; 9 items; PR; validated.	BMI [11]	**Food:** Caregiver modelling of 'healthy eating' associated with higher odds of OB (OR = 1.11). **PA:** No associations with weight status. **Media:** Caregiver modelling of media use associated with higher odds for OB (OR =1.01). Caregiver limit setting of media use associated with lower BMI (-0.12, p<0.05).
Gubbels et al 2011 (34)	Prosp	Netherlands	2026 (51.2%), 5- 7 y	**Food:** Social - Caregiver support for healthy eating **Media:** Social - Caregiver limit setting around electronic media use **PA:** Social - Caregiver support and encouragement of child PA	Modified CFQ for food (9 items); ARPQ (9 items); PR; validated.	BMI z-score [5]	**Food:** Caregiver support/encouragement of 'healthy eating' at age 5 associated with lower BMI z-scores at age 7 (B coefficient = 0.07). **PA:** No association with BMI. **Media:** Caregiver limits of media use at age 5 associated with higher increases in BMI from age 5 to 7 (B coefficient = 0.06).

Schrempft et al. 2015 (30)	Cross	UK	1096 (49%), 4 y	**Food:** Physical – Food and beverages in the home. Social - Caregiver modelling of eating **Media:** Physical – Media equipment in home and bedroom. Social– Caregiver modelling and limit setting. **PA:** Physical – PA equipment at home. Social - Caregiver modelling/support of PA	HEI; 32 constructs; CATI PR; validated.	BMI z-score [3]	**Food:** No association with BMI. **Media:** No association with BMI. **PA:** No association with BMI. **Overall obesogenic risk:** No association with BM.

Footnotes:

NB: The measure used examines non-HE related aspects. Only some items from the named measure are relevant to the HE domains examined in this review. Therefore, only the number of items from the measure that were utilised are listed.

[1] Centre for Disease Control and Prevention (CDC, 2000) Growth Reference Charts;
[2] World Health Organisation (WHO) 2007 Child Growth Reference values
[3] UK Growth Reference 1990
[4] International Obesity Task Force (IOTF);
[5] WHO Growth reference (2006)
[6] INMU Thai Growth program as weight for height (WFH)
[7] Asian Population Criteria
[8] WHO Anthro-Plus (2009)
[9] Dutch population in 1997
[10] Child Growth Foundation 1996
[11] Not provided
[12] National Centre for Health Statistics
[13] NHANES I
[14] Capaldi, DM.; Pears, KC.; Wilson, J.; Bruckner, L. Parent Interview. Unpublished instrument. Oregon Social Learning Center; Eugene: 1998.
[15] 7 European countries are Belgium, Greece, Hungary, Holland, Norway, Spain, Slovenia
[16] The FNPA was used to create a composite score of the home "family obesogenic environment" which was associated with lower BMI z-score (β =-0.069 (0.032), $p<0.05$). However this score incorporated several aspects of family life outside the scope of this review. Therefore only the findings relevant to the current review are presented here.

Abbreviations: N = cohort size; SES = Socioeconomic Status; HE = Home Environment; OW = Overweight; OB = Obese; BMI = Body Mass Index; WHtR = Waist to Height Ratio; PA = Physical activity; NS = Not stated; Q = Questionnaire; WC = Weight Circumference; SSBs = Sugar Sweetened Beverages; OR = Odds Ratio; TV = Television; HOME-SF = Home Observation for Measurement of the Environment Short Form; CATI = Computer-assisted Telephone Interviewing; ENERGY = EuropeaN Energy balance Research to prevent excessive weight Gain among Youth project; SPEEDY = Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people; ISCOLE = International Study of Childhood Obesity, Lifestyle and the Environment; HNEQ = Home & Neighbourhood Environment Questionnaire; GECKO = Groningen expert center for kids with obesity; HomeSTEAD = Home Self-administered tool for environmental assessment of activity & diet family food practices survey; DASH = Determinants of Adolescents' Social Well-being and Health; COOL = Controlling Overweight and Obesity for Life; SQUASH = Short Questionnaire to Assess Health enhancing physical activity; NIK = Neighbourhood Impact on Kids; Project EAT-III (Eating and Activity in Teens and Young Adults)-III questionnaire; FEAHQ = Family Eating and Activity Habits Questionnaire, PARM = Parental Modelling of Eating Behaviour Scale; ACTS = Activity Support Scale for multiple groups; HEI = Home Environment Interview; EMS = Encouragement and Modelling Scale; ARPQ = Activity Related Parenting Questionnaire; CAFPP = Comprehensive Assessment of Food Parenting Practices; HEES = Home Electronic Equipment Scale; LRBQ = Lifestyle-related behaviour Questionnaire; ASAQ = Adolescent Sedentary Activity Questionnaire; FAQ = Food availability Questionnaire; FHBS = Family Health Behaviour Scale; AWQ = Active Where Parent-Child Questionnaire; ARPQ = Activity Related Parenting Questionnaire; FNPA = Family Nutrition & Physical Activity screening tool; FMTS = Food Modelling Telephone Survey.

3.4.3 Relationship between home environment and adiposity outcomes

Table 3.2. Summary of cross-sectional associations between food, physical activity and media domains and child adiposity outcomes (n=58[a]).

Constructs assessed	**N (%) studies examining construct**	**Association with child adiposity outcome**		
		Positive association	Negative association	Null association
Media domain				
Greater availability & access to electronic devices	29	21	0	8
Caregiver rules/ limits around media	16	2	5	9
Caregiver modelling of media use	5	2	0	3
Food domain				
Greater availability & access to EDF	12	3	1	8
Greater availability & access to F&V	11	1	2	8
Caregiver modelling of eating	10	1	3	6
Caregiver rules/ limits around unhealthy eating	3	0	0	3
Physical activity domain				
Greater availability of & access to PA	7	1	2	4
Caregiver modelling & support of PA	13	0	4[b]	9[b]

Abbreviations: EDF = Energy dense foods; F&V = Fruit and vegetables; PA = physical activity

[a] Four studies (30,41,86,87) are omitted from this table as it was not possible to summarise the findings of studies that created composite scores across two or three domains of the HE. Details of these studies can be found in Table 1.

[b] One study (85) examining caregiver modelling of PA reported different findings by the type of activity modelled: Modelling of commuting to school/work by bike or walking was associated with lower BMI Z-score (r = −0.062) but modelling of vigorous PA was not associated with BMI z-score or waist circumference.

3.4.3.1 Media domain

Twenty-nine studies examined physical aspects of the home media environment, with most studies (21/29; 72.4%) demonstrating positive associations between availability and access to electronic media equipment in the home and measures of child adiposity. This association was observed across children aged 3-12 in both cross-sectional (n=19)(16,28,32,40,43–58) and longitudinal studies (n=2) (50,59). One large prospective study of 12,556 children from the U.K. reported that having a TV in the bedroom at age 7 was associated with increased risk of children developing overweight at ages 7 and 11, compared to those without a TV in their bedroom (50). Similar results were reported in another prospective study following UK children from ages 9/10 to 10/11 (n=2064) (59). Over the past decade, there have been considerable changes in children's use of screens, with a decline in TV viewing and an increase in use of other devices (e.g. tablets, mobile phones, laptops) to access video content online (60). As such, more recent studies have expanded the scope of their measurement tools to capture a broader range of electronic devices in the home (e.g. games console, mobile phones, tablets, laptops etc.). These studies suggest that the number of electronic devices, as well as the types of devices available may have implications for child weight, with a greater number of electronic devices present in the home associated with higher BMI z-scores in children aged between 9-12 (43,49,54,55,57,58). A study of children aged 9-11 (n=502) reported that those with multiple devices (2-3 or more) in their bedroom had higher body fat percentage than children with no devices in their bedroom (43). The remaining studies (8/29; 27.6%) reported null associations between availability of media equipment and child adiposity (31,33,38,39,61–63).

Sixteen studies examined relationships between social aspects of the home media environment and child adiposity (15,27,29,32–34,38–40,47,48,61,64–67). Of these, five studies measured caregiver modelling of media use (29,39,66–68). Two studies conducted in children aged 2-5 years (29) and 3-12 years (68) reported positive associations between caregiver modelling of media use and child BMI. The remaining three studies, involving children aged 2-6 years (39), and 7-12 years from Australia (66) and Taiwan (67), found no associations between caregiver modelling of media use and child adiposity. Sixteen studies examined relationships between caregiver rules and limit setting around media use and child adiposity, with inconsistent findings (15,27,29,32–34,38–40,47,48,61,64–67). Four cross-sectional studies reported associations between fewer caregiver limits and less monitoring of media use with higher risk for abdominal obesity in Australian primary school aged children (aged 6-10 years, n=3884) (48) and higher BMI scores in Malaysian children aged 10-12 (n=802) (64), and preschool aged children from the US (n=8550) (27) and South Korea (n=241) (29). One longitudinal study from the US (n=213) reported similar findings with less caregiver monitoring of media use predicting steeper increases in children's BMI z-scores from ages 5 to 9 (65). However, two prospective studies from the Netherlands which pooled data from the Dutch KOALA birth cohort (n=1694 and n=1819) found the reverse relationship, with limits on electronic media use associated with greater increases in child BMI z-scores from ages 5 to 7 (15,34). Nine studies (56.3%) reported no relationships between caregiver rules and limits around media use and child weight (32,33,36,40,47,61,66,67,69). Findings are summarised visually in **Appendix B.4.**

3.4.3.2 Food domain

Fifteen studies examined relationships between physical aspects of the home food environment and child adiposity, demonstrating inconsistent findings. Six studies reported associations between food or drink availability and access, and child adiposity (31,35,70–73). Greater availability of nutrient dense foods (e.g.

fruits and vegetables) were associated with lower BMI- z-scores in Czech 10 to 11 year olds (n=97) (71), while higher availability and access to energy-dense foods (e.g. SSBs, sweets, etc.) predicted higher BMI among Chinese 3-6 year olds (n=222) (35) and Greek children aged 9 to 12 years (n=335) (70). But conversely, one study of Mexican children (n=684) aged 10-11 reported the opposite relationship; children with OW/OB had greater access to fruits and vegetables and less access to energy-dense foods (e.g. confectionary items, cookies, SSB and salted snacks) in the home (72). Eight studies exploring food availability and accessibility in the home with measures of child adiposity found no relationship between them (13,42,74–78).

In total, eleven studies assessed relationships between social aspects of the home food environment and child adiposity, but these varied in their scope. Eight assessed caregiver modelling and/or support of eating (29,34,40,61,78–81), one assessed caregiver rules and limit setting around food (48) and two assessed both caregiver modelling of eating and caregiver rules/limit setting (13,36). Of the ten studies examining the role of modelling, three demonstrated associations between caregiver modelling and/or support of healthy food intake and lower child BMI z-scores; this was observed both cross-sectionally in U.S. children aged 6-11 (n=699) and aged 6-7 (n=854) (13,40) and longitudinally in Dutch children followed from ages 5 to 7 (34). Contrastingly, one cross-sectional study conducted in South Korean preschool children (n=241; 2-5 years) found greater modelling of healthy eating was associated with higher child BMI (29). Null associations between caregiver modelling and/or support of food intake and child adiposity were observed in the remaining six studies (36,47,61,78–81). A further three studies assessed caregiver rules and policies around unhealthy eating and found null associations with child adiposity across all studies (13,36,48). The findings are summarised in **Appendix B.5.**

3.4.3.3 Physical Activity domain

Seven studies examined relationships between the home PA environment and measures of child adiposity. Two cross-sectional studies reported negative associations between availability and access to PA equipment and child adiposity outcomes (37,38). A large UK-based study (n=6467) of 3-7 year olds reported children with access to garden space had lower odds of OW/OB compared to those without garden access (37). These findings are consistent with a US study of children aged 3 to 12 years which found both the amount and condition of the PA equipment available in the HE was associated with lower BMI percentile (38). Conversely, one study (n=114) of 12 year olds in Puerto Rico reported greater access and availability of recreational and sports equipment at home was associated with higher child BMI (73). The remaining three cross-sectional (47,51,82) and one longitudinal (83) study all reported null associations between access and availability of PA equipment and child BMI.

Thirteen studies explored social PA environments in the home in relation to child adiposity. Two studies, a cross-sectional study of 854 children aged 6-7 from the U.S. and a longitudinal study of 879 Polish children aged 6-11 reported caregiver modelling and support of PA were associated with lower child BMI z-scores (40,84). In contrast, a study of pre-schoolers from the Netherlands (n=1554) found relationships with child adiposity varied according to the type of activity modelled by the parent. Higher levels of active travel (e.g. commuting to work via walking or bike) were associated with lower BMI z-scores in children aged 3-4 years old, but there were no associations for other types of modelled vigorous activity (e.g. running) (85). One cross-sectional study examined caregiver modelling, support and encouragement of PA as separate constructs and found variation in the association with adiposity outcome; with null associations observed between caregiver modelling of PA, while encouragement and support of PA were associated with lower BMI percentiles (68). The remaining nine studies reported null associations between caregiver modelling and/or support of children's PA and measures of adiposity (15,29,34,47,64,66,73,78,83). Findings are summarised in **Appendix B.6**.

3.4.3.4 Composite scores of multiple domains of home environment

Composite scores of the HE reflect the combined contribution of more than one of the pre-defined domains – food, PA or media - within the HE. In this review, we identified four studies which generated composite scores across two (n=2) or three (n=2) domains of the HE and examined associations with child adiposity (30,41,86,87), with mixed findings. One cross-sectional study of U.K. children aged 4 years (n=1096) developed a composite score for the overall physical and social aspects of the HE, and for each of the pre-defined domains – the food, PA and media environment. No relationship with child BMI z-scores were observed for the either the overall HE composite score, or any of the food, activity and media domains (30). A second study, conducted in children aged 8-12 in Bangkok (n=280), created a composite of the physical food and PA environments. Composite scores indicating a 'lower quality' (i.e. more obesogenic) HE were associated with 2.8 times higher risk of child obesity (86). A third cross-sectional study of U.S. children aged 5-12 (n=233) took a slightly different approach, developing a composite score called 'Parent behaviours' which assessed caregiver modelling of healthy eating and caregiver modelling and support of PA. No associations with child BMI z-scores were observed (87). The fourth cross-sectional study of children aged 8-12 from the Netherlands (n=1480), examined physical and social aspects of the HE by combining items into clusters capturing caregiver practices relating to food, PA and media-related energy balance behaviours. The study reported a weak positive association between ‘diet- and activity-related modelling’ and child BMI z-scores, suggesting that children with parents who exhibit greater modelling of healthy eating, lower sedentary behaviours and who live in a home with greater availability of PA equipment actually had higher BMI z-scores (41). Null associations were observed for the remaining four constructs (‘low availability of unhealthy food’, ‘High visibility and accessibility of screens and unhealthy food’, ‘diet and activity related positive modelling’, ‘positive modelling on sports and fruit’) and BMI z-scores. As these studies utilised a composite scoring system, it was not possible to establish the individual contribution of individual aspects of the HE on weight.

3.4.3.5 Risk of bias

Overall, 38/62 (61.3%) of the identified studies were rated as high quality based on the NOS quality assessment criteria. The most common methodological weaknesses were in selection and comparability of studies; with 37/62 of studies (59.7%) providing inadequate justification of sample size, 49/62 (79%) providing an inadequate description of response rate or lack of comparison between respondents/non-respondents, and 22/62 (35.5%) failing to control for important confounding factors such as age, sex, SES, energy balance behaviours or parental adiposity. Full details and individual study scores are described in **Appendix B.3.**

3.5 Discussion

This is the first systematic review to appraise and synthesise the evidence for associations between the physical and social aspects of the food, PA and media domains of the HE with measures of adiposity in childhood (≤12 years). The most consistent associations were observed between the physical aspects of the home media environment, with greater availability and access to electronic media devices in the home, and specifically in the child's bedroom, associated with higher risk of adiposity (21/29 studies). Findings were less consistent for the smaller number of studies examining physical aspects of the home food or PA environments. Half (8/15) of the studies examining physical food environments reported null associations, while similar numbers (6/15) demonstrated positive associations between more obesogenic food environments and higher child adiposity. Findings were similarly mixed for PA environments; with 4/7 reporting null associations, 2/7 reporting negative associations and 1/7 study reporting positive associations between access to physical activity equipment/garden space and adiposity. Fewer studies assessed social aspects (e.g. caregiver modelling or limit setting) of the home environment in relation to child adiposity and findings were again mixed; 9/16 media environment, 7/11 food environment and 9/13 physical activity environment studies reported null associations with child adiposity outcomes.

Although research has shown that children learn behaviour from those around them (7,88,89), we found limited evidence that behaviours learned at home translate into child weight outcomes. Caregiver modelling of behaviours, across the food, activity and media domains of the HE, were not consistently associated with child adiposity measures in expected directions. The variation in findings may in part result from a lack of consensus in how these constructs are defined and measured. Some studies defined modelling simply as how often parents consumed specific foods or beverages, or the length of time parents spent engaging in activities (e.g. PA or screen-based activities). This approach fails to consider a fundamental aspect of modelling - the frequency with which a child observes these behaviours. Additionally, associations with adiposity outcomes were largely explored cross-sectionally (39), hindering understanding of the directionality of associations, and failing to capture variations over time depending on children's age, family circumstances. One of the few studies to examine the prospective relationship between social aspects in the HE (e.g. caregiver modelling, caregiver rules/limit setting) and adiposity, revealed that caregiver encouragement of 'healthy eating' at age 5 was associated with lower BMI z-scores at age 7 and caregiver restriction of sedentary time at age 5 were associated with higher increases in BMI from age 5 to 7 (34). Importantly, this study was one of the first to simultaneously examine the influence of multiple aspects of the social HE. Such holistic approaches are important to incorporate a range of factors potentially contributing to child weight development.

Over half of the studies included at least one measure of the home media domain and it was the aspect of the HE most consistently linked to child weight outcomes. This is perhaps unsurprising as greater availability of media in the home has been shown to be associated with weight-related energy balance behaviours; increased sedentary behaviour, decreased activity levels and increased snacking (90). The more consistent relationship between child adiposity and the physical home media environment may partly result from the fact it is more stable, less complex, and therefore easier to characterise and measure than the home food environment. Unlike the food environment, the media environment is unlikely to fluctuate from day-to-day or vary with seasonal changes to the same extent. It is also arguably easier to report the number and location of electronic devices in the home, than of food and beverage products. Drawing on this point, studies examining availability of foods and beverages in the home were cross-sectional, collecting data at a single time point. This approach fails to capture fluctuations in the types and/or amount of foods and beverages available in the home over the course of days, weeks and months. Thus, the foods available at data collection may not reflect the foods that are typically available within the home (11). It is important for studies to account for this variation in the measurement. The general lack of longitudinal studies identified in this review also means we cannot conclude if features of the HE are driving excess weight gain in children or whether any observed associations result from parents modifying HEs in response to their child's weight status (or weight related behaviour). For example, parents of children with higher adiposity may reduce the availability of energy dense foods at home in an attempt to improve their child's dietary intake and achieve a healthier weight status.

Another possible explanation for the heterogeneity in findings across studies may be due to variation in the degree of adjustment in statistical models. Seven out of fifteen studies examining associations between food availability and child adiposity failed to include important potential confounding variables (e,g, SES or parental adiposity) in the statistical model. Controlling for such confounding variables is important to understand the true association between aspects of the HE and adiposity. This fact is highlighted in the results of a large study of 6-10 year olds in Australia (n=3884) which reported results based on unadjusted and adjusted models. In the unadjusted model, greater availability of SSBs was associated with higher odds of OW or OB and abdominal obesity (48). Conversely, in the statistical model adjusted for age, sex, SES and meeting recommended PA levels, no association with adiposity was observed. Varying degrees of adjustment in the included studies may partially account for variation in findings between studies.

Despite the arguably more straightforward composition of the home media environment, the measures utilised by studies included in this review were limited in scope and rarely captured the diversity of electronic devices currently available to children (91). Most studies (n=16/29) focussed on availability and access to televisions and/or computers within the home, perhaps reflecting the fact that growth in commercially available electronic devices is relatively recent. Ofcom figures reveal U.K. electronic device ownership and use has increased substantially over the last decade, with tablet ownership among 5-15 year olds, rising from 2% in 2011 to around 50% in 2018 (60). The most comprehensive measure of the media environment was utilised by Canadian researchers, Dube et al (2017) and Chahal (2013), who collected data in a cohort of children aged 10 to 11 (n=2334 and n=3398 respectively) (44,58). Home availability of multiple electronic devices, including TVs, DVD players, computers, video game consoles, tablets and cell phones, were positively associated with higher child weight status (44,58). As home media use continues to evolve, it is important for future research to capture the increasing diversity of electronic devices available, along with use of different media platforms, when exploring the impact of the home media environment on children’s weight development.

Evidence for relationships between the home PA environment and child adiposity was very inconsistent. Most studies reported null associations with adiposity for the social PA environment (caregiver modelling and support of PA), while findings for associations between the physical PA environment (availability of and access to PA equipment) and adiposity varied. It is possible that the home PA environment is less important than the home media environment for influencing energy balance and thus weight in childhood. The home media environment has been found to contribute significantly towards sedentary behaviour (12), and energy intake (90), and was more consistently associated with weight in this review. The relationship between PA and child adiposity is complex, reviews have generally found an absence of convincing evidence for the contribution of PA to child adiposity (92,93), which may in part be due to methodological weaknesses and imprecise measurement of PA levels. Excess weight gain has also been linked to a reduction in physical activity levels further complicating the relationship (94–96). In addition, there may be age-related variation in the relationship between the home PA environment and child adiposity. The home PA environment may be more influential for younger children, who spend more of their time in the home setting. A large UK-based study (n=6467) of 3-7 year olds reported that children with access to garden space had lower odds of OW/OB compared to those without garden access (37). In contrast, as children reach secondary school age and gain independence, the neighbourhood and school activity environments may play a greater role in shaping energy balance behaviours and adiposity. More research measuring multiple components within the HE and in different age groups is needed to establish how and in what ways the home food, PA and media environments may interact to influence a child’s weight development.

Across all HE domains there was a notable lack of consensus on how to define and measure the HE. As a result, very few studies used validated measures (n=20/62). Additionally, few studies attempted to characterise the holistic obesogenic HE, instead focusing on individual aspects of a single domain and often using one or two items to measure a single construct (n=13). Studies that utilised validated measures (n=20) tended to be more comprehensive (e.g. 15,36,96), however it should be noted this did not always result in clearer relationships with child weight outcomes (30,34). For example, Schrempft et al (30) used a validated measure to comprehensively examine the three pre-defined domains of the HE but failed to ascertain associations with adiposity.

3.5.1 Limitations and recommendations for future research

This review is not without limitations. It was restricted to studies published in English-language, and non-clinical, non-intervention studies. As such we excluded studies in which the population received some type of intervention, for example federal support schemes (e.g. Head Start), which likely limited the number of studies included in the review and limited the number of low-income populations. Although interventions are important for determining causal relationships, this review focussed on observational studies as it is important to understand the effect of 'real-world' home environments before deciding how and where to intervene.

There are several problems with the current evidence base, limiting the conclusions of this review. The majority of included studies (n=51/62) were cross-sectional. As discussed, the lack of longitudinal research (11/62 studies) means it is not possible to uncover the direction of relationships between the HE and child adiposity or infer causality. Prospective studies from birth with measurement at multiple time points are needed to identify which aspects of the HE promote or protect against excess weight gain in childhood. Ultimately robust randomized controlled trials of intervention studies will be necessary to determine which aspects of the home environment can be effectively modified to reduce excess weight gain in childhood.

The majority of included studies also predominantly relied on caregiver report and were thus susceptible to social desirability biases (98). This may present a particular problem when exploring associations with child adiposity if reporting bias varies by weight status. For example, parents of children with overweight or obesity may be more likely to underreport availability of energy dense food in the home. However, caregiver report measures remain the best method for collecting HE information at scale, and they have been shown to be validated using objective measures (e.g. wearable cameras) (99).

There is a lack of research conducted in minority ethnic groups and low socioeconomic status (SES) families (only 15/62 studies (24.2%) considered differences in HE by SES). SES may well confound or moderate the relationship between the HE and child adiposity. For example, in economically developed countries, low SES households are more likely to have electronic devices available in the child's bedroom compared with higher SES households (16,100). Little is currently known about the HE in low-income countries, or about how social inequalities influence the overall obesogenic nature of the home and how this in turn may influence children's weight development. Alongside differences by age-groups and SES, future research should also consider individual variation in susceptibility to obesity. Not everyone interacts with the obesogenic environment in the same way (101); for example, availability of energy dense foods may only be associated with increased adiposity in children with an avid appetite. Individual differences in susceptibility to an obesogenic environment likely influence associations between the HE and child adiposity.

Finally, heterogeneity in the measures used and a lack of consensus in both language and definitions of constructs means comparison of findings across studies is impeded. This review emphasises the need to harmonize definitions and measurement of the HE, in order to gain a reliable understanding of how factors within the home contribute to adiposity in childhood, and ultimately inform targeted family obesity prevention and treatment programs.

3.5.2 Conclusion

This review suggests that the most robust associations between the HE and child adiposity are observed within the physical home media environment. It is not clear whether this is due to a stronger relationship between the media environment and child weight development, compared to the food or PA environments, or whether it is an artefact of it being the HE domain most frequently investigated, and most accurately captured, in current research. This review also highlights that despite the large number of studies identified, there is a lack of agreement on how to conceptualise and measure salient aspects of the HE hypothesised to relate to health outcomes. Consensus is needed for a ‘gold standard’ measurement of the multidimensional HE. Future research should focus on utilising comprehensive measures of multiple HE domains in order to understand how, and to what extent, the different aspects of the HE interact to influence children's weight development. Such efforts would facilitate the development of evidence-based guidance on how best to modify the HE to reduce childhood obesity risk.

Abbreviations

HE: Home Environment

PA: Physical Activity

SSB: Sugar Sweetened beverages

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-analysis

PROSPERO: International Prospective Register of Systematic Reviews

BMI: Body Mass Index

NOS: Newcastle Ottawa Scale

SES: Socioeconomic Status

HomeSTEAD: Home Self-Administered Tool for Environmental Assessment of Activity and Diet

OB: Obese

OW: Overweight

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Data generated as part of this systematic review are included as supplementary material. Additional information may be available upon request.

Competing interests

Dr Clare Llewellyn (CHL) reports personal fees from Yellow Kite; personal fees from The Experiment; and personal fees from Diamond Inc, outside the submitted work. The remaining authors have no conflicts of interest to declare.

Acknowledgements

Special acknowledgement to Judith Fortmann (JF), Laura Kudlek (LK) and Karima Abdou (KA) for helping with reviewing of the papers and quality checking.

Funding

This work was supported by the Economic and Social Research Council Advanced Quantitative Methods Studentship (Project reference: 1948633) which was award to Alice Kininmonth.

Authors Contributions

AK and AF were responsible for the conceptualisation and design of the systematic review, and the generation of the systematic review terms. AK conducted the literature search. Screening and article review were performed by AK, JF and KA. AK conducted data extraction and synthesis, and this was independently evaluated by LK. AK was responsible for creating the first draft of the manuscript and all revised versions of the manuscript. AF, AS and CL oversaw the review process and contributed to multiple revisions of the manuscript. All authors have read, contributed to and approved the final manuscript.

3.6 References

1. Boodhna G. Chapter 11: Children's body mass index, overweight and obesity. [Internet]. Vol. 1. 2014. p. 1–24. Available from: https://files.digital.nhs.uk/publicationimport/pub16xxx/pub16076/hse2013-ch11-child-bmi.pdf
2. S NH. National Child Measurement Programme, England - 2017/18 School Year

[PAS]. 2018 Heal Soc Care Inf Cent [Internet]. 2018; Available from: https://digital.nhs.uk/data-and-information/publications/statistical/national-child-measurement-programme/2017-18-school-year

3. Boonpleng W, Park CG, Gallo AM, Corte C, McCreary L, Bergren MD. Ecological Influences of Early Childhood Obesity. West J Nurs Res [Internet]. 2013 Jul 14 [cited 2019 Sep 19];35(6):742–59. Available from: http://journals.sagepub.com/doi/10.1177/0193945913480275

4. Kelder SH, Perry CL, Klepp KI, Lytle LL. Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. Am J Public Health. 1994;84(7):1121–6.

5. Rosenkranz RR, Dzewaltowski DA. Model of the home food environment pertaining to childhood obesity. 2008 [cited 2020 Mar 10]; Available from: https://academic.oup.com/nutritionreviews/article-abstract/66/3/123/1858048

6. Anzman SL, Rollins BY, Birch LL. Parental influence on children's early eating environments and obesity risk: implications for prevention. Int J Obes [Internet]. 2010 Jul 2 [cited 2019 Jun 13];34(7):1116–24. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20195285

7. Savage JS, Fisher JO, Birch LL. Parental Influence on Eating Behavior: Conception to Adolescence. J Law, Med Ethics [Internet]. 2007 Mar 23 [cited 2019 Jun 6];35(1):22–34. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17341215

8. Chai W, Nepper MJ. Associations of the Home Food Environment with Eating Behaviors and Weight Status among Children and Adolescents. J Nutr Food Sci. 2015;12.

9. Pinard CA, Yaroch AL, Hart MH, Serrano EL, McFerren MM, Estabrooks PA. The Validity and reliability of the Comprehensive Home Environment Survey (CHES). Health Promot Pract [Internet]. 2014;15(1):109–17. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=23471699

10. Gattshall ML, Shoup J, Marshall JA, Crane LA, Estabrooks PA. Validation of a survey instrument to assess home environments for physical activity and healthy eating in overweight children. Int J Behav Nutr Phys Act [Internet]. 2008 Jan 11 [cited 2019 Jun 2];5(1):3. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18190709

11. Bryant M, Stevens J. Measurement of Food Availability in the Home. 2006 [cited 2020 Mar 4];67–76. Available from: https://academic.oup.com/nutritionreviews/article-abstract/64/2/67/1894775

12. Aftosmes-Tobio A, Ganter C, Gicevic S, Newlan S, Simon CL, Davison KK, et al. A systematic review of media parenting in the context of childhood obesity research. BMC Public Health. 2016;

13. Couch SC, Glanz K, Zhou C, Sallis JF, Saelens BE. Home food environment in relation to children's diet quality and weight status. J Acad Nutr Diet [Internet]. 2014/07/30. 2014;114(10):1569-1579.e1. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4177359/pdf/nihms616850.pdf

14. Bryant MJ, Ward D, Hales D, Vaughn A, Tabak RG, Stevens J. Reliability and validity of the Healthy Home Survey: A tool to measure factors within homes hypothesized to relate to overweight in children. Int J Behav Nutr Phys Act Vol 5 2008, ArtID 23 [Internet]. 2008;5. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D

=psyc6&AN=2014-47886-001

15. Sleddens EFC, Gubbels JS, Kremers SPJ, van der Plas E, Thijs C. Bidirectional associations between activity-related parenting practices, and child physical activity, sedentary screen-based behavior and body mass index: a longitudinal analysis. Int J Behav Nutr Phys Act [Internet]. 2017;14(1):89. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medl&AN=28683749

16. Adachi-Mejia A, Longacre M, Gibson J, Beach M, Titus-Ernstoff L, Dalton M. Children with a TV in their bedroom at higher risk for being overweight. Int J Obes [Internet]. 2007;31(4):644–51. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc5&AN=2007-05536-004

17. Oude Groeniger J, de Koster W, van der Waal J. Time-varying Effects of Screen Media Exposure in the Relationship Between Socioeconomic Background and Childhood Obesity. Epidemiology [Internet]. 2020 Jul 1 [cited 2020 Jun 16];31(4):578–86. Available from: https://journals.lww.com/10.1097/EDE.0000000000001210

18. Pinard CA, Yaroch AL, Hart MH, Serrano EL, McFerren MM, Estabrooks PA. Measures of the home environment related to childhood obesity: a systematic review. Public Health Nutr [Internet]. 2012 Jan 7 [cited 2019 Jun 6];15(1):97–109. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21899786

19. Pinard CA, Yaroch AL, Hart MH, Serrano EL, McFerren MM, Estabrooks PA. The Validity and Reliability of the Comprehensive Home Environment Survey (CHES). Health Promot Pract [Internet]. 2014 Jan 7 [cited 2019 Jun 6];15(1):109–17. Available from: http://journals.sagepub.com/doi/10.1177/1524839913477863

20. Bryant MJ, Ward DS, Hales D, Vaughn A, Tabak RG, Stevens J. Reliability and validity of the Healthy Home Survey: A tool to measure factors within homes hypothesized to relate to overweight in children. Int J Behav Nutr Phys Act [Internet]. 2008 Apr 28 [cited 2019 Jun 6];5(1):23. Available from: http://ijbnpa.biomedcentral.com/articles/10.1186/1479-5868-5-23

21. Rosenkranz RR, Dzewaltowski DA. Model of the home food environment pertaining to childhood obesity. Nutr Rev [Internet]. 2008;66(3):123–40. Available from: http://dx.doi.org/10.1111/j.1753-4887.2008.00017.x

22. Vaughn AE, Tabak RG, Bryant MJ, Ward DS. Measuring parent food practices: a systematic review of existing measures and examination of instruments [Internet]. Vol. 10, International Journal of Behavioral Nutrition and Physical Activity. 2013 [cited 2020 Mar 9]. Available from: http://www.ijbnpa.org/content/10/1/61

23. Aftosmes-Tobio A, Ganter C, Gicevic S, Newlan S, Simon CL, Davison KK, et al. A systematic review of media parenting in the context of childhood obesity research. BMC Public Health [Internet]. 2016 Apr 14 [cited 2020 Oct 29];16(1):320. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-016-2981-5

24. Kaushal ∗ N, Rhodes RE. The home physical environment and its relationship with physical activity and sedentary behavior: A systematic review. Prev Med (Baltim) [Internet]. 2014 [cited 2020 Nov 1];67:221–37. Available from: http://dx.doi.org/10.1016/j.ypmed.2014.07.026

25. Dallacker M, Hertwig R, Mata J. The frequency of family meals and nutritional health in children: a meta-analysis. Obes Rev [Internet]. 2018/01/16. 2018

May;19(5):638–53. Available from: http://doi.wiley.com/10.1111/obr.12659

26. Modesti PA, Reboldi G, Cappuccio FP, Agyemang C, Remuzzi G, Rapi S, et al. Panethnic Differences in Blood Pressure in Europe: A Systematic Review and Meta-Analysis. Fuchs FD, editor. PLoS One [Internet]. 2016 Jan 25 [cited 2019 Sep 17];11(1):e0147601. Available from: https://dx.plos.org/10.1371/journal.pone.0147601

27. Anderson SE, Whitaker RC. Household routines and obesity in US preschool-aged children. Pediatrics. 2010/02/10. 2010;125(3):420–8.

28. Sijtsma A, Koller M, Sauer PJ, Corpeleijn E. Television, sleep, outdoor play and BMI in young children: the GECKO Drenthe cohort. Eur J Pediatr [Internet]. 2015;174(5):631–9. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25367053

29. Kim HS, Park YH, Park HB, Kim SH. Estimation of effects of factors related to preschooler body mass index using quantile regression model. Asian Nurs Res (Korean Soc Nurs Sci) [Internet]. 2014/12/23. 2014;8(4):293–9. Available from: https://www.asian-nursingresearch.com/article/S1976-1317(14)00076-0/pdf

30. Schrempft S, Van Jaarsveld CHM, Fisher A, Wardle J. The obesogenic quality of the home environment: Associations with diet, physical activity, TV viewing, and BMI in preschool children. PLoS One [Internet]. 2015;10(8):e0134490. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=26248313

31. Huynh DT, Dibley MJ, Sibbritt D, Tran HT, Le QT. Influence of contextual and individual level risk factors on adiposity in a preschool child cohort in Ho Chi Minh City, Vietnam. Int J Pediatr Obes [Internet]. 2011;6(2–2):e487–500. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc8&AN=2011-14759-060

32. Hardy LL, King L, Hector D, Lloyd B. Weight status and weight-related behaviors of children commencing school. Prev Med (Baltim) [Internet]. 2012;55(5):433–7. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=22995371

33. Rutherford L, Brown JE, Skouteris H, Fuller-Tyszkiewicz M, Bittman M. Screen media, parenting practices, and the family environment in Australia: A longitudinal study of young children’s media use, lifestyles, and outcomes for healthy weight. J Child Media [Internet]. 2015;9(1):22–39. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc12&AN=2015-03175-003

34. Gubbels JS, Kremers SP, Stafleu A, de Vries SI, Goldbohm R, Dagnelie PC, et al. Association between parenting practices and children’s dietary intake, activity behavior and development of body mass index: The KOALA Birth Cohort Study. Int J Behav Nutr Phys Act Vol 8 2011, ArtID 18 [Internet]. 2011;8. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc8&AN=2012-31145-001

35. Chen JL, Esquivel JH, Guo J, Chesla CA, Tang S. Risk factors for obesity in preschool-aged children in China. Int Nurs Rev [Internet]. 2017/03/23. 2018;65(2):217–24. Available from: https://onlinelibrary.wiley.com/doi/pdf/10.1111/inr.12371

36. Vaughn AE, Dearth-Wesley T, Tabak RG, Bryant M, Ward DS. Development of a Comprehensive Assessment of Food Parenting Practices: The Home Self-Administered Tool for Environmental Assessment of Activity and Diet Family Food Practices Survey. J Acad Nutr Diet [Internet]. 2016/09/24. 2017;117(2):214–27. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5276728/pdf/nihms817865.pdf

37. Schalkwijk AA, van der Zwaard BC, Nijpels G, Elders PJ, Platt L. The impact of greenspace and condition of the neighbourhood on child overweight. Eur J Public Health [Internet]. 2018;28(1):88–94. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-05454-017

38. Hales D, Vaughn AE, Mazzucca S, Bryant MJ, Tabak RG, McWilliams C, et al. Development of HomeSTEAD's physical activity and screen time physical environment inventory. Int J Behav Nutr Phys Act [Internet]. 2013;10:132. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=24313962

39. Jones RA, Okely AD, Gregory P, Cliff DP. Relationships between weight status and child, parent and community characteristics in preschool children. Int J Pediatr Obes [Internet]. 2009;4(1):54–60. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2009-02079-005

40. Ihmels MA, Welk GJ, Eisenmann JC, Nusser SM. Development and preliminary validation of a Family Nutrition and Physical Activity (FNPA) screening tool. Int J Behav Nutr Phys Act Vol 6 2009, ArtID 14 [Internet]. 2009;6. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2012-30463-001

41. Rodenburg G, Oenema A, Kremers SP, van de Mheen D. Clustering of diet- and activity-related parenting practices: cross-sectional findings of the INPACT study. Int J Behav Nutr Phys Act [Internet]. 2013;10:36. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=23531232

42. MacFarlane A, Cleland V, Crawford D, Campbell K, Timperio A. Longitudinal examination of the family food environment and weight status among children. Int J Pediatr Obes [Internet]. 2009;4(4):343–52. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105253163&site=ehost-live

43. Chaput JP, Leduc G, Boyer C, Belanger P, LeBlanc AG, Borghese MM, et al. Electronic screens in children's bedrooms and adiposity, physical activity and sleep: do the number and type of electronic devices matter? Can J Public Heal Rev Can Sante Publique [Internet]. 2014;105(4):e273-9. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medc&AN=25166130

44. Chahal H, Fung C, Kuhle S, Veugelers PJ. Availability and night-time use of electronic entertainment and communication devices are associated with short sleep duration and obesity among Canadian children. Pediatr Obes [Internet]. 2013;8(1):42–51. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=22962067

45. Cameron AJ, van Stralen MM, Brug J, Salmon J, Bere E, Chinapaw MJ, et al. Television in the bedroom and increased body weight: potential explanations for

their relationship among European schoolchildren. Pediatr Obes [Internet]. 2013;8(2):130–41. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=23239631

46. Borghese MM, Tremblay MS, Katzmarzyk PT, Tudor-Locke C, Schuna Jr. JM, Leduc G, et al. Mediating role of television time, diet patterns, physical activity and sleep duration in the association between television in the bedroom and adiposity in 10 year-old children. Int J Behav Nutr Phys Act [Internet]. 2015;12:60. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25967920

47. Crawford DA, Ball K, Cleland VJ, Campbell KJ, Timperio AF, Abbott G, et al. Home and neighbourhood correlates of BMI among children living in socioeconomically disadvantaged neighbourhoods. Br J Nutr [Internet]. 2012;107(7):1028–36. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=104434240&site=ehost-live

48. Mihrshahi S, Drayton BA, Bauman AE, Hardy LL. Associations between childhood overweight, obesity, abdominal obesity and obesogenic behaviors and practices in Australian homes. BMC Public Health [Internet]. 2017;18:1–10. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=124286766&site=ehost-live

49. Ferrari GL, Araujo TL, Oliveira LC, Matsudo V, Fisberg M. Association between electronic equipment in the bedroom and sedentary lifestyle, physical activity, and body mass index of children. J Pediatr (Rio J) [Internet]. 2015;91(6):574–82. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=26126700

50. Heilmann A, Rouxel P, Fitzsimons E, Kelly Y, Watt R. Longitudinal associations between television in the bedroom and body fatness in a UK cohort study. Int J Obes [Internet]. 2017;41(10):1503–9. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-02265-005

51. Rosenberg DE, Sallis JF, Kerr J, Maher J, Norman GJ, Durant N, et al. Brief scales to assess physical activity and sedentary equipment in the home. Int J Behav Nutr Phys Act Vol 7 2010, ArtID 10 [Internet]. 2010;7. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc7&AN=2012-31433-001

52. Paduano S, Borsari L, Salvia C, Arletti S, Tripodi A, Pinca J, et al. Risk Factors for Overweight and Obesity in Children Attending the First Year of Primary Schools in Modena, Italy. J Community Health [Internet]. 2020 Apr 1 [cited 2020 Nov 2];45(2):301–9. Available from: https://pubmed.ncbi.nlm.nih.gov/31522302/

53. Gomes TN, Katzmarzyk PT, dos Santos FK, de Chaves RN, Santos D, Pereira S, et al. Are BMI and Sedentariness Correlated? A Multilevel Study in Children. Nutrients [Internet]. 2015;7(7):5889–904. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=26193311

54. Lane A, Harrison M, Murphy N. Screen time increases risk of overweight and obesity in active and inactive 9-year-old Irish children: a cross sectional analysis. J Phys Act Health [Internet]. 2014;11(5):985–91. Available from:

http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=23799255

55. Li B, Adab P, Cheng KK. Family and neighborhood correlates of overweight and obesogenic behaviors among Chinese children. Int J Behav Med [Internet]. 2014;21(4):700–9. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24057407

56. Lehto R, Ray C, Lahti-Koski M, Roos E, Lehto R, Ray C, et al. Health behaviors, waist circumference and waist-to-height ratio in children. Eur J Clin Nutr [Internet]. 2011;65(7):841–8. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=104654161&site=ehost-live

57. Farajian P, Panagiotakos DB, Risvas G, Malisova O, Zampelas A. Hierarchical analysis of dietary, lifestyle and family environment risk factors for childhood obesity: the GRECO study. Eur J Clin Nutr [Internet]. 2014;68(10):1107–12. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24824010

58. Dube N, Khan K, Loehr S, Chu Y, Veugelers P. The use of entertainment and communication technologies before sleep could affect sleep and weight status: a population-based study among children. Int J Behav Nutr Phys Act. 2017/07/21. 2017;14(1):97.

59. Atkin AJ, Corder K, van Sluijs EM. Bedroom media, sedentary time and screen-time in children: a longitudinal analysis. Int J Behav Nutr Phys Act [Internet]. 2013/12/18. 2013;10:137. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3895703/pdf/1479-5868-10-137.pdf

60. Ofcom. Children and parents media use and attitudes: annex 1 [Internet]. 2019 [cited 2019 Jun 7]. Available from: https://www.ofcom.org.uk/__data/assets/pdf_file/0027/134892/Children-and-Parents-Media-Use-and-Attitudes-Annex-1.pdf

61. Keihner AJ, Mitchell PR, Kitzmann C, Sugerman S, Foerster SB. Psychosocial, socioeconomic, behavioral, and environmental risk factors for BMI and overweight among 9- to 11-year-old children. Californian J Health Promot [Internet]. 2009;7(S1):1–20. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105071284&site=ehost-live

62. Ferrari GLM, Matsudo V, Katzmarzyk PT, Fisberg M. Prevalence and factors associated with body mass index in children aged 9-11 years. J Pediatr (Rio J) [Internet]. 2017;93(6):601–9. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medl&AN=28506666

63. Park SH, Park CG, Bahorski JS, Cormier E. Factors influencing obesity among preschoolers: multilevel approach. Int Nurs Rev [Internet]. 2019 [cited 2020 Nov 2];66(3):346–55. Available from: https://pubmed.ncbi.nlm.nih.gov/31016729/

64. Mathialagan A, Nallasamy N, Razali SN. Physical activity and media environment as antecedents of childhood obesity in malaysia. Asian J Pharm Clin Res [Internet]. 2018;11(9):287–92. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emexb&AN=624270344

65. Tiberio SS, Kerr DC, Capaldi DM, Pears KC, Kim HK, Nowicka P. Parental monitoring of children's media consumption: the long-term influences on body mass index in children. JAMA Pediatr [Internet]. 2014/03/19. 2014;168(5):414–21. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4034749/pdf/nihms-553696.pdf

66. Taylor A, Wilson C, Slater A, Mohr P. Parent- and child-reported parenting. Associations with child weight-related outcomes. Appetite [Internet]. 2011;57(3):700–6. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc8&AN=2011-26397-022

67. Lin YC, Fung XCC, Tsai MC, Strong C, Hsieh YP, Lin CY. Insufficient Physical Activity and Overweight: Does Caregiver Screen-Viewing Matter? J Child Fam Stud [Internet]. 2019 Jan 15 [cited 2020 Nov 2];28(1):286–97. Available from: https://link.springer.com/article/10.1007/s10826-018-1247-5

68. Vaughn AE, Hales DP, Neshteruk CD, Ward DS. HomeSTEAD's physical activity and screen media practices and beliefs survey: Instrument development and integrated conceptual model. PLoS One [Internet]. 2019 Dec 1 [cited 2020 Nov 2];14(12). Available from: https://pubmed.ncbi.nlm.nih.gov/31891610/

69. Jones BL, Fiese BH. Parent routines, child routines, and family demographics associated with obesity in parents and preschool-aged children. Front Psychol Vol 5 2014, ArtID 374 [Internet]. 2014;5. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc11&AN=2014-41178-001

70. Cassimos D, Sidiropoulos H, Batzios S, Balodima V, Christoforidis A. Sociodemographic and dietary risk factors for excess weight in a greek pediatric population living in Kavala, Northern Greece. Nutr Clin Pr [Internet]. 2011/03/31. 2011;26(2):186–91. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1177/0884533611399772

71. Humenikova L, Gates GE. Social and physical environmental factors and child overweight in a sample of American and Czech school-aged children: A pilot study. J Nutr Educ Behav [Internet]. 2008;40(4):251–7. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2008-08654-005

72. Lopez-Barron RG, Jimenez-Cruz A, Bacardi-Gascon M. Modifiable environmental obesity risk factors among elementary school children in a Mexico-us border city. Nutr Hosp [Internet]. 2015;31(5):2047–53. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25929373

73. Torres R, Serrano M, Perez CM, Palacios C. Physical environment, diet quality, and body weight in a group of 12-year-old children from four public schools in Puerto Rico. P R Health Sci J [Internet]. 2014;33(1):14–21. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24665604

74. Downs SM, Arnold A, Marshall D, McCargar LJ, Raine KD, Willows ND. Associations among the food environment, diet quality and weight status in Cree children in Québec. Public Health Nutr [Internet]. 2009;12(9):1504–11. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105401266&site=ehost-live

75. Gable S, Lutz S. Household, parent, and child contributions to childhood obesity.

Fam Relations An Interdiscip J Appl Fam Stud [Internet]. 2000;49(3):293–300. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc3&AN=2000-00053-008

76. Terry K, Beck S. Eating style and food storage habits in the home: Assessment of obese and nonobese families. Behav Modif [Internet]. 1985;9(2):242–61. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc2&AN=1986-01647-001

77. Van Lippevelde W, Te Velde SJ, Verloigne M, Van Stralen MM, De Bourdeaudhuij I, Manios Y, et al. Associations between family-related factors, breakfast consumption and BMI among 10- to 12-year-old European children: the cross-sectional ENERGY-study. PLoS ONE [Electronic Resour [Internet]. 2013;8(11):e79550. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=24282508

78. Serene TE, Shamarina S, Mohd NM. Familial and socio-environmental predictors of overweight and obesity among primary school children in Selangor and Kuala Lumpur. Malays J Nutr. 2012/02/07. 2011;17(2):151–62.

79. Serrano M, Torres R, Perez CM, Palacios C. Social environment factors, diet quality, and body weight in 12-year-old children from four public schools in Puerto Rico. P R Health Sci J [Internet]. 2014;33(2):80–7. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24964643

80. Palfreyman Z, Haycraft E, Meyer C. Development of the Parental Modelling of Eating Behaviours Scale (PARM): links with food intake among children and their mothers. Matern Child Nutr [Internet]. 2014;10(4):617–29. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=103897038&site=ehost-live

81. Quah PL, Syuhada G, Fries LR, Chan MJ, Lim HX, Toh JY, et al. Maternal feeding practices in relation to dietary intakes and BMI in 5 year-olds in a multi-ethnic Asian population. PLoS One [Internet]. 2018 Sep 1 [cited 2020 Nov 2];13(9). Available from: https://pubmed.ncbi.nlm.nih.gov/30226881/

82. Umstattd Meyer MR, Sharkey JR, Patterson MS, Dean WR. Understanding contextual barriers, supports, and opportunities for physical activity among Mexican-origin children in Texas border colonias: a descriptive study. BMC Public Health [Internet]. 2013;13:14. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=23297793

83. Chivers P, Parker H, Bulsara M, Beilin L, Hands B. Parental and early childhood influences on adolescent obesity: A longitudinal study. Early Child Dev Care [Internet]. 2012;182(8):1071–87. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc9&AN=2012-17073-011

84. Liszewska N, Scholz U, Radtke T, Horodyska K, Liszewski M, Luszczynska A. Association between children’s physical activity and parental practices enhancing children’s physical activity: The moderating effects of children’s BMI z-score. Front Psychol Vol 8 2018, ArtID 2359 [Internet]. 2018;8. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-04598-001

85. Sijtsma A, Sauer PJ, Corpeleijn E. Parental correlations of physical activity and body mass index in young children-The GECKO Drenthe cohort. Int J Behav Nutr Phys Act Vol 12 2015, ArtID 132 [Internet]. 2015;12. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc12&AN=2015-47173-001

86. Sirikulchayanonta C, Ratanopas W, Temcharoen P, Srisorrachatr S. Self discipline and obesity in Bangkok school children. BMC Public Health [Internet]. 2011;11(1):158. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=104861300&site=ehost-live

87. Moreno JP, Kelley M Lou, Landry DN, Paasch V, Terlecki MA, Johnston CA, et al. Development and validation of the Family Health Behavior Scale. Int J Pediatr Obes [Internet]. 2011 Jun;6(2–2):e480–6. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc8&AN=2011-14759-059

88. Rosenkranz RR, Dzewaltowski DA. Model of the home food environment pertaining to childhood obesity. Nutr Rev [Internet]. 2008 Feb 13 [cited 2019 Sep 18];66(3):123–40. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18289177

89. Ventura AK, Birch LL. Does parenting affect children’s eating and weight status? Int J Behav Nutr Phys Act. 2008 Mar;5:15.

90. Pearson N, Biddle SJH, Griffiths P, Johnston JP, Haycraft E. Clustering and correlates of screen-time and eating behaviours among young children. BMC Public Health [Internet]. 2018 Jun 18 [cited 2020 Jun 16];18(1):753. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-018-5698-9

91. Chassiakos YR, Radesky J, Christakis D, Moreno MA, Cross C, Hill D, et al. Children and adolescents and digital media. Pediatrics. 2016 Nov 1;138(5).

92. Abbott RA, Davies PSW. Habitual physical activity and physical activity intensity: Their relation to body composition in 5.0-10.5-y-old children. Eur J Clin Nutr. 2004;

93. Must A, Tybor DJ. Physical activity and sedentary behavior: A review of longitudinal studies of weight and adiposity in youth. Int J Obes. 2005;

94. Berkey CS, Rockett HR, Field AE, Gillman MW, Frazier AL, Camargo CA, et al. Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. Pediatrics [Internet]. 2000 [cited 2020 Jul 31];105(4). Available from: https://pubmed.ncbi.nlm.nih.gov/10742377/

95. Frieden TR, Dietz W, Collins J. Reducing childhood obesity through policy change: Acting now to prevent obesity. Vol. 29, Health Affairs. Health Affairs ; 2010. p. 357–63.

96. Kelley GA, Kelley KS, Pate RR. Exercise and adiposity in overweight and obese children and adolescents: a systematic review with network meta-analysis of randomised trials. [cited 2020 Jul 31]; Available from: http://bmjopen.bmj.com/

97. Couch SC, Glanz K, Zhou C, Sallis JF, Saelens BE. Home food environment in relation to children’s dietquality and weight status. J Acad Nutr Diet. 2014 Oct 1;114(10):1569-1579.e1.

98. Bornstein MH, Putnick DL, Lansford JE, Pastorelli C, Skinner AT, Sorbring E, et al. Mother and father socially desirable responding in nine countries: Two kinds

of agreement and relations to parenting self-reports. Int J Psychol. 2015 Jun 1;50(3):174–85.

99. Schrempft S, van Jaarsveld CH, Fisher A. Exploring the Potential of a Wearable Camera to Examine the Early Obesogenic Home Environment: Comparison of SenseCam Images to the Home Environment Interview. J Med Internet Res [Internet]. 2017 Oct 12 [cited 2020 Feb 26];19(10):e332. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29025695

100. Tandon PS, Zhou C, Sallis JF, Cain KL, Frank LD, Saelens BE. Home environment relationships with children’s physical activity, sedentary time, and screen time by socioeconomic status. Int J Behav Nutr Phys Act. 2012 Jul 26;9.

101. Llewellyn CH. Genetic susceptibility to the “obesogenic” environment: the role of eating behavior in obesity and an appetite for change. Am J Clin Nutr [Internet]. 2018 [cited 2020 Jun 1];108:429–30. Available from: https://doi.org/

Introduction to Chapter Four

Chapter Three highlighted a lack of comprehensive measures of the home environment. With existing measures found to focus on individual aspects (e.g. access to garden, availability of electronic devices), rather than attempting to capture the obesogenic home environment in its entirety. The findings also highlighted that the home media environment was the aspect of the obesogenic home environment most consistently associated with children’s weight cross-sectionally. Despite this, existing measures of the media environment were shown to be limited in their scope, failing to capture the range of devices currently available to children.

The study presented in Chapter Four aims to build on the knowledge gained in Chapter Three by updating and validating a comprehensive measure of the home environment, the home environment interview (HEI) via multiple phases. The HEI is a measure of physical and social aspects of the food, physical activity and media domains in the home environment, originally developed for parents with pre-school aged children. The HEI was previously administered in the Gemini cohort in 2011, when the twins were aged four. This study updates the measure, to reflect technological advances over the past decade and for use in school-aged children, with the aim of exploring associations between the home environment and children’s energy balance behaviours and weight.

Chapter 4

The Home Environment Interview and associations with energy balance behaviours and body weight in school-aged children – A feasibility, reliability, and validity study

Chapter type:	Journal Article
Journal:	*International Journal of Behavioral Nutrition and Physical Activity*
Submission date:	November 2020
Submission status:	Published 23 December 2021
Reference:	Kininmonth, A.R., Schrempft, S., Smith, A.D., Dye, L., Lawton, C., Fisher, A., Llewellyn, C.H., & Fildes, A. (2021). The Home Environment Interview and associations with energy balance behaviours and body weight in school-aged children – A feasibility, reliability, and validity study. *International Journal of Behavioral Nutrition and Physical Activity,* 18, 167. https://doi.org/10.1186/s12966-021-01235-3

Note. *As this paper is accepted and published, the formatting and layout are consistent with the requirements for International Journal of Behavioral Nutrition and Physical Activity, references will not follow the APA style and will be placed at the end of the chapter rather than at the end of the thesis.*

4.1 Abstract

Background: The home environment is thought to influence children's weight trajectories. However, few studies utilise composite measures of the home environment to examine associations with energy balance behaviours and weight. The present study aimed to adapt and update a comprehensive measure of the obesogenic home environment previously developed for pre-schoolers, and explore associations with school-aged children's energy balance behaviours and weight.

Methods: Families from the Gemini cohort (n=149) completed the Home Environment Interview (HEI) via telephone when their children were 12 years. The HEI comprises four composite scores: one for each domain (food, activity and media) of the environment, as well as a score for the overall obesogenic home environment. The primary caregiver also reported each child's height and weight (using standard scales and height charts), diet, physical activity and sedentary screen-based behaviours. A test-retest sample (n=20) of caregivers completed the HEI a second time, 7-14 days after the initial interview, to establish test-retest reliability.

Results: Children (n=298) living in 'higher-risk' home environments (a 1 unit increase in the HEI obesogenic risk score) were less likely to consume fruits (OR; 95% CI=0.40; 0.26-0.61, $p<0.001$), and vegetables (0.30; 0.18-0.52, $p<0.001$), and more likely to consume energy-dense snack foods (1.71; 1.08-2.69, $p=0.022$), convenience foods (2.58; 1.64-4.05, $p<0.001$), and fast foods (3.09; 1.90-5.04, $p<0.001$). Children living in more obesogenic home environments also engaged in more screen-time (β *(SE)* = 4.55 (0.78), $p<0.001$), spent more time playing video games (β *(SE)* = 1.56 (0.43), $p<0.001$), and were less physically active (OR; 95% CI=0.57; 0.40-0.80, $p<0.01$). Additionally, there was a positive

association between higher-risk overall home environment composite score and higher BMI-SDS *(β (SE) = 0.23 (0.09), $p<0.01$)*. This finding was mirrored for the home media specific composite (*β (SE) = 0.12* (0.03), $p<0.001$). The individual home food and activity composite scores were not associated with BMI-SDS.

Conclusion: Findings reveal associations between the overall obesogenic home environment and dietary intake, activity levels and screen-based sedentary behaviours, as well as BMI in 12 year olds. These findings suggest that the home environment, and in particular the home media environment, may be an important target for obesity prevention strategies.

4.2 Background

The home environment has been shown to play an influential role in shaping children's food intake (1,2), physical activity levels, and screen-based sedentary behaviours (3–5). Various socio-ecological models have been developed to conceptualise how different aspects of the home environment may influence children's growth and development (6–8). The 'obesogenic' home environment can be categorised into three domains: food, physical activity and media. Each domain consists of physical (e.g. availability and access) and social factors (e.g. caregiver modelling, rules and limit setting) that have been associated with children's food intake (1), physical activity, and sedentary behaviours (3,9,10) . Evidence highlights that these aspects of the home environment may predict children's weight trajectories (6,11), and thus may be important for obesity prevention and treatment strategies (2,12,13).

Despite the importance of the home environment, there are few measures that comprehensively assess both physical and social aspects. A recent systematic review highlighted that existing measures are limited, with most focussing on individual aspects of a single domain (e.g. availability of fruits and vegetables in the home, access to TV in bedroom, etc.), rather than assessing the overall obesogenic home environment (11). As individual aspects of the home environment are likely to have a limited influence on children's weight-related outcomes, comprehensive measures are required to better understand how, and to what extent the home environment relates to children's energy balance behaviours and subsequently weight. Additionally, many existing measures of the home environment lack appropriate evaluation, or reporting of, the psychometric properties (e.g. validity and reliability) of the measurement tool (11,14).

One of the few comprehensive measures of obesogenic risk in the home environment was developed by Schrempft et al. (15) for use in pre-school children. The Home Environment Interview (HEI) comprises four composite scores; one for each individual domain (food, activity and media) of the environment, as well as a score for the overall obesogenic home environment. This measure was found to be reliable over a 2 week period, and showed good validity when compared against data from objective wearable recording devices (16). Findings indicated cross-sectional associations between the home environment composite score and food intake, physical activity levels and sedentary behaviours in pre-school children, but no relationships were found with child weight (15). The home environment composite scores were also associated with heritability of BMI (17), with higher heritability of BMI observed among children living in higher-risk home environments compared to lower-risk home environment (86% vs 39%). This suggests the home environment moderates the extent to which the genetic influence on BMI is expressed, and indicates the family home may offer some protection for children who are genetically susceptible to obesity. It is possible that 4 years of age is too young for the relationship between the obesogenic quality of the home environment and body weight to be fully expressed or observed, but these relationships may manifest later in childhood, following longer exposure. The aim of the present study was: (i) to update and adapt the home environment interview, for use in school-aged children, and (ii) to examine associations between the home environment composites and energy balance behaviours and BMI-SDS in school-aged children.

4.3 Methods

4.3.1 Instrument development: Home Environment Interview

The original HEI assesses both physical (e.g. availability and accessibility of foods) and social (e.g. parental modelling and support of healthy eating) aspects of the food, physical activity and media domains within the home environment and was validated in pre-school children (Schrempft et al., 2015). This study updated and validated the revised HEI for use in older children in three phases.

In the first phase, the original HEI was circulated to a panel of six experts in the field of childhood obesity to gather input and achieve consensus about the relevance of existing items, alongside suggestions for additional items. The expert consultation highlighted the need to widen the scope of questions about the media environment, to reflect technological advances (e.g. increases in amount and types of devices available) and changes in how children use and interact with media since the development of the original HEI in 2012. Peer-reviewed published studies examining the home media environment were identified and the measures used were reviewed. The largest national survey of media and electronic devices in the UK (The Ofcom report) was also reviewed (18,19). Where possible, these resources were used to refine and modify the wording of the existing HEI questions, and to add additional questions. The instrument was iteratively refined based on feedback from the panel of aforementioned experts.

In the second phase, one-to-one cognitive interviews were conducted with a sample of parents (n=14) of children aged 11-13 years old living in the U.K. Participants were recruited via social advertisements and word-of-mouth.

Cognitive interviewing techniques were utilised to ascertain parents' comprehension of items and response options (e.g. clarity of interpretation and understanding), and the acceptability and relevance of items. Modifications were made to the HEI based on feedback gained at this stage. Overall, cognitive interviews revealed good acceptability, comprehension and face validity.

In the third and final phase, a further panel of experts in the field of childhood obesity research were consulted using a Delphi method (20). Expert opinion was sought between March and June 2020 to gain consensus about the constructs to include in the composite scores. Fifty-four experts from the US (n=24), Europe (n=20) and Australia/New Zealand (n=10) were contacted via email and invited to complete an online questionnaire anonymously. Twenty-one (39%) experts completed the survey and were presented with each of the proposed HEI variables. Experts were asked to indicate whether each of the items were associated with an increased or decreased risk of weight gain in childhood (response options; 'probably/definitely associated with decreased risk for weight gain', 'not sure', or 'probably/definitely associated with increased risk for weight gain'). There was also a free text box for experts to provide additional comments. The results of the survey are provided in **Appendix C.1**.

4.3.2 Construct validity: HEI Instrument administration

The final version of the HEI was administered as a computer-assisted telephone interview by a trained researcher using the secure, web-based software platform REDCap (Research Electronic Data Capture) (21,22). Study data were collected and managed using REDCap electronic data capture tools hosted at University College London (UCL). Primary caregivers were asked to complete the interview at home in one sitting and were prompted to check the foods and beverages in their home, to ensure accurate responding. The interview took around 45 minutes to complete. Parental feeding practices were assessed using validated questionnaires, which were completed online by caregivers in the weeks prior to completion the HEI (23–26).

4.3.3 Construct validity sample

Participants were from the Gemini study, a longitudinal birth cohort of families with twins born in England and Wales between March and December 2007. A total of 2402 families with monozygotic (identical) and dizygotic (non-identical) twins consented to take part. Additional details are provided elsewhere (27). Families were previously invited to take part in a home environment interview (HEI) when the children were on average 4.2 years old (SD=0.4) (Schrempft et al., 2015). Only families who had taken part in the HEI at age 4 (n=1113), and those who completed parental feeding practices questionnaires in the month prior (n=219), were invited to take part in the present study.

4.3.4 Test-retest reliability sample

A convenience sample of participants were invited to take part in the HEI a second time, 7-14 days after initial interview (mean ±SD days = 10.6 ±3.02), to examine test-retest reliability of the measure. Due to the Covid-19 coronavirus pandemic, data collection in the Gemini cohort was halted early and consequently the remainder of the test-retest sample was recruited from the general population when stay at home restrictions had eased in summer 2021. As such, information about birth weight, gestational age, BMI-SDS or maternal BMI for the test-retest sample could not be collected. A total of 20 caregivers took part in this portion of the data collection, whose children were aged on average 12.4 (±0.74) years old at the time of reporting.

4.3.5 Creating the composite score of obesogenic home environment

A Delphi method was used to gain expert consensus about the relevant constructs for inclusion in the composite scores. A variable was included in the composite if the majority (60% or more) of experts (n=21) identified it as being associated with increased or decreased risk for weight gain (**Appendix C.1**).

Constructs identified as being associated with a decreased risk for childhood weight gain were reverse scored so that a higher total score on each composite would reflect 'higher-risk' for weight gain. The HEI contains continuous, categorical, and ordinal variables. Therefore, to ensure all variables were on a common scale each variable was standardised using z-scores. Before standardising the food and beverage availability variables (vegetables, fruit, salty snacks, sweet snacks, confectionery and sugar-sweetened beverages), linear regression analyses were conducted to examine relationships with 'typical' availability (more than usual, less than usual or about the same), and the number of days since the participant last shopped for food/drink. In each regression model, the particular food/beverage availability was the dependent variable (DV) and how typical the reported availability was and the days since last shopped were the independent variables (IVs). If only one of the IVs was significantly associated with food/drink availability, the model was re-run to include just the significant variable and the standardised residuals for the model were used in the composite (15). This method was used to account for how typical the food in the home was at the time of data collection compared to 'usual'. To create the standardised energy-dense snack availability variable, the standardised residuals for salty snack, sweet snack and confectionery availability were summed. The variable was then standardised again to have a mean of 0 and a standard deviation of 1.

Finally, the standardised variables (Z-scores) were summed to create three composites: the home food environment (21 variables), the home physical activity environment (6 variables), and the media environment (5 variables). The food, PA and media composites were then summed to create an overall home environment composite, dividing by the number of variables per composite so that each composite contributed equally to the overall score (food composite/21 + activity composite/6 + media composite/5). Higher scores on each composite scale reflect 'higher-risk' environments.

The final list of constructs included in the composite, with descriptive statistics, are detailed in **Table 4.1.** This updated composite score was similar in structure to the original HEI composite score (15), however, notable changes were made to constructs included in the home media domain. Full modifications are shown in **Appendix C.2.**

4.3.6 Energy balance behaviours

4.3.6.1 Dietary intake

Parents were asked to report how often their children consumed fruit (excluding fruit juice), vegetables, energy-dense snacks (e.g. crisps and chocolate), sugar-sweetened drinks, artificially-sweetened drinks, milk, fruit juice and smoothies. Responses were recorded on an eight-point scale (1=never or less than once a month, 2=1-3 times a month, 3=once a week, 4=2-4 times a week, 5=5-6 times a week, 6=once a day, 7=2-3 times per day, 8=four or more times per day). The questions were based on those used in brief dietary assessment methods, such as the Dietary Instrument for Nutrition (DINE), which has been validated against 4-day diet diaries (28). In accordance with the 5-a-day UK dietary recommendation, fruit and vegetable consumption was categorised so that the higher consumption group represented consuming two or more portions a day. Energy-dense snack, sugar-sweetened and artificially sweetened beverage consumption were collapsed so the highest consumption group represented consuming once or more per day.

4.3.6.2 Physical activity levels

Physical activity levels were assessed using the item ‘Compared to other children of the same age and sex, how physically active is your child?’ with a five-point response scale (1=much less active, 2=somewhat less active, 3=average, 4=somewhat more active, 5=much more active); which has been shown to be associated with objectively measured physical activity at age 11 (*β (SE)=60.5 (17.0), $p<0.01$*) (29). For ease of interpretation, physical activity level was categorised so that the active group included those who were more active (response 4; somewhat more active and 5; much more active) than other children of the same age and sex; the comparison group were less active (response 1; much less active, 2; somewhat less active; or 3; about average).

4.3.6.3 Sedentary behaviours

Parents were asked to report children's use of electronic devices to watch TV or other online media using the item 'On average, how long does your child watch TV programmes, movies, or online media (e.g. Netflix, Amazon Prime, YouTube videos) on an electronic device (e.g. desktop computer/laptop/tablet computer) on a typical weekday (Monday to Friday), at this time of year?'. Parents were also asked to report children's video game use using the item 'On average, how long does your child spend playing video games on a typical weekday (Monday to Friday), at this time of year? This includes on a handheld device, games console or computer/laptop.' There are no specific guidelines for duration of screen-time and video game use in this age group (30), therefore media use was kept as a continuous variable.

4.3.6.4 Socioeconomic status

Parents provided information about multiple indicators of SES, including: highest maternal educational qualification; current occupation (both parents); total annual household income; postcode; home ownership status; number of bedrooms in the home; and number of cars. Principal component analysis was used to create the SES composite score, which incorporated these seven indicators of SES. Higher composite scores reflect higher SES. Full details of the SES composite are described elsewhere (31).

4.3.6.5 Anthropometric measurements at 12 years

Electronic weighing scales were sent to all Gemini families when the children were 2 years old and updated height charts were sent when the children were 10 years old to collect measurements at 3-month intervals. At the time of the HEI, parents were also asked to provide their child's height and weight measurements. Child date of birth (used to calculate age at the time of the interview), sex and gestational age were parent reported at baseline. Standard deviation scores (SDS) for child BMI (BMI-SDS) were calculated using the UK90 British growth reference data (32), adjusting for age at the time of measurement, sex, and gestational age.

4.3.7 Statistical analysis

All analyses were performed using SPSS version 26.0 (33), with a p-value <0.05 considered statistically significant.

Single measure intraclass correlation coefficients (ICC) with 95% confidence intervals (95% CI) were used to assess test-retest reliability of each home environment composite score. ICC values were categorised as <0.40 = poor, 0.40-0.75 = fair to good agreement, >0.75=excellent (34).

For categorical outcomes, Complex Samples Logistic Regression was used to examine associations between domain-specific home environment composites and corresponding diet, physical activity and sedentary behaviours of each individual child. For continuous outcomes, Complex Samples General Linear Models were used to examine associations between domain specific home environment composites and corresponding sedentary behaviours. Analyses were adjusted to account for clustering within families (complex samples analyses), sex of child and the child's age at time of home environment interview.

4.4 Results

4.4.1 Sample characteristics

In total, 219 families were invited to take part and 149 families (68.0%) with 298 children participated in the current study. There were no significant differences in baseline characteristics (i.e. age of mother, maternal BMI, SES, gestational age) between those invited to take part and the final sample. The study sample comprised families with data on all variables included in the analysis. Primary caregivers completed the HEI by telephone when the twins were on average 12.51 years old (SD = 0.22). Of responding caregivers, 98.7% (n=147) were the child's mother and 1.3% (n=2) were the father. The mean (±SD) duration of interviews was 44.65 (±10.73) minutes. Characteristics of the sample are shown in Table 4.2**.**

Table 4.1. Descriptive statistics for the variables included in the HEI composite scores (n=149 families; n=298 children), mean (SD) for continuous variables and percentage (N) for categorical variables.

Home food environment	Mean (SD) or % (N)
Availability	
Number of fruit types[1]	9.65 (4.25)
Number of vegetable types[1]	13.58 (4.63)
Number of energy-dense snack types	6.96 (3.22)
Number of sugar-sweetened drinks	1.44 (1.05)
Accessibility (visibility)	
Fruit on display[1]	95.3 (284)
Vegetables ready-to-eat[1]	43 (128)
Energy-dense snacks on display	4.0 (12)
Sugar-sweetened drinks on display	6.0 (18)
Accessibility (child can help him/herself)	
Fruit[1]	92.6 (276)
Vegetables[1]	94.6 (282)
Energy-dense snacks	55.4 (165)
Sugar-sweetened drinks	41.6 (124)
Parental feeding practices	
Emotional feeding[2]	1.45 (0.47)
Instrumental feeding[2]	1.81 (0.53)
Encouragement[1, 2]	2.28 (0.59)
Modelling[1,2]	3.65 (0.68)

Home food environment	Mean (SD) or % (N)
Monitoring[1,2]	2.44 (0.98)
Covert restriction[1, 2]	3.23 (0.89)
Restriction[1, 3]	3.52 (1.16)
Family meal frequency at the table (days per /week)	3.43 (2.18)
Frequency child eats while watching TV and/or using a device (days per /week)	1.66 (1.09)
Home activity environment	
Garden/outdoor space[1]	98.7 (294)
Garden play equipment[1, 4]	65.8 (196)
Allowed to be physically active indoors[1, 4, 5]	4.30 (1.07)
Allowed to be physically active outdoors[1, 4, 5]	4.76 (0.56)
Parental modelling of physical activity[1]	3.97 (0.96)
Parental support of physical activity[1]	3.53 (0.77)
Home media environment	
Number of media equipment items in home	15.48 (4.20)
Number of media equipment in child's bedroom	1.70 (1.37)
Caregiver rules around use of media equipment[1,6]	2.38 (0.78)
Maternal time engaged in screen-based viewing (hours/week)	14.26 (8.55)
Partner time engaged in screen-based viewing (hours/week)	14.94 (9.61)

[1]Variables identified as being associated with decreased risk for weight gain were reverse scored.
[2] Measured using a five-point Likert scale (1= never, 5= always).
[3] Measured using a seven-point Likert scale (1= not at all, 7= strictly).
[4]n= 294 as four children did not have access to a garden or outdoor space.
[5]Measured using a five-point Likert scale (1=never; 5=all the time)
[6](0 = no rules, 1=rules around one device, 2 = rules around two devices, 3 = rules around 3 or more devices)

When examining differences based on SES, lower SES was associated with 'higher-risk' overall home environments (r=-.26, p=.002), as well as 'higher-risk' home activity environments (r=-.21, p=.01) and 'higher-risk' home media environments (r=-.20, p=.014). No association was observed between SES and the home food environment (r=-.05, p=.529).

Table 4.2. Characteristics of families in the HEI sample at age 12 and test-retest reliability sample, mean (SD) for continuous variables and percentage (N) for categorical variables.

	HEI at age 12 (n=149 families, 298 children)	Test-retest sample (n=20 families)
	Mean (SD) or % (n)	**Mean (SD) or % (n)**
Age of child at HEI (years)	12.51 (0.22)	12.40 (0.74)
Gestation (weeks)	36.07 (2.6)	-
Birth weight SDS	-0.57 (0.96)	-
BMI-SDS at age 12	-0.06 (1.14)	-
Sex of child		
Male	48.7 (145)	55.0 (11)
Female	51.3 (106)	45.0 (9)
Zygosity		
MZ	28.9 (43)	-
DZ	70.5 (105)	-
Maternal age at twin's birth (years)	35.1 (4.22)	32.8 (5.94)
Maternal BMI at baseline[1]	24.26 (4.22)	-
SES[2] composite at baseline	5.03 (1.01)	-
SES[2] composite at HEI	5.15 (1.03)	4.94 (0.97)
Maternal ethnicity		
White	94.6 (141)	100 (20)
Non-white	5.4 (8)	0 (0)
Marital status		
Married or cohabiting	94 (140)	80 (16)
Separated or divorced	4 (6)	10 (2)
Single	2 (3)	10 (2)
Child's dietary intake		
Fruit consumption		
≥ twice a day	58.1 (173)	60.0 (12)
< twice a day	41.9 (125)	40.0 (8)
Vegetable consumption		
≥ twice a day	80.2 (239)	65.0 (13)
< twice a day	19.8 (59)	35.0 (7)
Energy-dense snack consumption		
≥ once a day	75.2 (224)	80.0 (16)
< once a day	24.8 (74)	20 (4)
Fast food consumption		
≥ once a week	19.8 (59)	20.0 (4)
Never or less than once a week	80.2 (239)	80.0 (16)
Convenience food		
≥ twice per week	35.6 (106)	35.0 (7)
< twice per week	64.4 (192)	65.0 (13)
Sugar-sweetened drink consumption		
≥ once a day	8.4 (25)	0.0 (0)
< once a day	91.6 (273)	100.0 (20)
Artificially-sweetened drink consumption		
≥ once a day	67.4 (201)	65.0 (13)

	HEI at age 12 (n=149 families, 298 children)	Test-retest sample (n=20 families)
< once a day	32.6 (97)	35.0 (7)
Fruit juice & smoothie consumption		
≥ once a day	41.9 (125)	45.0 (9)
< once a day	58.1 (173)	55.0 (11)
Milk consumption		
≥ twice a day	71.4 (212)	40.0 (8)
< twice a day	28.6 (85)	60.0 (12)
Physical activity level[3]		
Somewhat or much more active	59.4 (177)	55.0 (11)
About average or less active	40.6 (121)	45.0 (9)
Sedentary behaviours		
TV viewing and online media use (hours/week)	16.73 (9.70)	13.37 (7.52)
Video game use (hours/week)	6.91 (6.82)	6.13 (8.58)
Home environment composites	**Range**	
Home food environment composite	-13.67-23.15	-
Home PA environment composite	-4.54-15.45	-
Home media environment composite	-5.45-9.31	-
Overall home environment composite	-2.17-3.02	-

[1]Data were missing for 0.7% (n=1) families.

[2]The SES composite score is a weighted score which takes into account the following indicators of SES: gross annual household income (before tax deductions), index of multiple deprivation (IMD), maternal education, home ownership status, household National Statistics Socioeconomic classification (NS-SEC) based on the household representative person, number of bedrooms and number of cars (31).

[3]Compared to other children of the same age and sex.

4.4.2 Test-retest reliability

Test-retest reliability (ICC; 95% CI) of the home environment composite scores over a mean period of 10.6 (±3.02) days were excellent for food (0.77; 0.52-0.90), media (0.83; 0.61-0.93) and the overall score (0.76; 0.49-0.90), and were good for activity (0.62; 0.27-0.83).

4.4.3 Construct validity

The ranges (for the standardised scores) on each home environment composite indicated that there was considerable variation between households: food (-

13.67–23.15), physical activity (-4.54–15.45), media (-5.45-9.31) and overall (-2.17-3.02). Associations between the composites were low for food and activity (r=.21, p<.001), and moderate for media and food (r=.37, p<.001), and for the activity and media (r=.05, p=.579).

As shown in **Table 4.3,** for each 1 unit increase in obesogenic risk in the home food environment children were 11% less likely to consume fruits at least twice per day (OR; 95% CI = 0.89; 0.84-.96; p<.001) and 12% less likely to consume vegetables at least twice per day (OR: 0.88; OR: 0.83-0.93; p<.001). On the other hand, for each 1 unit increase in obesogenic risk in the home food environment children were 13% more likely to consume energy-dense snacks at least once per day (OR: 1.13; 1.05-1.21; p<.001), 15% more likely to consume fast foods at least once per week (OR: 1.15; 1.07-1.23; p<.001) and 11% more likely to consume convenience foods at least twice per week (OR: 1.11; 1.05-1.17, p=.001). There were no significant associations between the home food environment and children's consumption of sugar-sweetened beverages, artificially sweetened beverages, fruit juice or milk (ns; see table 3).

No association was observed between home physical activity environments and children's physical activity levels. However, for each 1 unit increase in obesogenic risk in the media environments children were 11% more likely to be less physically active than other children (OR; 95% CI=0.89; 0.80-0.99, p=.037). Children living in 'higher-risk' media environments also had higher overall screen time (TV viewing and online media: *β (SE)* =1.85 (.24), p<.001) and higher video game use (*β (SE)* =0.61 (0.14), p<.001), such that children's overall screen-time was 1.87

units (hours/week) higher and video game use was 0.61 units (hours/week) higher for each 1 unit increase in obesogenic risk in the home media environment.

Table 4.3. Complex samples logistic regression and CSGLM[1]: associations between food, physical activity and media home environments and corresponding diet, physical activity and screen-based sedentary behaviours (n=298).

	Home food environment			
Outcome variables	**N (%)**	**OR (95%CI)[1]**		***P value***
Dietary intake behaviours				
Fruit (≥twice per day)	173 (58.1%)	**0.89 (0.84-0.96)**		**<.001**
Vegetables (≥twice per day)	239 (80.2%)	**0.88 (0.83-0.93)**		**<.001**
Energy-dense snacks (≥once per day)	224 (75.2%)	**1.13 (1.05-1.21)**		**<.001**
Fast food intake (≥once per week)	59 (19.8%)	**1.15 (1.07-1.23)**		**<.001**
Convenience food (≥twice per week)	106 (35.6%)	**1.11 (1.05-1.17)**		**.001**
Sugar Sweetened Beverages (≥once per day)	25 (8.4%)	1.03 (0.97-1.10)		.334
Artificially-sweetened beverages (≥once per day)	97 (32.6%)	1.05 (0.99-1.10)		.084
Fruit juice (≥once per day)	125 (41.9%)	0.98 (0.94-1.03)		.508
Milk (≥twice per day)	85 (28.6%)	1.00 (0.95-1.06)		.995
Activity behaviours	**Home physical activity environment**			
Physical activity (more active)	177 (59.4%)	0.89 (0.78-1.03)		.130
Screen-based sedentary behaviours[2]	**Home media environment**			
	Mean (SD)	**B (±SE)**	**R^2**	***P value***
TV viewing and online media (hours/ week)	16.73 (9.70)	**1.85 (±0.24)**	**.276**	**<.001**
Video games (hours/ week)	6.91 (6.82)	**0.61 (±0.14)**	**.344**	**<.001**

[1]Adjusting for clustering within families (complex samples analyses), the child's age at time of home environment interview, child sex.
[2] Screen-based sedentary behaviours were treated as a continuous variable as there are no specific guidelines for duration of screen-time and video game use in this age group (Hill et al., 2016).
OR = Odds Ratio, 95% CI = 95% confidence interval.

Similar findings were observed for the overall home environment (**Table 4.4**), each 1 unit increase in obesogenic risk in the home environment was associated with children being 60% less likely to consume fruit at least twice per day (OR; 95% CI=0.40; 0.26-0.61, p<.001), 70% less likely to consume vegetables at least twice per day (OR: 0.30; 0.18-0.52, p<.001) and 71% more likely to consume energy-dense snacks at least once per day (OR: 1.71; 1.08-2.69, p = 0.022), 3 times more likely to consume fast food at least once per week (OR: 3.09; 1.90-5.04, p<0.001), and 2.6 times more likely to consume convenience foods at least twice per week (OR: 2.58; 1.64-4.05, p<0.001).

Each 1 unit increase in obesogenic risk in home environments was associated with children being 43% less physically active (OR; 95% CI=0.57; 0.40-0.80, p<.01). Children living in 'higher-risk' home environments also had significantly higher overall screen-time (TV viewing and online media content) (*β (SE)* = 4.55 (.78), p<.001) and higher video game use (*β (SE)* = 1.56 (.43), p<0.001), such that children's overall screen-time was 4.55 units (hours/week) higher and video game use was 1.56 units (hours/week) higher for each 1 unit increase in obesogenic risk in the overall home environment.

Table 4.4. Complex samples logistic regression and CSGLM[1]: associations between overall home environment composite and corresponding diet, physical activity and screen-based sedentary behaviours (n=298).

	Home environment composite			
Dietary intake behaviours	**N (%)**	**OR (95%CI)[1]**		**P value**
Fruit (≥twice per day)	173 (58.1%)	**0.40 (0.26-0.61)**		**<.001**
Vegetables (≥twice per day)	239 (80.2%)	**0.30 (0.18-0.52)**		**<.001**
Energy-dense snacks (≥once per day)	224 (75.2%)	**1.71 (1.08-2.69)**		**.022**
Fast food intake (≥once per week)	59 (19.8%)	**3.09 (1.90-5.04)**		**<.001**
Convenience food (≥twice per week)	106 (35.6%)	**2.58 (1.64-4.05)**		**<.001**
Sugar Sweetened Beverages (≥once per day)	25 (8.4%)	1.61 (0.92-2.82)		.097
Artificially-sweetened Beverages (≥once per day)	97 (32.6%)	**1.54 (1.03-2.29)**		**.034**
Fruit juice (≥once per day)	125 (41.9%)	0.93 (0.66-1.31)		.678
Milk (≥twice per day)	85 (28.6%)	1.36 (0.97-1.93)		.076
Activity behaviours	**N (%)**	**OR (95% CI)**		
Physical activity (more active)	177 (59.4%)	**0.57 (0.40-0.80)**		**.002**
Screen-based sedentary behaviours[2]	**Mean (SD)**	**B (±SE)**	**R^2**	
TV viewing and screen time (hours/ week)	16.73 (9.70)	**4.55** (±.78)	**.175**	**<.001**
Video game use (hours/week)	6.91 (6.82)	**1.56** (±.43)	**.325**	**<.001**

	Home environment composite

[1]Adjusting for clustering within families (complex samples analyses), the child's age at time of home environment interview, child sex.
[2]Sedentary behaviours were treated as a continuous variable as there are no specific guidelines for duration of screen-time and video game use in this age group (30).
OR = Odds Ratio, 95% CI = 95% confidence interval.

As shown in **Table 4.5**, 'higher-risk' overall home environment was associated with higher BMI-SDS at age 12 *(β (SE)=0.23 (0.09), p=.014),* such that children's BMI-SDS was 0.23 units higher for each 1 unit increase in obesogenic risk of the overall home environment. Additionally, 'higher-risk' media environments were associated with higher BMI-SDS at age 12 (*β (SE) =0.12 (0.03), p<.001*). No association was observed between the activity and food domains and BMI-SDS at 12 years.

Table 4.5. Associations[1] between the home environment composites and BMI-SDS at age 12 (N=298).

Composite scores	BMI-SDS at age 12		
	β (±SE)	**R^2**	**P value**
Home food composite	.006 (±.01)	.002	.674
Home activity composite	-.001 (±.03)	.001	.970
Home Media composite	**.12 (±.03)**	**.079**	**<.001**
Overall home environment composite	**.23 (±.09)**	**.034**	**.014**

[1]Adjusting for clustering within families (complex samples analyses), the child's age at time of home environment interview, child sex.

4.5 Discussion

This study provides evidence in support of the feasibility, reliability and validity of a comprehensive measure of the obesogenic home environment in 12 year old children. The revised HEI was feasible for administration via telephone interviews with primary caregivers. Additionally, the 2-week test-retest reliability of the home environment composite scores were good to excellent. Moreover, this is the first study to demonstrate cross-sectional associations between a comprehensive measure of physical and social aspects of the home environment, and BMI in school-aged children. The findings also characterise relationships between the home environment (overall composite score and the food, activity and media composites separately) and children's energy balance behaviours (food intake, physical activity and screen-based sedentary behaviours). This reflects similar findings observed in the same cohort when the children were four years old (15).

While the observed relationships between the home environment and energy balance behaviours have been previously demonstrated (3,15,35,36), earlier research in this sample found no cross-sectional association with BMI-SDS at age four (15). However, previous research in this cohort at age four demonstrated that the heritability of BMI was stronger in 'higher-risk' home environments compared to 'lower-risk' environments (17). This suggests obesity-related genes are more strongly associated with BMI in more obesogenic environments and children with higher genetic risk for obesity are particularly vulnerable to these obesogenic environments. The positive association between the overall home environment composite score and BMI-SDS observed at age 12 in the present study, supports previous suggestions that the relationship between the home environment and child weight may not manifest until later childhood by which time children have experienced a longer exposure to the home environment, and genetic susceptibility has had the opportunity to be fully expressed in 'higher-risk' environments (15,17). However, it is important to note that this study is cross-sectional precluding insight into the directionality of these associations. Longitudinal research is needed to examine prospective relationships between the home environment and child weight development.

This finding was also seen for the home media environment with ‘higher-risk’ home media environments being cross-sectionally associated with higher BMI-SDS at 12 years of age. In contrast, the home food and physical activity environment composites were not associated with BMI-SDS in this sample. These findings align with a recent systematic review which highlighted consistent associations between the home media environment and child adiposity (11), but reported mixed findings for the home food and physical activity environments.

The home food environment composite was positively correlated with the home activity *(r=.21, p<.001)* and media composites *(r=.37, p<.001).* This suggests that ‘higher-risk’ in the home food environment was also reflected to some extent in the home activity and media composites*, and vice versa.* Conversely, there was no clear association between the home activity and media environments (*r=.03, ns)*, indicating that some aspects of the home may present greater risk for weight gain than others. For example, a household may have a higher score for the media composite, indicating ‘higher-risk’ media environment, but a lower score for the activity composite, indicating ‘lower-risk’ activity environment. This finding is supported by previous research (15) and highlights the importance of utilising measures that capture the overall obesogenic nature of the home environment. Other evidence has suggested that physical activity and sedentary behaviours are largely independent of one another, and engaging in sedentary activities is not necessarily an obstacle to also being physically active (37).

The determinants of physical activity are complex; children’s activity levels are influenced by factors on an individual, interpersonal and environmental level

(38,39). Existing research has found limited evidence for the role of the home activity environment on children's physical activity levels (40). Our findings similarly revealed no association between the home physical activity composite and activity levels in school-aged children. This is perhaps unsurprising, given that as children approach adolescence they increasingly engage in the majority of their physical activity away from the home, through active travel or in school or activity club settings (41–43). However, associations were observed between the overall home environment and children's physical activity levels, with children in 'higher-risk' home environments found to be less physically active than those living in 'lower-risk' home environments. The difference in findings between the overall home environment composite and the individual activity domain highlights the importance of utilising composite measures, as the lower activity levels were largely driven by the home media environment. Other aspects of the home environment likely combine with the activity domain to influence children's physical activity levels. This view is supported by research conducted in US children (n=713 children, aged 6-11) which found that variables within the home media (e.g. bedroom media devices, parental screen-time) and activity environments (e.g. parental support of PA, PA equipment at home) interact to influence children's sedentary behaviour and activity levels and, combined, these aspects have greater influence on behaviour than either factor alone (44). In line with this, the effect sizes for the ORs for the overall home environment composite were substantially larger than for each of individual home environment (food, activity and media) composites, suggesting that the individual aspects of the home environment are correlated with one another, and together have a cumulative effect on childrens' energy balance behaviours. As such, it is important for future research to utilise composite measures of the home environment, rather than looking at a single domain in isolation.

Evidence highlights that the ‘availability’ and ‘accessibility’ of foods and beverages within the home are important correlates of children’s dietary intake (45–47). In the present study, children from ‘higher-risk’ home food environments were less likely to consume fruits and vegetables, and were more likely to consume energy-dense snacks, fast food and convenience food. The same patterns of association were observed for the overall home environment composite, but with considerably larger effect sizes. These findings are consistent with previous research conducted in pre-school aged children (15). However, unlike this previous study (15), findings revealed no association between the home food environment and children’s consumption of sugar-sweetened beverages (SSBs). This difference in findings may be due to the age of the children. At 12 years old, children spend greater time away from the home and have more autonomy over their food choices. It is possible that environments external to the home, are more influential in older children’s consumption of SSBs (10,48,49). However, research conducted in children aged 10-12 years from Eight European countries (n=7,915) revealed greater availability of SSB at home was strongly associated with greater consumption of these drinks (50). Similar findings were also observed in a cross-sectional study of 2,719 Australian children aged 11-16 (51). In both these studies, the children were asked to report their own SSB consumption, whereas the present study utilised parent-reports. Conflicting results may reflect the fact that parents are less aware of their children’s SSB consumption compared to other food and beverage types, or that parents are more susceptible to social desirability biases than their children when reporting dietary intakes (52). Another possible explanation is that consumption of SSBs was low in the present sample, with only 8.4% of children consuming SSBs ≥once a day, resulting in insufficient variation to observe associations. Future research is required to examine agreement between parent- and child-reported measures of SSB intake in this age group.

In the present research, living in ‘higher-risk’ home media environments (characterised by greater availability of electronic devices in the home and child’s bedroom, fewer parental rules around electronic devices, and greater parental modelling of screen-based sedentary behaviours), was associated with children spending more time watching screens (TV viewing and online media) and playing video games each week. In line with previous research, our findings indicate the environment within the home may be an important factor in shaping children’s behaviours (53). Therefore, targeting modifiable aspects of the home environment, such as reducing access to electronic devices at home, and setting limits around electronic devices, could be an effective way to reduce screen-time and lower risk for weight gain (10,54–56). Furthermore, a recent meta-analysis also revealed that exposure to screen-based junk food advertisements correlates with increases in energy consumption and BMI, these findings suggests that increased exposure to food advertisements via screen time may be another aspect by which the media domain may be predisposing to greater risk for weight gain (57).

Unlike previous research which captures SES using a single indicator (e.g. household income or parental education), the present study utilised a comprehensive composite measure of SES that incorporates individual, household and neighbourhood level factors. In the present study, lower SES was associated with ‘higher-risk’ home environments. These findings are in line with previous research which highlights that lower SES households had greater access to electronic devices in the child’s bedroom (58–60), less access to physical activity equipment and garden space (61–63), and less availability of fruits and vegetables (64–66). For lower SES families, decisions about food purchasing are largely dictated by price, ease of preparation and a product’s shelf-life. Regular eating routines and family mealtimes are also harder to achieve for caregivers with limited resources and unpredictable working schedules (67,68). These factors make it harder for families of lower SES to establish a healthier home environment and must be considered when developing home-based interventions. Future research is needed to examine pathways linking SES, the home environment and weight.

4.5.1 Strengths and limitations

Strengths of this study include the systematic development and utilisation of a comprehensive measure of the home environment which was guided by expert consultation and cognitive interviews with the target population. This work resulted in a comprehensive measure of the obesogenic home environment that captures composite scores for the food, physical activity and media domains as well as the overall home environment. However, there are several limitations that should be addressed. Firstly, this study relied on parent-report for both the characteristics of the home environment and their children’s energy balance behaviours, and thus may be susceptible to social desirability biases (52). However, previous research utilising an earlier version of the HEI revealed good to excellent validity when compared to objective measures of the home environment (e.g. wearable devices) (16). Nevertheless, future research should aim to utilise more objective measures of energy balance behaviours. Although our analyses adjusted for covariates, it is likely that residual confounding from other unmeasured factors remains (i.e. household stress, family dynamics, etc.). It should also be noted that the study sample was small in comparison to the prior study undertaken in participants from the same cohort of children (15). In comparison, it was also fairly homogenous, with the majority identifying as White (94.6% vs 86.0%) and a large proportion of higher SES households compared with the general population, meaning our findings may not be representative. Furthermore, this study utilised BMI-SDS as the primary measure of adiposity. There are limitations to using BMI as it cannot differentiate between weight attributable to fat mass or lean mass therefore misclassification of weight status can occur at an individual level, especially during later childhood when maturation occurs at differing rates. Thus, utilising other measures of adiposity such as waist circumference, body fat percentage or skinfold thickness may be beneficial. Finally, the cross-sectional nature of this research prevents conclusions regarding the directionality of observed relationships and causality cannot be established. It is possible that children's energy balance behaviours and/or adiposity influence the home environment, or that the association is bidirectional. Future longitudinal research is required: (1) to examine the stability of the home environment over time, (2) to understand the role of the obesogenic home environment on children's weight development from early childhood to adolescence, and (3) to investigate the direction of associations between the home environment and adiposity in childhood.

4.5.2 Conclusion

This study revealed cross-sectional associations between the overall home environment composite score and dietary intake, physical activity and screen-based sedentary behaviours in 12-year-old children. These findings mirror similar observations in the same sample at age four. However, contrary to the earlier findings, positive associations were also observed between BMI-SDS and the overall home environment composite and the home media environment composite. This study provides further evidence for the importance of utilising composite measures of the overall home environment to understand relationships between the home environment and children's health behaviours and weight trajectories across childhood.

Abbreviations

HEI: Home Environment Interview

OR: Odds Ratio

PA: Physical Activity

SSB: Sugar Sweetened beverages

BMI: Body Mass Index

SDS: Standard Deviation Score

SES: Socioeconomic Status

Declarations

Ethics approval and consent to participate

Ethical approval was originally granted for the study in 2007 by the University College London (UCL) Committee for the Ethics of non-National Health Service Human Research. In 2018, ethical approval for the continuation of the study was again granted by the UCL Research Ethics Committee (Project ID 1624/004).

Written informed consent was provided by all Gemini families. All aspects of data collection and storage were in compliance with the standards specified by this body.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the Economic and Social Research Council Advanced Quantitative Methods Studentship (Project reference: 1948633) which was award to Alice Kininmonth. The funders had no role in any element of this research.

Authors' contributions

AK and AF, in collaboration with CHL and AS, were responsible for the conceptualisation and design of the study. All authors were involved in the update of the measure. AK conducted the data collection, cleaning, analysis and was responsible for creating the first draft of the manuscript and all revisions of the manuscript. AF, CHL, AS, SS & AF oversaw this process. All authors have read, contributed to and approved the final manuscript.

Acknowledgements

We would like to thank the Gemini families for participating in the study. We would also like to thank Dr Emma Boyland (Institute of Population Health, University of Liverpool) who made an invaluable contribution to the update of the media domain of the HEI. In addition, we would like to thank the expert panel for their important contribution to the update of the Home Environment Interview.

4.6 References

1. Couch SC, Glanz K, Zhou C, Sallis JF, Saelens BE. Home food environment in relation to children's dietquality and weight status. J Acad Nutr Diet. 2014 Oct 1;114(10):1569-1579.e1.
2. Rosenkranz RR, Dzewaltowski DA. Model of the home food environment pertaining to childhood obesity. Nutr Rev [Internet]. 2008;66(3):123–40. Available from: http://dx.doi.org/10.1111/j.1753-4887.2008.00017.x
3. Hales D, Vaughn AE, Mazzucca S, Bryant MJ, Tabak RG, McWilliams C, et al. Development of HomeSTEAD's physical activity and screen time physical environment inventory. Int J Behav Nutr Phys Act [Internet]. 2013;10:132. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=24313962
4. Jago R, Thompson JL, Sebire SJ, Wood L, Pool L, Zahra J, et al. Cross-sectional associations between the screen-time of parents and young children: Differences by parent and child gender and day of the week. Int J Behav Nutr Phys Act. 2014 Apr 23;11(1):54.
5. Jago R, Page A, Froberg K, Sardinha LB, Klasson-Heggebø L, Andersen LB. Screen-viewing and the home TV environment: The European Youth Heart Study. Prev Med (Baltim) [Internet]. 2008 Nov [cited 2021 Jan 27];47(5):525–9. Available from: https://pubmed.ncbi.nlm.nih.gov/18722400/
6. Gattshall ML, Shoup J, Marshall JA, Crane LA, Estabrooks PA. Validation of a survey instrument to assess home environments for physical activity and healthy eating in overweight children. Int J Behav Nutr Phys Act [Internet]. 2008 Jan 11 [cited 2019 Jun 2];5(1):3. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18190709

7. Pinard CA, Yaroch AL, Hart MH, Serrano EL, McFerren MM, Estabrooks PA. The Validity and reliability of the Comprehensive Home Environment Survey (CHES). Health Promot Pract [Internet]. 2014;15(1):109–17. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=23471699

8. Rosenkranz RR, Dzewaltowski DA. Model of the home food environment pertaining to childhood obesity. Nutr Rev [Internet]. 2008 Feb 13 [cited 2019 Sep 18];66(3):123–40. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18289177

9. Vaughn AE, Hales DP, Neshteruk CD, Ward DS. HomeSTEAD's physical activity and screen media practices and beliefs survey: Instrument development and integrated conceptual model. PLoS One [Internet]. 2019 Dec 1 [cited 2020 Nov 2];14(12). Available from: https://pubmed.ncbi.nlm.nih.gov/31891610/

10. Verloigne M, Van Lippevelde W, Maes L, Brug J, De Bourdeaudhuij I. Family- and school-based correlates of energy balance-related behaviours in 10-12-year-old children: A systematic review within the ENERGY (EuropeaN Energy balance Research to prevent excessive weight Gain among Youth) project [Internet]. Vol. 15, Public Health Nutrition. Cambridge University Press; 2012 [cited 2021 Feb 3]. p. 1380–95. Available from: https://www.cambridge.org/core.

11. Kininmonth A, Smith AD, Llewellyn CH, Dye L, Lawton CL, Fildes A. The relationship between the home environment and child adiposity: a systematic review. Int J Behav Nutr Phys Act [Internet]. 2021 Dec 6 [cited 2021 Jan 7];18(1):4. Available from: https://ijbnpa.biomedcentral.com/articles/10.1186/s12966-020-01073-9

12. Golan M. Parents as agents of change in childhood obesity - From research to practice. Int J Pediatr Obes [Internet]. 2006 [cited 2021 Jan 18];1(2):66–76. Available from: https://pubmed.ncbi.nlm.nih.gov/17907317/

13. Davison KK, Birch LL. Childhood overweight: a contextual model and recommendations for future research. Obes Rev [Internet]. 2001;2(3):159–71. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1046/j.1467-789x.2001.00036.x

14. Pinard CA, Yaroch AL, Hart MH, Serrano EL, McFerren MM, Estabrooks PA. Measures of the home environment related to childhood obesity: a systematic review. Public Health Nutr [Internet]. 2012 Jan 7 [cited 2019 Jun 6];15(1):97–109. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21899786

15. Schrempft S, Van Jaarsveld CHM, Fisher A, Wardle J. The obesogenic quality of the home environment: Associations with diet, physical activity, TV viewing, and BMI in preschool children. PLoS One [Internet]. 2015;10(8):e0134490. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=26248313

16. Schrempft S, van Jaarsveld CH, Fisher A. Exploring the Potential of a Wearable Camera to Examine the Early Obesogenic Home Environment:

Comparison of SenseCam Images to the Home Environment Interview. J Med Internet Res [Internet]. 2017 Oct 12 [cited 2019 Jun 13];19(10):e332. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29025695

17. Schrempft S, van Jaarsveld CM, Fisher A, et al. Variation in the heritability of child body mass index by obesogenic home environment. JAMA Pediatr [Internet]. 2018;172(12):1153–60. Available from: http://dx.doi.org/10.1001/jamapediatrics.2018.1508

18. Ofcom. Children and parents: media use and attitudes report 2019 [Internet]. 2020 [cited 2021 May 11]. Available from: https://www.ofcom.org.uk/making-sense-of-media.

19. Ofcom. Children and parents media use and attitudes: annex 1 [Internet]. 2019 [cited 2019 Jun 7]. Available from: https://www.ofcom.org.uk/__data/assets/pdf_file/0027/134892/Children-and-Parents-Media-Use-and-Attitudes-Annex-1.pdf

20. Okoli C, Pawlowski SD. The Delphi method as a research tool: An example, design considerations and applications. Inf Manag. 2004 Dec 1;42(1):15–29.

21. Harris P, Taylor R, Thielke R, Payne J, Gonzalez N, Conde J. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform [Internet]. 2009 Apr [cited 2021 Aug 13];42(2):377–81. Available from: https://pubmed.ncbi.nlm.nih.gov/18929686/

22. Harris PA, Taylor R, Minor B, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: Building an international community of software platform partners. J Biomed Inform [Internet]. 2019 Jul 1 [cited 2021 Aug 13];95. Available from: https://pubmed.ncbi.nlm.nih.gov/31078660/

23. Wardle J, Sanderson S, Guthrie CA, Rapoport L, Plomin R. Parental feeding style and the intergenerational transmission of obesity risk. Obes Res [Internet]. 2002 Jun 1 [cited 2020 Mar 4];10(6):453–62. Available from: http://doi.wiley.com/10.1038/oby.2002.63

24. Birch LL, Fisher JO, Grimm-Thomas K, Markey CN, Sawyer R, Johnson SL. Confirmatory factor analysis of the Child Feeding Questionnaire: A measure of parental attitudes, beliefs and practices about child feeding and obesity proneness. Appetite. 2001;36(3):201–10.

25. Musher-Eizenman D, Holub S. Comprehensive feeding practices questionnaire: Validation of a new measure of parental feeding practices. J Pediatr Psychol [Internet]. 2007 Sep [cited 2020 Mar 16];32(8):960–72. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17535817

26. Ogden J, Reynolds R, Smith A. Expanding the concept of parental control: A role for overt and covert control in children's snacking behaviour? Appetite [Internet]. 2006 Jul [cited 2021 Jan 8];47(1):100–6. Available from: https://pubmed.ncbi.nlm.nih.gov/16682098/

27. van Jaarsveld CH, Johnson L, Llewellyn C, Wardle J. Gemini: a UK twin birth cohort with a focus on early childhood weight trajectories, appetite and the family environment. Twin Res Hum Genet [Internet]. 2010/02/18. 2010;13(1):72–8. Available from: https://www.cambridge.org/core/services/aop-cambridge-

core/content/view/4623D47702F56FC4F999B09DED3FA7D6/S1832427400010434a.pdf/div-class-title-gemini-a-uk-twin-birth-cohort-with-a-focus-on-early-childhood-weight-trajectories-appetite-and-the-family-environment-div.pdf

28. Roe L, Strong C, Whiteside C, Neil A, Mant D. Dietary intervention in primary care: Validity of the dine method for diet assessment. Fam Pract. 1994;11(4).

29. Purslow LR, van Jaarsveld CHM, Semmler C, Wardle J. Validity and prognostic value of parental ratings of children's activity. Prev Med (Baltim). 2009;49(1).

30. Hill D, Ameenuddin N, Chassiakos YR, Cross C, Radesky J, Hutchinson J, et al. Media use in school-aged children and adolescents. Pediatrics [Internet]. 2016 Nov 1 [cited 2021 Feb 4];138(5). Available from: www.aappublications.org/news

31. Kininmonth AR, Smith AD, Llewellyn CH, Fildes A. Socioeconomic status and changes in appetite from toddlerhood to early childhood. Appetite [Internet]. 2019 Mar;146:104517. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0195666319304908

32. Freeman J V, Cole TJ, Chinn S, Jones PR, White EM, Preece MA. Cross sectional stature and weight reference curves for the UK, 1990. Arch Dis Child [Internet]. 1995;73(1):17. Available from: http://adc.bmj.com/content/73/1/17.abstract

33. IBM Corp. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp; 2019.

34. Fleiss J. Reliability of measurement. In: The design and analysis of clinical experiments. Wiley, New York. 1986;

35. Verloigne M, Lippevelde W Van, Maes L, Brug J, Bourdeaudhuij I De. Family- and school-based correlates of energy balance-related behaviours in 10–12-year-old children: a systematic review within the ENERGY (EuropeaN Energy balance Research to prevent excessive weight Gain among Youth) project. Public Health Nutr [Internet]. 2012 Aug [cited 2021 Sep 9];15(8):1380–95. Available from: https://www.cambridge.org/core/journals/public-health-nutrition/article/family-and-schoolbased-correlates-of-energy-balancerelated-behaviours-in-1012yearold-children-a-systematic-review-within-the-energy-european-energy-balance-research-to-prevent-excessive-weight-gain-among-youth-project/A76CD0F65BC37CF5A49F4A520029155A

36. Pinard CA, Yaroch AL, Hart MH, Serrano EL, McFerren MM, Estabrooks PA. The Validity and Reliability of the Comprehensive Home Environment Survey (CHES). Health Promot Pract [Internet]. 2014 Jan 7 [cited 2019 Jun 6];15(1):109–17. Available from: http://journals.sagepub.com/doi/10.1177/1524839913477863

37. Biddle SJH, Gorely T, Marshall SJ, Murdey I, Cameron N. Physical activity and sedentary behaviours in youth: Issues and controversies [Internet]. Vol. 124, Journal of The Royal Society for the Promotion of Health. Sage PublicationsSage CA: Thousand Oaks, CA; 2004 [cited

2021 Feb 1]. p. 29–33. Available from: http://journals.sagepub.com/doi/10.1177/146642400312400110

38. Biddle SJH, Atkin AJ, Cavill N, Foster C. Correlates of physical activity in youth: a review of quantitative systematic reviews. Int Rev Sport Exerc Psychol [Internet]. 2011 [cited 2021 Jan 19];4(1):25–49. Available from: https://www.tandfonline.com/action/journalInformation?journalCode=rirs20

39. Wilk P, Clark AF, Maltby A, Smith C, Tucker P, Gilliland JA. Examining individual, interpersonal, and environmental influences on children's physical activity levels. SSM - Popul Heal [Internet]. 2018 Apr 1 [cited 2021 Jan 19];4:76–85. Available from: /pmc/articles/PMC5769121/?report=abstract

40. Maitland C, Stratton G, Foster S, Braham R, Rosenberg M. A place for play? The influence of the home physical environment on children's physical activity and sedentary behaviour [Internet]. Vol. 10, International Journal of Behavioral Nutrition and Physical Activity. BioMed Central; 2013 [cited 2021 Jan 19]. p. 1–21. Available from: https://link.springer.com/articles/10.1186/1479-5868-10-99

41. Rainham DG, Bates CJ, Blanchard CM, Dummer TJ, Kirk SF, Shearer CL. Spatial classification of youth physical activity patterns. Am J Prev Med. 2012 May 1;42(5):e87–96.

42. Dunton GF, Kawabata K, Intille S, Wolch J, Pentz MA. Assessing the social and physical contexts of children's leisure-time physical activity: An Ecological Momentary Assessment study. Am J Heal Promot [Internet]. 2012 Jan 1 [cited 2021 Jan 19];26(3):135–42. Available from: http://journals.sagepub.com/doi/10.4278/ajhp.100211-QUAN-43

43. Engelen L, Bundy AC, Lau J, Naughton G, Wyver S, Bauman A, et al. Understanding patterns of young children's physical activity after school - It's all about context: A cross-sectional study. J Phys Act Heal [Internet]. 2015 Mar 1 [cited 2021 Jan 19];12(3):335–9. Available from: https://journals.humankinetics.com/view/journals/jpah/12/3/article-p335.xml

44. Tandon P, Grow HM, Couch S, Glanz K, Sallis JF, Frank LD, et al. Physical and social home environment in relation to children's overall and home-based physical activity and sedentary time. Prev Med (Baltim). 2014;66:39–44.

45. Cook LT, O'Reilly GA, Derosa CJ, Rohrbach LA, Spruijt-Metz D. Association between home availability and vegetable consumption in youth: A review [Internet]. Vol. 18, Public Health Nutrition. Cambridge University Press; 2015 [cited 2020 Mar 13]. p. 640–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24785645

46. Dave JM, Evans AE, Pfeiffer KA, Watkins KW, Saunders RP. Correlates of availability and accessibility of fruits and vegetables in homes of low-income Hispanic families. Health Educ Res [Internet]. 2010 Feb 1 [cited 2020 Mar 13];25(1):97–108. Available from: https://academic.oup.com/her/article-lookup/doi/10.1093/her/cyp044

47. Hanson NI, Neumark-Sztainer D, Eisenberg ME, Story M, Wall M.

Associations between parental report of the home food environment and adolescent intakes of fruits, vegetables and dairy foods. Public Health Nutr. 2005 Feb 8;8(1):77–85.

48. Hebden L, Hector D, Hardy LL, King L. A fizzy environment: Availability and consumption of sugar-sweetened beverages among school students. Prev Med (Baltim). 2013 Jun 1;56(6):416–8.

49. Bere E, Sørli Glomnes E, Te Velde SJ, Klepp KI. Determinants of adolescents' soft drink consumption. Public Health Nutr [Internet]. 2008 Jan [cited 2021 Feb 3];11(1):49–56. Available from: https://www.cambridge.org/core.

50. Van Lippevelde W, te Velde SJ, Verloigne M, De Bourdeaudhuij I, Manios Y, Bere E, et al. Associations between home- and family-related factors and fruit juice and soft drink intake among 10- to 12-year old children. The ENERGY project. Appetite. 2013;61.

51. Denney-Wilson E, Crawford D, Dobbins T, Hardy L, Okely DEd AD. Influences on consumption of soft drinks and fast foods in adolescents. Vol. 18, Asia Pac J Clin Nutr. 2009.

52. Bornstein MH, Putnick DL, Lansford JE, Pastorelli C, Skinner AT, Sorbring E, et al. Mother and father socially desirable responding in nine countries: Two kinds of agreement and relations to parenting self-reports. Int J Psychol. 2015 Jun 1;50(3):174–85.

53. Granich J, Rosenberg M, Knuiman MW, Timperio A. Individual, social, and physical environment factors associated with electronic media use among children: Sedentary behavior at home. J Phys Act Heal [Internet]. 2011 Jul [cited 2021 Jan 19];8(5):613–25. Available from: https://journals.humankinetics.com/view/journals/jpah/8/5/article-p613.xml

54. Bjelland M, Soenens B, Bere E, Kovács É, Lien N, Maes L, et al. Associations between parental rules, style of communication and children's screen time Health behavior, health promotion and society. BMC Public Health [Internet]. 2015 Oct 1 [cited 2021 Feb 3];15(1):1002. Available from: http://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-015-2337-6

55. Ramirez ER, Norman GJ, Rosenberg DE, Kerr J, Saelens BE, Durant N, et al. Adolescent screen time and rules to limit screen time in the home. J Adolesc Heal [Internet]. 2011 Apr 1 [cited 2021 Feb 3];48(4):379–85. Available from: http://www.jahonline.org/article/S1054139X10003447/fulltext

56. Saelens BE, Sallis JF, Nader PR, Broyles SL, Berry CC, Taras HL. Home environmental influences on children's television watching from early to middle childhood. J Dev Behav Pediatr [Internet]. 2002 Jun [cited 2021 Feb 3];23(3):127–32. Available from: http://journals.lww.com/00004703-200206000-00001

57. Russell SJ, Croker H, Viner RM. The effect of screen advertising on children's dietary intake: A systematic review and meta-analysis. Vol. 20, Obesity Reviews. Blackwell Publishing Ltd; 2019. p. 554–68.

58. Mihrshahi S, Drayton BA, Bauman AE, Hardy LL. Associations between

childhood overweight, obesity, abdominal obesity and obesogenic behaviors and practices in Australian homes. BMC Public Health [Internet]. 2017;18:1–10. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=124286766&site=ehost-live

59. Adachi-Mejia A, Longacre M, Gibson J, Beach M, Titus-Ernstoff L, Dalton M. Children with a TV in their bedroom at higher risk for being overweight. Int J Obes [Internet]. 2007;31(4):644–51. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc5&AN=2007-05536-004

60. Borghese MM, Tremblay MS, Katzmarzyk PT, Tudor-Locke C, Schuna Jr. JM, Leduc G, et al. Mediating role of television time, diet patterns, physical activity and sleep duration in the association between television in the bedroom and adiposity in 10 year-old children. Int J Behav Nutr Phys Act [Internet]. 2015;12:60. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25967920

61. Schalkwijk AA, van der Zwaard BC, Nijpels G, Elders PJ, Platt L. The impact of greenspace and condition of the neighbourhood on child overweight. Eur J Public Health [Internet]. 2018;28(1):88–94. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-05454-017

62. Tandon P, Zhou C, Sallis JF, Cain KL, Frank LD, Saelens BE. Home environment relationships with children’s physical activity, sedentary time, and screen time by socioeconomic status. Int J Behav Nutr Phys Act [Internet]. 2012 Jul 26 [cited 2021 Feb 1];9(1):88. Available from: http://ijbnpa.biomedcentral.com/articles/10.1186/1479-5868-9-88

63. Umstattd Meyer MR, Sharkey JR, Patterson MS, Dean WR. Understanding contextual barriers, supports, and opportunities for physical activity among Mexican-origin children in Texas border colonias: a descriptive study. BMC Public Health [Internet]. 2013;13:14. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=23297793

64. Boles RE, Johnson SL, Burdell A, Davies PL, Gavin WJ, Bellows LL. Home food availability and child intake among rural families identified to be at-risk for health disparities. Appetite. 2019 Mar 1;134:135–41.

65. Carolyn Grunseit A, Taylor AJ, Lawson Hardy L, King L. Composite Measures Quantify Households’ Obesogenic Potential and Adolescents’ Risk Behaviors128:e000. Pediatrics [Internet]. 2011 [cited 2021 Jan 18];128(2). Available from: www.pediatrics.org/cgi/doi/10.1542/peds.2010-3331

66. Schrempft S, van Jaarsveld CHM, Fisher A, Fildes A, Wardle J. Maternal characteristics associated with the obesogenic quality of the home environment in early childhood. Appetite [Internet]. 2016;107:392–7. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fullt

ext&D=medc&AN=27554185

67. Bauer KW, Hearst MO, Escoto K, Berge JM, Neumark-Sztainer D. Parental employment and work-family stress: associations with family food environments. Soc Sci Med. 2012/05/18. 2012;75(3):496–504.

68. Shift. Families and Food: How the environment influences what families eat [Internet]. 2018 [cited 2021 Jan 28]. Available from: https://www.gsttcharity.org.uk/sites/default/files/Bite_Size_Report.pdf

Introduction to Chapter Five

The findings presented in Chapter Three highlight the lack of longitudinal research exploring relationships between the home environment and measures of child adiposity. Chapter Five presents the third study in this thesis which aimed to address this gap by examining the stability and continuity of the home environment from ages four to 12, as well as bi-directional associations between the obesogenic quality of the home environment and BMI-SDS from ages four to 12. Paper three (Chapter Five) represents the first study to longitudinally examine the stability and continuity of the obesogenic home environment, and the first to examine bi-directional relationships between the home environment and BMI-SDS.

Chapter 5

Associations between the obesogenic home environment and childhood weight: a cross-lagged panel analysis.

Chapter type:	Journal Article
Journal:	*International Journal of Obesity*
Submission date:	December 2021
Submission status:	Under review

Note. *This paper is currently under review therefore the formatting and layout are consistent with the requirements for International Journal of Obesity. References will not follow the APA style and will be placed at the end of the chapter rather than at the end of the thesis.*

5.1 Abstract

Background: The obesogenic quality of the home environment is hypothesised to play an important role in children's weight development but few prospective studies have investigated relationships between the home environment and adiposity across childhood.

Objective: To investigate the continuity and stability of the home environment from ages 4 to 12, and bi-directional relationships between the home environment and BMI-SDS from ages 4 to 12.

Methods: Parents from the Gemini cohort completed the Home Environment Interview (HEI), a comprehensive measure of the obesogenic home environment, when their children were aged 4 and 12 (n=149 families, n=298 children). The obesogenic home environment was measured using four composite scores capturing the food, activity, media environments, and the overall home environment. Child weights and heights were used to calculate BMI-SDS. Continuity was assessed with Pearson's correlations between scores at each time point, and stability by changes in mean scores over time. Cross-lagged analyses were performed (HEI composites at age 4 to BMI-SDS at age 12 and the reverse) to measure the magnitude and direction of associations.

Results: The home environment showed moderate-to-high continuity from ages 4 to 12 (r=0.30-0.64). The overall home environment *($r=0.21$, $p<0.01$)* and media composites *($r=0.23$, $p<0.01$)* were cross-sectionally associated with child BMI-SDS at age 12, but not at age 4. Longitudinally, the home media environment at age 4 predicted increases in child BMI-SDS at age 12 *(β; 95% CI=0.18; 0.08,0.28, $p<0.01$)*. No associations were observed for the reverse path, or the remaining composites (the overall, food and activity) in either direction.

Conclusion: This study provides evidence that the obesogenic home environment tracks across childhood and highlights the importance of the early home media environment for child weight development. The findings provide insight into key aspects of the home environment that could be targeted when developing obesity treatment or prevention strategies.

Keywords: Home environment, BMI-SDS, Weight, Child, Obesogenic

5.2 Introduction

A growing body of evidence suggests early childhood experiences are important for predicting obesity risk[1–3]. The family home environment is thought to be particularly influential in shaping early life obesogenic dietary and physical activity behaviours associated with excess weight gain[4–7]. However, few studies have successfully demonstrated robust relationships between measures of the home environment and weight development in childhood[8].

The ‘obesogenic’ home environment can be conceptualised in terms of three separate domains: the food, physical activity and media domains. Each domain consists of physical (e.g. availability and access) and social factors (e.g. caregiver modelling, rules and limit setting), which have been shown to predict a child’s dietary intake and activity levels[9–11], and thus deemed important for weight trajectories.

Consistent evidence for the role of the home environment in childhood weight development has not yet been established. For the home media domain, reliable cross-sectional associations have been observed between greater availability of, and access to, electronic devices and higher adiposity outcomes in children aged 3-12 years old[8,12–16]. Evidence for the role of the home food domain is more mixed. Some studies have demonstrated cross-sectional associations between greater availability and access to energy-dense foods and beverages with higher BMI in pre-school[17] and school-aged children[18], while other studies report no association[9,19–21]. Findings for associations between the home physical activity domain and child weight are also equivocal. Studies have reported access to physical activity equipment and garden space at home were associated with lower BMI z-scores[22,23], but others have reported inverse[24] or null associations[25,26]. Findings are similarly mixed for social aspects of the home environment, such as parental modelling, and parental rules and limit setting[8]. This conflicting evidence likely reflects the fact that individual aspects of the home environment alone have limited influence on child weight development [8,11]. Composite measures that take into account multiple aspects of the home environment are required to evaluate the obesogenic risk within the home with greater precision, and to explore relationships with child weight trajectories.

Longitudinal research in this area is limited and has tended to focus on a single aspect of the home environment[8], with mixed results. One large longitudinal study of UK children (n=12,556) found that having a TV in the child's bedroom at age 7 was associated with greater risk of overweight at age 11[27]. However, a prospective Australian study revealed no association between home food availability and child BMI z-scores in 5-6 year old (n=161) and 10-12 year old (n=132) children[20]. Longitudinal research has also been largely unidirectional, measuring the home environment at a single time point and examining the influence on child weight in later life, rather than the reverse. Gaining insights on directionality of associations is important as it allows us to understand whether the home environment is driving child weight or child weight is driving the obesogenic nature of the home environment. Two cross-sectional studies of a sample of British children in early (4 years) and later (12 years) childhood used a comprehensive measure of obesogenic risk within the home food, physical activity, and media environments and revealed that children living in higher-risk home environments had poorer diets, engaged in less physical activity and more sedentary screen-based behaviours than children living in lower-risk home environments[11,28]. Higher-risk home environments were also associated with higher BMI-SDS at age 12 but not age 4[11,28], suggesting that effects on weight may not manifest until later childhood. However, the cross-sectional nature of these studies prevents understanding of the directionality of associations.

To our knowledge, no previous studies have used comprehensive measures to capture the home environment at multiple time-points, limiting understanding of how the home environment and relationships with child weight change over time, as children transition from early childhood into adolescence. The present study utilised a comprehensive measure of the home environment to explore: 1) how the obesogenic nature of the home environment tracks over time, and 2) bi-directional associations between the home environment and child BMI-SDS from ages 4 to 12.

5.3 Methods

5.3.1 Sample

Participants were part of the Gemini study, a longitudinal birth cohort of families with twins born in England and Wales between March and December 2007. Gemini was established to examine genetic and environmental influences on energy balance behaviours and weight development during childhood[29]. A total of 2402 families with monozygotic (identical) and dizygotic (non-identical) twins consented to take part and completed baseline questionnaires when their twins were on average 8.2 months old (SD=2.2), additional details on recruitment, data collection and baseline characteristics are provided elsewhere[29]. The Gemini cohort is largely representative of the UK population for most baseline characteristics, except for maternal age and education[29]. As described elsewhere[11], families were invited to take part in a home environment interview (HEI) when the children were on average 4.2 years old (SD=0.4). Families who participated in the HEI at age 4 (n=1113 families, n=2226 children) were invited to participate in the HEI again when the children were on average 12.51 years old (SD=0.22)[28]. Only families who had taken part in the HEI at age 4 (n=1113), and those who completed caregiver feeding practices questionnaires in the month prior (n=219 families, 438 children), were invited to take part in the present study. Of those invited to take part, a total of 149 families (68%) completed the HEI at age 12.

The study sample (n=149 families, n=298 children) comprised families with data on all variables included in the analysis. Compared with the full sample of families that completed the HEI at age 4 (n=1113), parents in the current sample were slightly older at the child's birth (35.1 (4.23) vs 33.7 (4.79)), and were of higher SES (5.03 (1.01) vs 4.48 (1.28)). There were no differences in maternal BMI at baseline, gestational age, sex of the child, birth weight or weight at 4 years. When comparing the current sample to those completing the HEI at age 4, no significant differences were observed between the food and activity composite scores, but differences were observed for the media composite and the overall HE composite.

5.3.2 Measures

5.3.2.1 Home Environment Interview

Primary caregivers completed the HEI by telephone with a trained researcher when their children were 4 years of age, and again when they were 12 years of age. The HEI is a comprehensive measure of the home environment which assesses a range of physical and social aspects of the home food, physical activity and media environments[11,28]. Caregiver feeding practices were assessed using validated questionnaires[30–33]. The HEI was originally developed for use in families with pre-school aged children[11], and later updated for school aged children[28]. As described elsewhere[11,28], the obesogenic quality of the home environment was determined by creating composite scores. A total of 32 constructs were included in the composite scores (see **Appendix D.1**). Constructs identified as being associated with decreased risk for excess childhood weight gain were reverse-scored so that a higher total score would reflect 'higher-risk' for excess weight gain. Each variable was standardized using z-scores for the total sample at age 4 and age 12 and the standardized variables were summed to create three composite scores: the home food environment (21 variables), the physical activity environment (6 variables) and the media environment (5 variables). The food, activity and media composites were then summed to create an overall home environment composite score, dividing by the number of variables per composite so that each composite contributed equally to the overall score (food composite/21 + activity composite/6 + media composite/5). Higher scores on each composite reflect 'higher-risk' environments[11,28].

The HEI was shown to have acceptable to high test-retest reliability over a two-week period at 4 and 12 years. Intraclass correlation coefficient (ICC); 95% confidence interval (CI) at age 4 was: food (ICC; 95% CI = 0.71; 0.52–0.83), activity (0.83; 0.72–0.91), media (0.92; 0.85–0.95), overall (0.92; 0.86–0.96)[11] and at age 12 was: food (0.77; 0.52-0.90), activity (0.62; 0.27-0.83), media (0.83; 0.61-0.93), overall (0.76; 0.49-0.90)[28]. Additionally, at age 4 the HEI had good to excellent validity when compared with images from a wearable camera of the home environment[34].

5.3.2.2 Anthropometric measurement

Information on weight at birth was obtained from the child's health record and reported by the primary caregivers. Electronic weighing scales and height charts were sent to all Gemini families when the children were two years old and updated height charts were sent when the children were 10 years old for parents to report measurements at three-month intervals. At the time of the HEI, parents were also asked to provide their child's height and weight measurements. Age, sex and gestational age were parent reported. Standard deviation scores (SDS) for child BMI (BMI-SDS) were calculated using the UK90 British growth reference data[35], adjusting for age, sex, and gestational age. Maternal BMI at baseline and 12 years was calculated using self-reported height and weight squared (kg/m^2).

5.3.2.3 Covariates

The following covariates were included, as previous literature indicated that they may be related to the predictor and outcome variables: child age at measurement, sex of child, and baseline maternal BMI[36,37].

5.3.3 Statistical analysis

Pearson's correlation was used to assess the continuity of the home environment composites from ages 4 to 12 years. Partial correlations were also calculated controlling for the time interval between each HEI. Paired samples t-tests were employed to examine differences in the home environment composite scores (overall and for the food, activity and media domains) between 4 and 12 years old. Again, the analysis was re-run controlling for the time interval between each HEI. There were no differences in mean HE composite score change by sex or zygosity so data from the whole sample were used in the final analyses. To understand how the home environment changed from ages 4 to 12, paired samples t-tests or McNemar's tests were used to examine differences in the raw scores for the constructs included in the home environment composite scores (food, activity and media domains). These analyses were conducted using SPSS v26, with an alpha level of 0.05.

A cross-lagged structural equation model (SEM) was used to estimate effects of the obesogenic quality of the home environment on child BMI-SDS and vice versa. These analyses examined cross-sectional correlations between the overall home environment composite and BMI-SDS at ages 4 and 12, as well as prospective associations between the home environment composites and BMI-SDS at both time points. This process was repeated for the separate food, activity, and media composites. Age at measurement, sex of child, and maternal BMI were entered as covariates. All analyses were conducted in R version 4.0.3 using the statistical package lavaan[38] and the add-on lavaan.survey[39] which allows adjustment for clustering of twins within families. Utilising this approach means that both twins in a pair can be included in the analyses, maximising the sample size and statistical power. Standardized β were used to determine and compare the strength of associations. Model fit indices were calculated, with cut-offs in parentheses indicating acceptable to good fit: Comparative Fit Index (CFI ≥ 0.95), Tucker-Lewis Index (TLI; acceptable ≥0.90; good ≥0.95), Root Mean Square Error of Approximation (RMSEA ≤ 0.06), Standardized Root Mean Square Residuals (SRMR ≤ 0.08), chi-square (χ p>0.05)[40]. The CFI, TLI, RMSEA, SRMR and variance explained (R^2) are presented for each model[41]. Again, the analyses were re-run controlling for the time interval between each HEI. Previous literature suggests that any SEM model should include more than 200 participants[42], the current study included 298 participants at both time points.

5.4 Results

5.4.1 Sample characteristics

The analysis sample comprised 149 families (n=298 children). All responders were the primary caregiver, with 98.7% (n=147) being the child's mother and 1.3% (n=2) the father. Characteristics of the sample at ages 4 and 12 are outlined in **Table 5.1.**

Table 5.1. Characteristics of sample (n=149 families, n=298 children).

	Mean (SD) or % (n)
Maternal characteristics	
Maternal age at birth (years)	35.1 (4.23)
Maternal BMI at baseline	24.33 (4.19)
Maternal BMI at 12 year measurement	25.18 (4.79)
Maternal ethnicity	
White	94.6 (141)
Non-white	5.4 (8)
Marital status at baseline	
Married or cohabiting	98.7 (147)
Separated or divorced	0.7 (1)
Single	0.7 (1)
Marital status at 12 year measurement	

	Mean (SD) or % (n)
Married or cohabiting	94 (140)
Separated or divorced	4 (6)
Single	2 (3)
Child characteristics	
Sex of child (boys)	48.7 (145)
Zygosity[1]	
MZ pairs	28.9 (43)
DZ pairs	70.5 (105)
Gestational age (weeks)	36.07 (2.6)
Birth weight, SDS	-0.57 (0.96)
Age of child at 4 years measurement	4.08 (0.43)
Age of child at 12 years measurement	12.51 (0.22)
BMI-SDS of child at 4 years measurement	0.02 (0.87)
BMI-SDS of child at 12 years measurement	-0.06 (1.14)
Home environment composites	*Range*
Food environment at 4 years	-18.93–15.87
Physical activity environment at 4 years	-4.94–10.90
Media environment at 4 years	-6.45–18.11
Overall home environment at 4 years	-2.11–2.92
Food environment at 12 years	-13.67–23.15
Physical activity environment at 12 years	-4.54–15.45
Media environment at 12 years	-5.45-9.31
Overall home environment at 12 years	-2.17-3.02

[1]Zygosity information was missing for one family (n=2 children)

5.4.2 Stability and continuity of home environment over time

Correlations over time for each of the home environment composites are presented in **Table 5.2**. The strength of associations were moderate to large for all correlations; ranging from 0.30 for activity composite and 0.64 for the media composite ($p<0.001$). Partial correlations controlling for time difference between the visits produced almost identical results (not tabulated).

Paired Samples t-tests assessed the stability of the home environment composites between ages 4 and 12, revealing the food ($t=-2.37$, $p=0.018$), media ($t=-7.22$, $p<0.001$) and overall HE ($t=-4.63$, $p<0.001$) composite scores were higher (more obesogenic) at age 12 than age 4. No differences were observed for the activity composite ($t=0.52$, $p=0.606$) between 4 and 12 years. Paired Samples t-tests or McNemar's tests were used to compare raw scores for individual constructs included in the home environment composite scores between ages 4 and 12. The mean number of energy-dense snacks available in the home increased between ages 4 (4.97 ± 2.14) and 12 (6.96 ± 3.22; $p<0.001$). Similar findings were observed for the availability of sugar sweetened beverages in the home (age 4 $=0.51 \pm 0.78$; age $12=1.44 \pm 1.05$; $p<0.001$), and the number of electronic media devices present in the home (age 4 $=4.98 \pm 2.30$; age $12=15.48 \pm 4.20$; $p<0.001$) and in children's bedrooms (age 4 $=0.07 \pm 0.29$; age $12=1.70 \pm 1.37$; $p<0.001$), indicating that these aspects of the home environment became more obesogenic from 4 to 12 years. Raw scores for the home environment constructs included in the composite scores at age 4 and age 12 are shown in **Appendix D.2.**

Table 5.2. Bivariate correlations for the home environment composite scores between age 4 and 12 years.

		Home environment at age 4				Home environment at age 12			
		Food composite	**Activity composite**	**Media composite**	**Overall HE composite**	**Food composite**	**Activity composite**	**Media composite**	**Overall HE composite**
Home environment at age 4	Food composite	1.00	.23***	.13*	.57***	.45***	.14*	.18***	.34***
	Activity composite		1.00	-.07	.65***	.13*	.30***	.02	.21***
	Media composite			1.00	.64***	.32***	.12*	.64***	.57***
	Overall HE composite				1.00	.44***	.31***	.48***	.60***
Home environment at age 12	Food composite					1.00	.21*	.37***	.67***
	Activity composite						1.00	.03	.60***
	Media composite							1.00	.76***
	Overall HE composite								1.00

*p<.05, **p<.01, ***p<.001

5.4.3 Bi-directional associations between HE and BMI-SDS

Cross-lagged analyses for the overall HE composite and BMI-SDS at ages 4 and 12 and vice versa are shown in Figure 5.1**.** The findings revealed children's BMI tracked from ages 4 to 12 *(β=0.41; 0.30, 0.53, p<0.001)* and the home environment tracked strongly from ages 4 to 12 (*β=0.61; 0.50, 0.72, p<0.001).* Analyses revealed a small positive cross-sectional correlation between the home environment and BMI-SDS at age 12 *(r=.21, p=0.02).* The cross-lagged paths were not significant in either direction, indicating the home environment did not predict longitudinal changes in BMI-SDS, nor did BMI-SDS at age 4 predict longitudinal changes in the home environment to age 12.

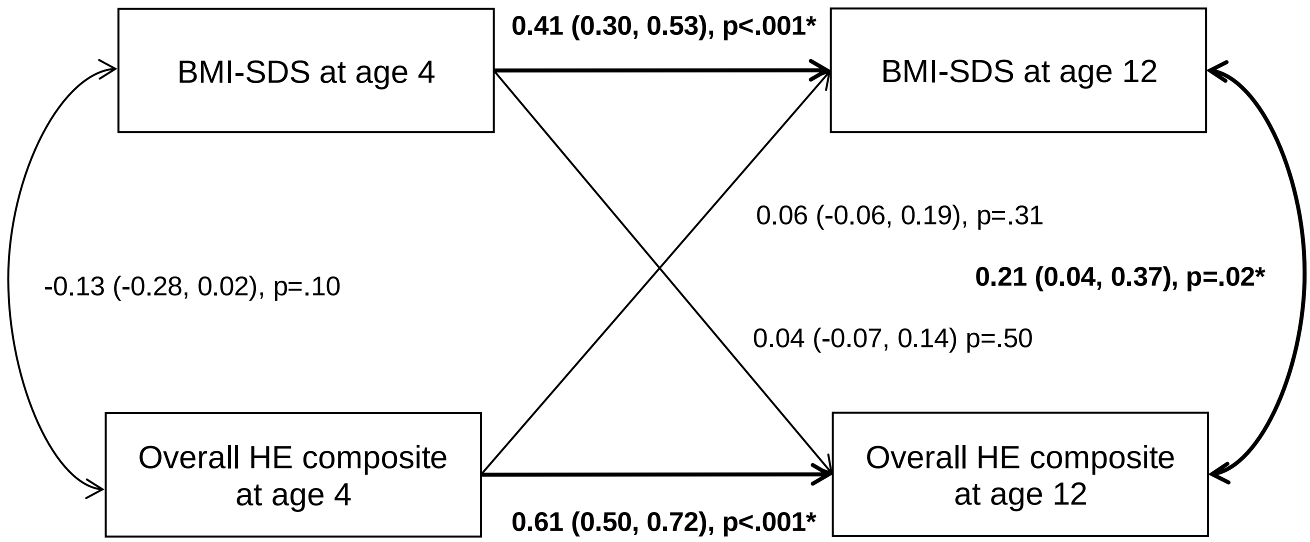


Figure 5.1. Cross-lagged model showing the associations between the overall home environment composite and BMI-SDS at ages 4 and 12 and vice versa.

Analyses were adjusted for clustering within families and covariates; age of child at measurement, sex of child, and maternal BMI at baseline. *denotes statistical significance. CFI: 0.98; TLI: 0.94; RMSEA: 0.04 (p=0.57); SRMR: 0.05. R^2 HE at age 12 = 0.37, R^2 BMI-SDS age 12: 0.17

Cross-sectional and cross-lagged analyses between the home media environment and BMI-SDS are shown in **Figure 5.2.** The findings revealed the home media environment tracked strongly from ages 4 to 12 (β=0.64; 0.53, 0.75, p<.001). Analyses indicated a small positive cross-sectional correlation between the home media environment and BMI-SDS at age 12 *(r=.23, p<0.05).* The cross-lagged paths revealed a significant but small relationship between the media composite at age 4 and BMI-SDS at age 12 *(β=0.18; 0.08, 0.28, p<.001),* indicating that a 'higher-risk' media environment at age 4 predicted higher BMI-SDS at age 12. However, the reverse relationship from BMI-SDS at age 4 to media composite at age 12 was not significant.

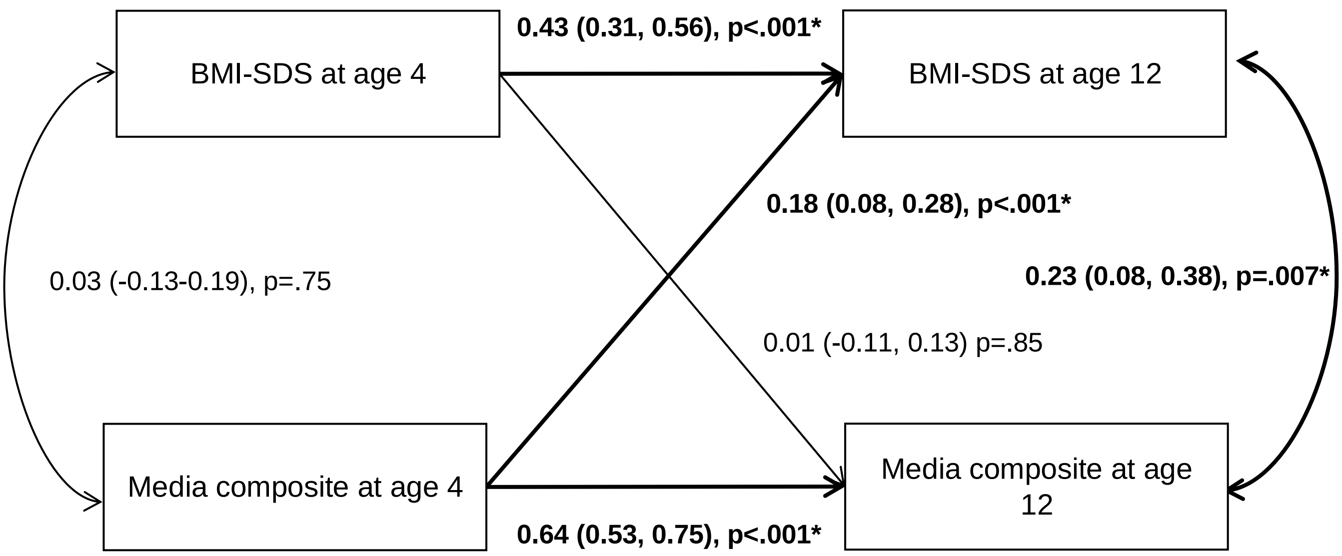


Figure 5.2. Cross-lagged model showing the associations between the home media environment composite and BMI-SDS at ages 4 and 12 and vice versa.

Analyses were adjusted for clustering within families and covariates; age of child at measurement, sex of child, and maternal BMI. *denotes statistical significance CFI: 0.98; TLI: 0.96; RMSEA: 0.03 (p=0.75); SRMR: 0.05. R^2 home media composite at age 12 = 0.41, R^2 BMI-SDS age 12: 0.22

Cross-lagged analyses for the home food and the home physical activity composites are presented in **Figure 5.3** and **Figure 5.4** respectively. Pathways were not significant in either direction.

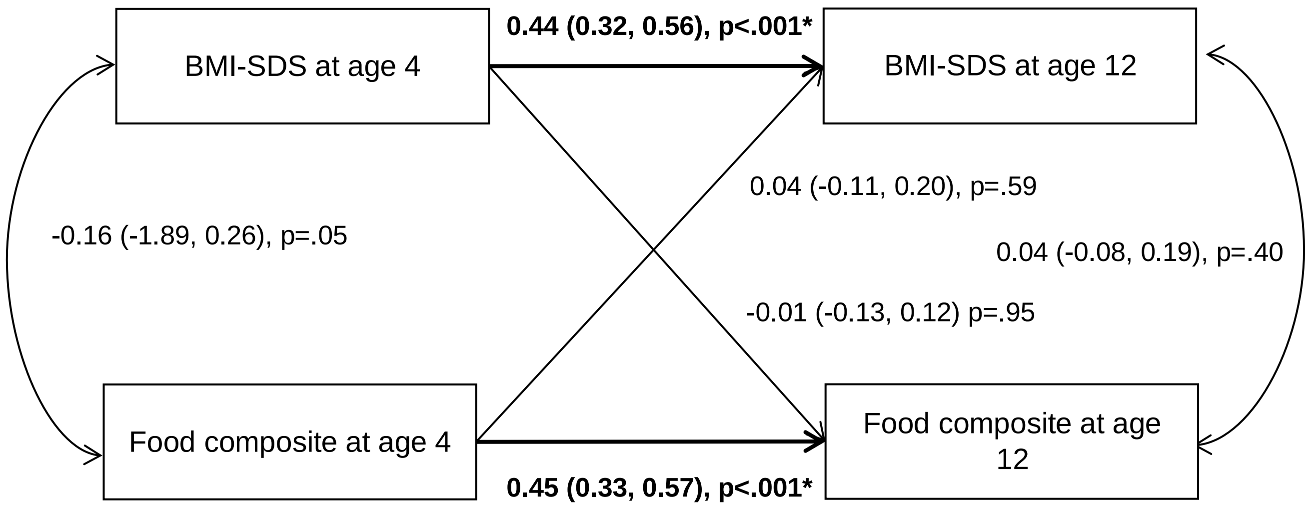


Figure 5.3. Cross-lagged model showing the associations between the home food environment composite and BMI-SDS at ages 4 and 12 and vice versa.

Analyses were adjusted for clustering within families and covariates; age of child at measurement, sex of child, and maternal BMI. *denotes statistical significance CFI: 0.98; TLI: 0.94; RMSEA: 0.03 (p=0.75); SRMR: 0.05. R^2 home food composite at age 12 = 0.20, R^2 BMI-SDS age 12: 0.19

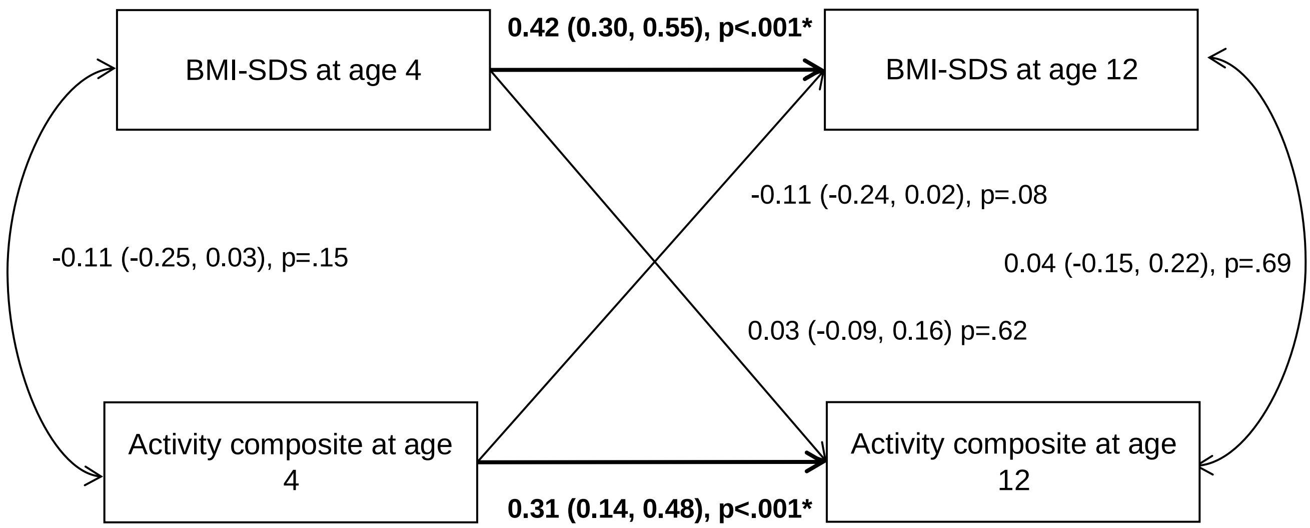


Figure 5.4. Cross-lagged model showing the associations between the home activity environment composite and BMI-SDS at ages 4 and 12 and vice versa.

Analyses were adjusted for clustering within families and covariates; age of child at measurement, sex of child, and maternal BMI. *denotes statistical significance CFI: 0.97; TLI: 0.94; RMSEA: 0.03 (p=0.78); SRMR: 0.05. R^2 home activity composite at age 12 = 0.09, R^2 BMI-SDS age 12: 0.20

Sensitivity analyses controlling for time interval differences between each HEI produced almost identical results to those presented above (not reported here for brevity).

5.5 Discussion

To our knowledge, this is the first study to examine longitudinally the stability and continuity of the obesogenic home environment across childhood, and the first to examine bi-directional relationships between the obesogenic nature of the home environment and child BMI. Cross-sectional associations were observed between both the overall and media domains of the home environment and child BMI-SDS at 12 years, but not 4 years. Cross-lagged paths also revealed that the media composite score at age 4 was positively associated with child BMI-SDS at age 12, suggesting that living in a more obesogenic media environment predicted greater increases in child BMI-SDS from ages 4 to 12 years. There were no associations for the reverse paths, from BMI-SDS at age 4 to media composite at age 12, nor were associations observed between the other home environment composite scores (the overall, the food and activity composites respectively) and BMI-SDS.

The home environment showed moderate to strong tracking from ages of 4 to 12 years, with correlations ranging from 0.30 to 0.64 for all home environment composites (the overall HE composite, as well as food, activity and media domains) across the two time points. These findings indicate that children living in higher-risk, more obesogenic, home environments at age 4 tended to remain in higher-risk environments at age 12 and, similarly, those in lower-risk home environments at age 4 tended to remain in lower-risk environments at age 12.

While findings indicated continuity in the home environment composites at an individual level, significant increases were observed for the food, media and overall home environment composite scores from ages 4 to 12. Significant differences were also observed for the individual constructs that comprise the composite scores, with notable increases in the availability of energy dense snacks and sugar sweetened beverages in the home, as well as significant increases in electronic devices both in the home and children's bedrooms between ages 4 and 12. Together these findings indicate that while each household tends to keep their relative position in the obesogenic nature of their home environment, aspects of the home environments became more obesogenic in nature over the 8-year period. The increases in availability of electronic devices may also in part reflect societal and technological developments over the past decade[43]. Age-related increases in the obesogenic nature of the home environment have been demonstrated previously, with reported decreases in the frequency of family mealtimes as children get older[44], and increases in availability and access to electronic devices as children reach adolescence[43]. The tracking of the home environment over time highlights the importance of early intervention to try to support families to establish a home environment that encourages healthy eating, physical activity and age-appropriate media use, from early childhood.

In accordance with previous research[8], the most consistent relationships between the home environment and child BMI-SDS were observed in the media domain, with the media composite at age 4 predicting changes in child BMI-SDS from age 4 to 12. In addition, cross-sectional associations were observed between child BMI-SDS and the home media environment. These findings suggest that the media environment that a child is exposed to in early life (age 4) predicts greater increases in BMI from age 4 to 12, and that a child's BMI continues to be influenced by the media environment they are exposed to in later childhood (age 12). It is however important to note that the cross-sectional nature of the association at age 12 means we are unable to determine directionality, and thus it may be that a child's BMI at age 12 influences the media environment or that the two influence each other. These findings suggest that relationships between aspects of the home environment and child weight may not manifest until later childhood. One possible reason for this may be that older children have more autonomy over their food choices and behaviours than younger children and are also exposed to a wider range of external obesogenic influences, which may have a cumulative effect on weight[45]. Our findings build on previous longitudinal research highlighting potential relationships between individual aspects of the media environment and child adiposity[8]. The longitudinal relationship between the home media environment at age 4 and child BMI-SDS eight years later, suggests the media environment plays an influential role in shaping children's weight trajectories, and thus may be an important avenue to explore when designing obesity prevention and treatment strategies.

Pathways between the overall home environment composite and child BMI-SDS were not significant in either direction. Similar results were observed for the home food and activity composites. These findings may partly result from the small size and limited diversity (in terms of ethnicity and socioeconomic status) of the present sample. Children of lower socioeconomic status (SES) are more likely to live in more obesogenic home environments [12,46–48], and have higher rates of adiposity than those of higher SES[49,50]. In addition, there are difficulties in measuring some aspects of the home environment as they rely on parent-report, which is susceptible to biases. As such the true range of potential scores for the obesogenic home environment may not have been captured in the current sample, limiting the ability to uncover both cross-sectional and longitudinal relationships with BMI. Future research should replicate the findings in a more generalizable sample.

Another potential explanation for the lack of association between the overall home environment composite and child BMI could be that these relationships are complex, involving gene-environment interactions. Individual variation in susceptibility to obesogenic environments may influence associations between the home environment and child weight trajectories[51]. In line with this, research has demonstrated that the heritability of BMI is significantly higher for children living in more obesogenic home environments compared to those from healthier homes (heritability of 86% vs 39%)[52]; suggesting children with greater genetic susceptibility to obesity are at greater risk of developing obesity when they grow up in more obesogenic environments[52].

The finding of no clear relationship between child BMI and either the food or physical activity domains reflect the inconsistency of previous evidence in this area[8]. Reviews have generally found an absence of convincing evidence for the contribution of physical activity to child adiposity[53,54]. The home food environment is similarly complex[55], and is influenced by both social and physical factors[8,11]. Previous research has shown clear associations between the home food environment and children's food intake, with more 'obesogenic' home food environments associated with lower frequency of fruit and vegetable consumption and higher frequency of energy-dense snack consumption at both ages 4 and 12[11]. However, the frequency with which different varieties of foods are consumed does not necessarily equate to overall energy intake or directly impact weight status. Furthermore, unlike the media and activity environment, the food environment is more likely to fluctuate from day-to-day and vary with seasonal changes, adding to the complexity of measurement.

5.5.1 Strengths and Limitations

The strengths of this study include the prospective study design, with repeated measures of the comprehensive obesogenic home environment and children's heights and weights at ages 4 and 12, and the ability to control for important confounding variables. Despite this, there are a number of limitations to this study that need to be considered. The HEI is parent-reported and thus susceptible to social desirability and recall biases [56,57], and such biases may vary dependent on child weight status [58], which can make it difficult to disentangle the role of the home environment in child weight development and must be taken into consideration when interpreting the results. However, as mentioned in the methods, the HEI has shown acceptable to high test-retest reliability over a two week period, and good to excellent validity when compared with images from a wearable camera of the home environment[34]. Additionally, the sample size was small and relatively homogenous, with a large proportion of higher SES households and White-British compared to the general population, meaning findings may not be representative. Future research should aim to replicate our findings in a socioeconomically and ethnically diverse sample. Thirdly, height and weight measurements were parent-reported, which may introduce inaccuracies and bias, however, parent-reports have been shown to correspond with researcher-report[59] and more so when parents are provided with electronic scales and height charts[60], as was the case in this study. Finally, the use of BMI-SDS as the primary measure of adiposity is a limitation, as it cannot differentiate between weight attributable to fat mass or lean mass therefore misclassification of weight status can occur at an individual level, especially during childhood when maturation occurs at differing rates. Thus, utilising other measures of adiposity such as waist circumference, body fat percentage, or skinfold thickness may be beneficial.

5.5.2 Conclusion

This is the first study to explore how physical and social aspects of the food, activity and media environments of the family home change from early childhood into adolescence. This study provides evidence for the tracking of the obesogenic home environment across childhood and, in particular, highlights the importance of the early home media environment for child weight development. These findings provide important insight into key aspects of the home environment, such as the media environment, that could be targeted when developing obesity treatment or prevention strategies.

Acknowledgements

We would like to thank the Gemini families for participating in the study.

Ethical approval and consent to participate

Ethical approval was originally granted for the study in 2007 by the University College London (UCL) Committee for the Ethics of non-National Health Service Human Research. In 2018, ethical approval for the continuation of the study was again granted by the UCL Research Ethics Committee (Project ID 1624/004). Written informed consent was provided by all Gemini families. All aspects of data collection and storage complied with the standards specified by this body.

Competing interests

This work was supported by the Economic and Social Research Council Advanced Quantitative Methods Studentship (Project reference: 1948633) which was awarded to Alice Kininmonth. The funders had no role in any element of this research. The remaining authors declare no competing interests.

Authors' contributions

AK and AF, in collaboration with CHL and AS, were responsible for the conceptualisation and design of the study. AK conducted the data analysis and was responsible for creating the first draft of the manuscript and all revisions of the manuscript. AF, CHL, AS, SS & AF oversaw this process. All authors have read, contributed to and approved the final manuscript.

5.6 References

1. Anzman SL, Rollins BY, Birch LL. Parental influence on children's early eating environments and obesity risk: implications for prevention. *Int J Obes*. 2010;34(7):1116-1124. doi:10.1038/ijo.2010.43
2. Monasta L, Batty GD, Cattaneo A, et al. Early-life determinants of overweight and obesity: A review of systematic reviews. *Obes Rev*. 2010;11(10):695-708. doi:10.1111/j.1467-789X.2010.00735.x
3. Quick V, Martin-Biggers J, Povis GA, Hongu N, Worobey J, Byrd-Bredbenner C. A socio-ecological examination of weight-related characteristics of the home environment and lifestyles of households with young children. *Nutrients*. 2017;9(6). doi:10.3390/nu9060604
4. Campbell K, Crawford D. Family food environments as determinants of preschool-aged children's eating behaviours: implications for obesity prevention policy. A review. *Aust J Nutr Diet*. 2001;58(1):19-25. Accessed March 13, 2020. https://daa.asn.au/wp-content/uploads/2016/12/58-1-

family-food....pdf

5. Campbell K, Crawford DA, Salmon J, Carver A, Garnett SP, Baur LA. Associations Between the Home Food Environment and Obesity-promoting Eating Behaviors in Adolescence*. *Obesity*. 2007;15(3):719-730. doi:10.1038/oby.2007.553

6. Golan M. Parents as agents of change in childhood obesity - From research to practice. *Int J Pediatr Obes*. 2006;1(2):66-76. doi:10.1080/17477160600644272

7. Rosenkranz RR, Dzewaltowski DA. Model of the home food environment pertaining to childhood obesity. *Nutr Rev*. 2008;66(3):123-140. doi:10.1111/j.1753-4887.2008.00017.x

8. Kininmonth A, Smith AD, Llewellyn CH, Dye L, Lawton CL, Fildes A. The relationship between the home environment and child adiposity: a systematic review. *Int J Behav Nutr Phys Act*. 2021;18(1):4. doi:10.1186/s12966-020-01073-9

9. Couch SC, Glanz K, Zhou C, Sallis JF, Saelens BE. Home food environment in relation to children’s diet quality and weight status. *J Acad Nutr Diet*. 2014;114(10):1569-1579.e1. doi:10.1016/j.jand.2014.05.015

10. Savage JS, Fisher JO, Birch LL. Parental Influence on Eating Behavior: Conception to Adolescence. *J Law, Med Ethics*. 2007;35(1):22-34. doi:10.1111/j.1748-720X.2007.00111.x

11. Schrempft S, Van Jaarsveld CHM, Fisher A, Wardle J. The obesogenic quality of the home environment: Associations with diet, physical activity, TV viewing, and BMI in preschool children. *PLoS One*. 2015;10(8):e0134490. doi:10.1371/journal.pone.0134490

12. Borghese MM, Tremblay MS, Katzmarzyk PT, et al. Mediating role of television time, diet patterns, physical activity and sleep duration in the association between television in the bedroom and adiposity in 10 year-old children. *Int J Behav Nutr Phys Act*. 2015;12:60. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25967920

13. Chahal H, Fung C, Kuhle S, Veugelers PJ. Availability and night-time use of electronic entertainment and communication devices are associated with short sleep duration and obesity among Canadian children. *Pediatr Obes*. 2013;8(1):42-51. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=22962067

14. Chaput JP, Leduc G, Boyer C, et al. Electronic screens in children’s bedrooms and adiposity, physical activity and sleep: do the number and type of electronic devices matter? *Can J Public Heal Rev Can Sante Publique*. 2014;105(4):e273-9. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medc&AN=25166130

15. Dube N, Khan K, Loehr S, Chu Y, Veugelers P. The use of entertainment and communication technologies before sleep could affect sleep and weight status: a population-based study among children. *Int J Behav Nutr Phys Act*. 2017;14(1):97. doi:10.1186/s12966-017-0547-2

16. Farajian P, Panagiotakos DB, Risvas G, Malisova O, Zampelas A. Hierarchical analysis of dietary, lifestyle and family environment risk factors for childhood obesity: the GRECO study. *Eur J Clin Nutr*. 2014;68(10):1107-1112. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24824010

17. Chen JL, Esquivel JH, Guo J, Chesla CA, Tang S. Risk factors for obesity in preschool-aged children in China. *Int Nurs Rev*. 2018;65(2):217-224. doi:10.1111/inr.12371

18. Cassimos D, Sidiropoulos H, Batzios S, Balodima V, Christoforidis A. Sociodemographic and dietary risk factors for excess weight in a greek pediatric population living in Kavala, Northern Greece. *Nutr Clin Pr*. 2011;26(2):186-191. doi:10.1177/0884533611399772

19. Gable S, Lutz S. Household, parent, and child contributions to childhood obesity. *Fam Relations An Interdiscip J Appl Fam Stud*. 2000;49(3):293-300. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc3&AN=2000-00053-008

20. MacFarlane A, Cleland V, Crawford D, Campbell K, Timperio A. Longitudinal examination of the family food environment and weight status among children. *Int J Pediatr Obes*. 2009;4(4):343-352. doi:10.3109/17477160902846211

21. Terry K, Beck S. Eating style and food storage habits in the home: Assessment of obese and nonobese families. *Behav Modif*. 1985;9(2):242-261. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc2&AN=1986-01647-001

22. Hales D, Vaughn AE, Mazzucca S, et al. Development of HomeSTEAD’s physical activity and screen time physical environment inventory. *Int J Behav Nutr Phys Act*. 2013;10:132. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=24313962

23. Schalkwijk AA, van der Zwaard BC, Nijpels G, Elders PJ, Platt L. The impact of greenspace and condition of the neighbourhood on child overweight. *Eur J Public Health*. 2018;28(1):88-94. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-05454-017

24. Torres R, Serrano M, Perez CM, Palacios C. Physical environment, diet quality, and body weight in a group of 12-year-old children from four public schools in Puerto Rico. *P R Health Sci J*. 2014;33(1):14-21. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24665604

25. Rosenberg DE, Sallis JF, Kerr J, et al. Brief scales to assess physical activity and sedentary equipment in the home. *Int J Behav Nutr Phys Act Vol 7 2010, ArtID 10*. 2010;7. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc7&AN=2012-31433-001

26. Umstattd Meyer MR, Sharkey JR, Patterson MS, Dean WR. Understanding contextual barriers, supports, and opportunities for physical activity among Mexican-origin children in Texas border colonias: a descriptive study. *BMC Public Health*. 2013;13:14. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=23297793

27. Heilmann A, Rouxel P, Fitzsimons E, Kelly Y, Watt R. Longitudinal associations between television in the bedroom and body fatness in a UK cohort study. *Int J Obes*. 2017;41(10):1503-1509. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-02265-005

28. Kininmonth AR, Schrempft S, Smith A, et al. The Home Environment Interview and associations with energy balance behaviours and body weight in school-aged children – A feasibility, reliability, and validity study. *Int J Behav Nutr Phys Act*.

29. van Jaarsveld CH, Johnson L, Llewellyn C, Wardle J. Gemini: a UK twin birth cohort with a focus on early childhood weight trajectories, appetite and the family environment. *Twin Res Hum Genet*. 2010;13(1):72-78. doi:10.1375/twin.13.1.72

30. Birch LL, Fisher JO, Grimm-Thomas K, Markey CN, Sawyer R, Johnson SL. Confirmatory factor analysis of the Child Feeding Questionnaire: A measure of parental attitudes, beliefs and practices about child feeding and obesity proneness. *Appetite*. 2001;36(3):201-210. doi:10.1006/appe.2001.0398

31. Musher-Eizenman D, Holub S. Comprehensive feeding practices questionnaire: Validation of a new measure of parental feeding practices. *J Pediatr Psychol*. 2007;32(8):960-972. doi:10.1093/jpepsy/jsm037

32. Ogden J, Reynolds R, Smith A. Expanding the concept of parental control: A role for overt and covert control in children's snacking behaviour? *Appetite*. 2006;47(1):100-106. doi:10.1016/j.appet.2006.03.330

33. Wardle J, Sanderson S, Guthrie CA, Rapoport L, Plomin R. Parental feeding style and the intergenerational transmission of obesity risk. *Obes Res*. 2002;10(6):453-462. doi:10.1038/oby.2002.63

34. Schrempft S, van Jaarsveld CH, Fisher A. Exploring the potential of a wearable camera to examine the early obesogenic home environment: Comparison of sensecam images to the home environment interview. *J Med Internet Res*. 2017;19(10):e332. doi:10.2196/JMIR.7748

35. Freeman J V, Cole TJ, Chinn S, Jones PR, White EM, Preece MA. Cross sectional stature and weight reference curves for the UK, 1990. *Arch Dis Child*. 1995;73(1):17. http://adc.bmj.com/content/73/1/17.abstract

36. Linabery AM, Nahhas RW, Johnson W, et al. Stronger influence of maternal than paternal obesity on infant and early childhood body mass index: the Fels Longitudinal Study. *Pediatr Obes*. 2013;8(3):159-169. doi:10.1111/J.2047-6310.2012.00100.X

37. Schrempft S, van Jaarsveld CHM, Fisher A, Fildes A, Wardle J. Maternal characteristics associated with the obesogenic quality of the home

environment in early childhood. *Appetite*. 2016;107:392-397. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medc&AN=27554185

38. Rosseel Y. *Lavaan: An R Package for Structural Equation Modeling and More Version 0.5-12 (BETA)*.; 2012. Accessed March 11, 2021. http://cran.r-project.org/.

39. Oberski D. Lavaan.survey: An R package for complex survey analysis of structural equation models. *J Stat Softw*. 2014;57(1):1-27. doi:10.18637/jss.v057.i01

40. Hooper D, Coughlan J, Mullen MR. Structural equation modelling: Guidelines for determining model fit. *Electron J Bus Res Methods*. 2008;6(1). doi:10.21427/D79B73

41. Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct Equ Model*. 1999;6(1):1-55. doi:10.1080/10705519909540118

42. Weston R, Gore PA. A Brief Guide to Structural Equation Modeling. *Couns Psychol*. 2006;34(5):719-751. doi:10.1177/0011000006286345

43. Ofcom. *Children and Parents: Media Use and Attitudes Report 2019*.; 2020. Accessed October 22, 2020. https://www.ofcom.org.uk/making-sense-of-media.

44. Harrison ME, Norris ML, Obeid N, Fu M, Weinstangel H, Sampson M. Systematic review of the effects of family meal frequency on psychosocial outcomes in youth. *Can Fam Physician*. 2015;61(2).

45. Campbell K. Biological, environmental, and social influences on childhood obesity. *Pediatr Res 2016 791*. 2015;79(1):205-211. doi:10.1038/pr.2015.208

46. Adachi-Mejia A, Longacre M, Gibson J, Beach M, Titus-Ernstoff L, Dalton M. Children with a TV in their bedroom at higher risk for being overweight. *Int J Obes*. 2007;31(4):644-651. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc5&AN=2007-05536-004

47. Atkin AJ, Corder K, van Sluijs EMF. Bedroom media, sedentary time and screen-time in children: a longitudinal analysis. *Int J Behav Nutr Phys Act 2013 101*. 2013;10(1):1-10. doi:10.1186/1479-5868-10-137

48. Ihmels MA, Welk GJ, Eisenmann JC, Nusser SM, Myers EF. Prediction of BMI change in young children with the family nutrition and physical activity (FNPA) screening tool. *Ann Behav Med*. 2009;38(1):60-68. doi:10.1007/s12160-009-9126-3

49. Shrewsbury V, Wardle J. Socioeconomic Status and Adiposity in Childhood: A Systematic Review of Cross-sectional Studies 1990–2005. *Obesity*. 2008;16(2):275-284. doi:10.1038/oby.2007.35

50. Wang Y, Beydoun MA. The obesity epidemic in the United States - Gender, age, socioeconomic, racial/ethnic, and geographic characteristics: A systematic review and meta-regression analysis. *Epidemiol Rev*. 2007;29(1). doi:10.1093/epirev/mxm007

51. Llewellyn CH. Genetic susceptibility to the “obesogenic” environment: the role of eating behavior in obesity and an appetite for change. *Am J Clin Nutr*. 2018;108:429-430. doi:10.1093/ajcn/nqy210

52. Schrempft S, van Jaarsveld CM, Fisher A, et al. Variation in the heritability of child body mass index by obesogenic home environment. *JAMA Pediatr*. 2018;172(12):1153-1160. doi:10.1001/jamapediatrics.2018.1508

53. Abbott RA, Davies PSW. Habitual physical activity and physical activity intensity: Their relation to body composition in 5.0-10.5-y-old children. *Eur J Clin Nutr*. Published online 2004. doi:10.1038/sj.ejcn.1601780

54. Must A, Tybor DJ. Physical activity and sedentary behavior: A review of longitudinal studies of weight and adiposity in youth. *Int J Obes*. Published online 2005. doi:10.1038/sj.ijo.0803064

55. Rosenkranz RR, Dzewaltowski DA. Model of the home food environment pertaining to childhood obesity. *Nutr Rev*. 2008;66(3):123-140. doi:10.1111/j.1753-4887.2008.00017.x

56. Hebert J, Clemow L, Pbert L, Ockene I, Ockene J. *Social Desirability Bias in Dietary Self-Report May Compromise the Validity of Dietary Intake Measures*. Vol 24.; 1995. doi:10.1093/ije/24.2.389

57. Bornstein MH, Putnick DL, Lansford JE, et al. Mother and Father Socially Desirable Responding in Nine Countries: Two Kinds of Agreement and Relations to Parenting Self-Reports HHS Public Access. *Int J Psychol*. 2015;50(3):174-185. doi:10.1002/ijop.12084

58. Nepper MJ, Chai W. Assessment of Home Food Environment among Healthy Weight and Overweight School-age Children. *Heal Behav Policy Rev*. 2016;3(6):568-580. doi:10.14485/hbpr.3.6.6

59. Wardle J, Carnell S, Haworth CM, Plomin R. Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment. *Am J Clin Nutr*. 2008;87(2):398-404. doi:10.1093/ajcn/87.2.398

60. Huybrechts I, Himes JH, Ottevaere C, et al. Validity of parent-reported weight and height of preschool children measured at home or estimated without home measurement: A validation study. *BMC Pediatr*. 2011;11. doi:10.1186/1471-2431-11-63

Introduction to Chapter Six

The papers presented in Chapters Three, Four and Five suggest the home environment plays an important role in children's food intake, physical activity levels and screen-based sedentary behaviours – key energy balance behaviours implicated in a child's risk of excess weight gain. The evidence presented in Chapters Four and Five highlight cross-sectional associations between the home environment (both the overall home environment and the home media environment) and child BMI at age 12. Additionally, Chapter Five demonstrates the importance of the early home media environment for child weight development.

Another important aspect, yet to be examined, is the role of appetite in a child's risk of obesity. Evidence suggests differences in appetite determine why some people over-eat, and others do not, in response to the obesogenic environment. Considered in relation to the home environment, appetite may be particularly important for understanding variation in individual susceptibility to gaining excess weight in response to the obesogenic nature of the home environment. A large number of studies have examined associations between appetitive traits and adiposity outcomes in childhood. However, no previous studies have synthesised peer-reviewed literature on this topic and this lack of synthesis limits our ability to: 1) understand whether appetitive traits relate to adiposity in childhood, and 2) establish the size and direction of associations between appetite and adiposity in childhood. This chapter details a comprehensive systematic review and meta-analysis, with the aim of assessing how and to what extent appetitive traits, measured by the Child Eating Behaviour Questionnaire (CEBQ) and Baby Eating

Behaviour Questionnaire (BEBQ), relate to children's weight cross-sectionally, as well as prospectively.

Chapter 6

The association between childhood adiposity and appetite assessed using the Child Eating Behaviour Questionnaire and Baby Eating Behaviour Questionnaire: A systematic review and meta-analysis.

Chapter type:	Journal Article
Journal:	*Obesity Reviews*
Submission date:	October 2020
Submission status:	Published 07 February 2021
Reference:	Kininmonth, A., Smith, A., Carnell, S., Steinsbekk, S., Fildes, A., & Llewellyn, C. (2021) The association between childhood adiposity and appetite assessed using the Child Eating Behavior Questionnaire and Baby Eating Behavior Questionnaire: A systematic review and meta-analysis. Obesity Reviews, 22(5), e13169. https://doi.org/10.1111/obr.13169

Note. *As this paper is accepted and published, the formatting and layout are consistent with the requirements for Obesity Review, references will not follow the APA style and will be placed at the end of the chapter rather than at the end of the thesis.*

6.1 Abstract

This systematic review and meta-analysis aimed to quantify associations between Child - (CEBQ) and Baby (BEBQ) - Eating Behaviour Questionnaire appetitive traits (food approach: Food Responsiveness [FR], Enjoyment of Food [EF], Emotional Overeating [EOE], Desire to Drink [DD]); food avoidant: Satiety Responsiveness [SR], Slowness in Eating [SE], Emotional Undereating [EUE], Food Fussiness [FF]) and measures of child adiposity. Searches of six databases up to February 2019 identified 72 studies (CEBQ, n=67; BEBQ, n=5), 27 met meta-analysis criteria. For cross-sectional studies reporting unadjusted correlations with BMIz (n=19), all traits were associated with BMIz in expected directions (positive: FR, EF, EOE, DD; negative: SR, SE, EUE, FF). Pooled estimates ranged from r=0.22 (FR) to r=-0.21 (SR). For cross-sectional studies reporting regression coefficients (n=10), three traits (FR, EF, EOE) associated positively, and three traits (SR, SE, EUE) negatively, with BMIz (β=-0.31 [SR] to β=0.22 [FR]). Eleven studies reported prospective relationships from appetite to adiposity measures for six scales (positive: FR, EF, EOE, DD; negative: SR, SE). Five studies reported relationships from adiposity measures to appetite for five traits (positive: FR, EF, EOE; negative: SR). All BEBQ-traits were consistently cross-sectionally associated with adiposity measures. Overall, CEBQ/BEBQ-assessed appetitive traits show consistent cross-sectional relationships with measures of child adiposity.

6.2 Introduction

Behavioural susceptibility theory (BST) was developed to explain how the food environment interacts with genetic susceptibility to influence weight[1,2]. BST proposes that differences in appetite determine why some people over- or under-eat, and others do not, in response to environmental opportunity[3]. Those who inherit genes promoting an avid appetite are vulnerable to overeating and developing obesity, while those who are genetically predisposed to have a smaller appetite and low interest in food are protected, or even at risk of underweight. By identifying these traits and their early precursors we may be able to prevent unhealthy weight trajectories. Twin studies demonstrate that, like body weight[4,5], appetitive traits have a strong genetic basis[6–8], and studies using measured genetic obesity risk indicate that appetite mediates the association between obesity-associated genetic variants and adiposity[9,10].

The Child Eating Behaviour Questionnaire (CEBQ),[11] was developed to test BST nearly twenty years ago. It has since been translated into fourteen languages and has become one of the most widely used psychometric measures of appetitive traits, with the development and validation papers receiving over 1500 citations to date [11,12]. The CEBQ has been used to investigate associations of child eating behaviour with environmental factors (e.g. parent feeding behaviours) as well as genetic factors [13,14]. The CEBQ is a comprehensive 35-item parent-report measure assessing eight appetitive traits. Most of the traits captured by the CEBQ were conceptualised on the basis of existing literature examining dimensions of eating behaviour thought to relate to obesity risk [15]. The CEBQ comprises four ‘food approach’ traits which characterise a larger, more avid appetite and a greater interest in food. Higher scores on these scales indicate a heartier appetite. Four ‘food avoidant’ traits characterize a smaller appetite and lower interest in food. Higher scores on these scales indicate a smaller appetite. Scales from the CEBQ have been validated against behavioural tests of appetite in pre-schoolers[12].The Baby Eating Behaviour Questionnaire (BEBQ) is an infant version of the CEBQ that assesses four of the appetitive traits and has been developed to capture variation in appetitive tendencies during the first six months of life[16].

The first study to explore relationships between CEBQ measured appetitive traits and child adiposity demonstrated that the ‘food approach’ trait, food responsiveness was positively associated, and the ‘food avoidant’ trait satiety responsiveness was negatively associated, with both child BMI and waist circumference [17]. Relationships were linear across the weight spectrum but associations were stronger for waist circumference than for BMI, which could reflect the fact that waist circumference is a more direct measure of adiposity. The main clinical parameters for characterising paediatric body composition draw on weight, height, BMI and waist circumference measures [18]. BMI is not an ideal measure because it reflects relative leg length, body frame size, and fat-free mass in addition to levels of adipose tissue. However, measures such as BMI percentile or BMI z-score remain the most pragmatic and therefore most commonly applied approach for studying variation in paediatric body composition in relation to health outcomes, both at the individual and population level.

Numerous studies have now examined associations between all of the appetitive traits assessed with the BEBQ and CEBQ, and measures of adiposity in infancy and childhood[19–21]. The present inquiry is the first to systematically review and meta-analyse these studies, with the goal of strengthening the evidence base for the relationship between appetite and child adiposity. Rigorous investigation into the relationships between different dimensions of appetite and weight across childhood is needed to evaluate BST – one of the original purposes of the CEBQ and BEBQ. A stronger evidence base for the relationship between appetite and weight in childhood would inform prevention and treatment of overweight and underweight/weight-related disorders, for example, by suggesting behavioural targets for environmental or clinical interventions. Confirmation of the relationship between CEBQ- and BEBQ-assessed appetitive traits and adiposity would support use of these questionnaires to investigate environmental as well as genetic influences on child eating behaviour (e.g. parent feeding behaviours), within a behaviour genetics framework [13]. While other measures have been applied to study relationships between appetite and weight (e.g. Dutch Eating Behaviour Questionnaire [DEBQ])[22], the CEBQ and BEBQ were specifically developed for pediatric use and to assess a broader range of traits implicated in development of both overweight and underweight, and are thus the focus of this review.

The primary objectives of this study were to: (i) conduct a systematic review to assess how CEBQ- and BEBQ-assessed appetitive traits relate to adiposity and prospective weight gain from birth to 18 years; and (ii) establish the size of the associations using meta-analysis.

6.3 Methods

The systematic review and meta-analysis followed the PRISMA reporting guidelines and was registered on PROSPERO (Registration Number: CRD42017081218).

6.3.1 Search strategy and selection criteria

A systematic search of the following six electronic databases was conducted: Medline, EBSCO CINAHL, Cochrane Library, EMBASE, Web of Science and PsycInfo until February 2019. Search terms were developed using combinations of relevant keywords and MESH terms and were searched for within relevant titles and abstracts. The search strategy is outlined in **Appendix E.1.** The reference list for relevant papers was also hand searched to capture any additional studies that were not identified in the search.

Studies were included if they were observational and reported at least one CEBQ- or BEBQ-measured trait. The CEBQ includes eight scales. Four assess ‘food approach’ traits: Enjoyment of Food (4 items; EF; e.g. ‘My child loves food’), Food Responsiveness (5 items; FR; e.g. ‘Given the choice, my child would eat most of the time’), Emotional Overeating (4 items; EOE; e.g. ‘My child eats more when worried’), Desire to Drink (3 items; DD; e.g. ‘My child is always asking for a drink’). Four assess ‘food avoidant’ traits: Food Fussiness (6 items; FF; e.g. ‘My child refuses new foods at first’), Emotional Undereating (4 items; EUE; e.g. ‘My child eats less when he/she is tired’), Slowness in Eating (4 items; SE; e.g. ‘My child eats slowly’), Satiety Responsiveness (5 items; SR; e.g. ‘My child gets full up easily’). The BEBQ assesses FR (5 items; e.g., ‘My baby was always demanding a feed’), EF (4 items; e.g. ‘My baby loved milk’), SE (4 items; e.g. ‘My baby fed slowly’), SR (5 items; ‘My baby got full up easily’) and a single item which correlates with all four scales, 'General appetite' (GA; e.g. 'My baby has a big appetite'). Each item is scored using a 5-point Likert scale (1=never, 2=seldom, 3=sometimes, 4=often, 5=always). Scale scores are means of all scale items. Higher scores indicate more frequent demonstrations of behaviours characterizing the trait. Further details of questionnaire development are published elsewhere[11,16].

In line with the WHO's definition of childhood, the population of interest was children aged <18 years[23], Meta-analysis was planned for all articles with sufficient data on the relationship between any scale (CEBQ or BEBQ) and any measure of adiposity (e.g. BMI z-score, BMI percentile, waist circumference or any measure of body composition). Papers not eligible for quantitative analysis were reviewed narratively, including studies providing quantitative estimates of differences in mean CEBQ or BEBQ scale scores across weight categories (e.g. underweight, healthy weight, overweight and obesity). Studies were excluded from the review if CEBQ/BEBQ scales had been modified from the original format (e.g. reorganizing scales into new dimensions such as 'Appetite Restraint' and 'Appetite Disinhibition'), or they were not published in English and no translation was available (n = 8). Eighteen studies incorporated modifications to one or more scales. As multiple studies (n=6) combined SR and SE into one composite scale these observations were retained in the narrative review. Study eligibility was assessed independently by two reviewers (AS and AK), and disagreements discussed until consensus was reached. See **Table 6.1-Table 6.5** for a summary of the study characteristics.

6.3.2 Data extraction and quality assessment of included studies

Descriptive data on the study characteristics, appetitive traits measured, adiposity measure used, and effect estimates of the relationship between appetitive traits and adiposity were extracted by two reviewers (AK and AS). Degree of adjustment for the reported effect estimates varied across studies. Both crude and the maximally adjusted values were extracted (i.e. the reported effect estimates within the individual study adjusted for the most covariates). For duplicate cohorts, the most complete study was taken forward (based on the greatest number of appetitive scales reported or highest n). Where necessary, authors were contacted to request additional information (n=45, e.g. authors provided specific correlation or regression coefficients for individual subscales when not specifically reported in the main manuscript).

Risk of bias was assessed and cross-checked by two reviewers (AK and AS). An overall risk of bias score was obtained using the semi-quantitative Newcastle Ottawa Scale (NOS). The NOS assesses three main areas of study quality, namely 1) the selection of the cohort, 2) the comparability of study analysis, and 3) the ascertainment of the outcome. The NOS tool was adapted as necessary to assess the quality of the included study designs. A NOS score $\geq$7/10 was considered indicative of high study quality (see **Appendix E.2**[24]).

6.3.3 Data synthesis for meta-analysis

Studies were classified based on whether effect estimates of associations between appetitive traits and adiposity measures were reported as correlation coefficients (r) and/or standardized regression coefficients (β). These measures were selected because they were most commonly reported. In order to utilise adiposity measures, a minimum of three studies was needed to pool effect estimates[25]. Therefore, only BMI z-scores (BMIz) were used in the meta-analytical models as insufficient data existed for other outcomes (e.g. body composition (n=3), weight-for-age (n=1))[26].

There were insufficient data to meta-analyse prospective studies, due to high heterogeneity in outcome measures and follow-up time (see **Table 6.3**), or studies using the BEBQ, due to variation in reported weight outcomes (see **Table 6.5**).

6.3.4 Statistical analysis for meta-analysis

Random effects meta-analysis using data from eligible studies was performed to approximate an overall pooled weighted mean effect estimate[25]. The random effects model was used to account for anticipated inter-study variance.

Meta-analytic models for unadjusted correlation coefficient effect estimates with BMIz were conducted. In addition, analyses stratified by level of adjustment were undertaken to assess whether the pooled effect size was sensitive to adjustment strategy.

Assessment of between-study heterogeneity was judged by the p-value for heterogeneity and calculation of the I^2 values. Moderate between-study heterogeneity was considered >50% for I^2 with levels of 75% deemed indicative of high inconsistency in approximation of the summarised effect size[27]. Subgroup analyses explored potential heterogeneity by age of participant or year of publication. Publication bias was assessed by funnel plot and Egger's test; a p value of <.01 was considered sufficient evidence of no publication bias[28].

Statistical analyses were performed using Stata v15 with a p-value of <.05 considered significant.

6.4 Results

6.4.1 Literature search

A total of 2416 papers were retrieved; 1338 remained after duplicate removal. 72 independent studies were eligible for inclusion in the final review (See **Figure 6.1)**. 67 studies explored relationships between CEBQ scales and adiposity (n=54 cross-sectional, n=12 prospective) and five relationships between BEBQ scales and adiposity (n=1 cross-sectional, n=4 prospective). Five CEBQ prospective studies also examined cross-sectional relationships between appetitive traits and adiposity; these results are discussed separately.

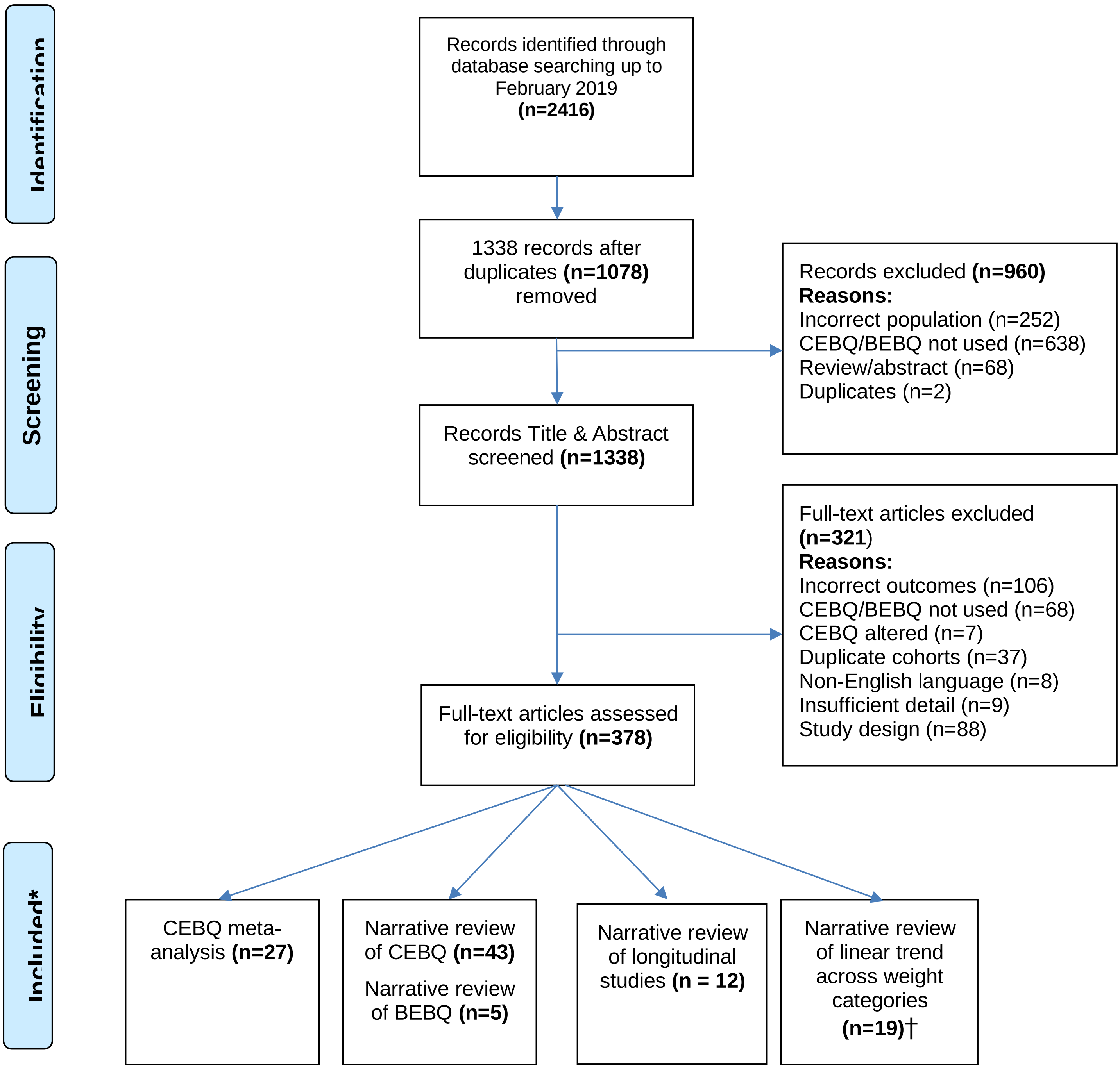


Figure 6.1. PRISMA flow diagram describing identification of literature for inclusion in this systematic review and meta-analysis.

***Outcome categories for CEBQ studies do not add up to n=67 as outcome categories are not mutually exclusive.**

† Eight of these studies were additionally included in the narrative review of CEBQ studies. Abbreviations: SR = Systematic review

6.4.2 Characteristics of included studies

6.4.2.1 CEBQ studies (n=67)

Study descriptives are in **Table 6.1, Table 6.2, and Table 6.3**. Sample sizes ranged from n=37[29] to n=10,364[6]. All samples were mixed sex, with ages from 1 month[30] to 13 years[31,32]. Most studies used the English language version of the CEBQ (n=40). Seventeen studies provided data on all 8 CEBQ scales, while the remaining studies reported on a reduced subset of the scales (n=50). Various measures of adiposity were reported including BMI z-scores (n=45), BMI percentile (n=5), BMI (n=3), weight (n=1), body fat percentage (n=1), and weight-for-age z-scores (n=2), and two studies used multiple measures of adiposity (body fat percentage, muscle mass, and BMI z-score) [20,33]. Study quality was inconsistent; 23 were rated as poor on the NOS scale, and among these, two included separate ratings for sub cohort data which were deemed of higher quality[34,35] **(Table E.2)**

6.4.2.2 BEBQ studies (n=5)

Five studies reported BEBQ data. Samples varied from n=31[36] to n=4804[37]. The BEBQ is designed for use with infants, explaining the younger age range observed (0 - 24 months of age). All studies used the English version of the BEBQ, with most studies reported for all four BEBQ scales (n=4). Four studies elicited parent-reports of current appetitive traits, whilst one study used a combination of current and retrospective reports for the first 3 months of life[37]. With respect to outcome measures, three studies reported BMI and two BMI z-scores. Four studies were rated high quality based on the NOS criteria (see **Table S2**), with only one study rated lower quality[36].

Table 6.1. Summary characteristics for cross-sectional CEBQ studies (n=43) included in narrative review.

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	**N, gender %**	**Age range/ mean (SD±)**	**Sub-scales**	**Language**	**Measure (reference data)**	**Positive**	**Negative**	**None**
Carnell & Wardle, 2008 [a 6]	UK	TEDS & Community sample	10364, 51.5% F; 572, 46.9% F	8-11 (9.9 ±0.86), 3-5 (4.4±0.62)	EF, SR/SE (combined)[g]	English	BMI z-scores (UK 1990 data)	EF	SR/SE	-
Cao, 2012 [38]	China	Community sample	219, 47.9% F	12-18m	EOE, DD[h]	Chinese (Mandarin) [f]	BMI z-scores (Chinese ref data)	-	-	EOE, DD
Bergmeier, 2014 [34]	Australia	Community sample	201, 57.7% F	2-5y (2.92 ±0.75)	FF, EF	English	BMI z-scores (CDC)	EF	-	FF
Boswell, 2018 [a 39]	Australia	Community sample	977, 50.6% F	2-4.9y (3.4 y)	FR, EF, SR, SE, FF	English	BMI z-scores (CDC)	FR, EF	SR, FF	SE
Braden, 2014[b 40]	USA	Community sample	106, 54.7% F	8-12 (10.34 ±1.31)	EOE	English	BMI percentile (CDC)	-	-	EOE
Brown, 2012 [41]	Wales	Community sample	298, NP	18-24m	FR, SR	English	Weight	-	-	FR, SR
Cross, 2014 [a, b, 42]	USA	Community sample	299, 50.3% F	4-5 y	FR, EF, SR	English	BMI z-scores (CDC)	FR, EF	SR	
Demir, 2017 [43]	Turkey	Primary school children	1201, (NP)	6-14 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Turkish	BMI (WHO)	FR, EOE, EF	SR, FF	DD, EUE, SE
Domoff, 2015 [a, b 44]	USA	Appetite, Behavior, and Cortisol [ABC] Cohort + "Growing Healthy" cohort	1002, 50.7% F	4.05 y (0.53±)	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI z-scores (CDC)	FR, EF, EOE	SR, SE, EUE, FF	DD
Emond, 2017 [a, b 45]	USA	Community sample	178, 51.1% F	9-10 y	FR, EF, SR	English	BMI z-scores (CDC)	EF, FR	SR	-

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Escobar, 2014 [a, b, d 46]	Canada	MAVAN	340, 50% F	48-72m	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI z-scores	FR, EF, DD, EOE	SR, FF, EUE	SE
Frankel, 2014 [a 47]	USA	Head Start Cohort	296, 51% F	4.42 (±0.71)	SR, FR, EF	English + Spanish) [f]	BMI z-scores (CDC)	FR, EF	SR	
Fuemmeler, 2013 [a, b 48]	USA	AMP Too for Twos	213, 44% F	2.1 (±0.11)	FR, EF, DD, SR/SE[g]	English	BMI z-scores (CDC)	FR, EF, DD	SR/SE	-
Gregory, 2010 [a 49]	Australia	The Child & Family Health Study	156, 51% F	2-4 y; 3.3 (±0.8)	FR[i]	English	BMI z-scores (CDC)	FR	-	-
Hankey, 2016 [a 50]	USA	Community sample	104, 51% F	3-5 y	SR, FR, EF, EOE	English	BMI z-scores (CDC)	FR, EF	SR	EOE
Hardman, 2016 [a, b 51]	UK	Community sample	77, 51% F	3-12 y	EOE	English	BMI z-score (WHO)	EOE	-	-
Haycraft, 2011 [a, b 52]	UK	Community sample	241, 45% F	3-8 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI z-scores (CGF)	FR, EOE, DD	SE	SR, EUE, FF, EF
Hayes, 2016 [a 53]	USA	Family- based behavioural treatment	170, 61.2% F	7-11 y (9.41 ±1.23)	FF	English	BMI z-scores (CDC 2000)	-	-	FF
Jansen, 2012 [a 54]	Netherlands	Generation R cohort	4987, 49.9% F	4 y	FR, EF, EOE, DD, SR, FF, EUE	Dutch [f]	BMI z-scores (Dutch national data)	FR, EF	EUE, SR, FF	EOE, DD
Koch, 2014 [a 55]	Germany	PIER cohort	1657, 52.1% F	6-11 y	FR, EF, EOE, DD	German	BMI z-scores (German national data)	FR, EOE, DD, EF	-	-
Larsen, 2017 [a 56]	Netherlands	School-based sample	206, 50.5% F	7-12 y (9.5 ±1.4)	FR	Dutch [f]	BMI z-score (Dutch national data)	FR	-	-

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Lipowska, 2018 [57]	Poland	Community sample	387, 55.1% F	5 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Polish	BF%	Girls: FR (BF%) Boys: EOE (BF%)	Girls: SR (BF%) Boys: EUE (BF%)	-
Loh, 2013 [a] [31]	Malaysia	Community sample	646, 73.2% F	13 y	FR, EF, EOE, DD, EUE, SE[j]	Malay [f]	BMI z-scores (IOTF)	-	-	EF, EOE, FR, DD, EUE, SE
Lora, 2016[b] [58]	USA	Community sample	110, 53.6% F	2-5 y	FR, EF, DD	English + Spanish	BMI percentile (CDC)	-	-	FR, EF, DD
Mallan, 2013[e] [35]	Australia	NOURISH cohort	244, 52% F	24 m (1±)	FR, EF, EOE, DD, SR, SE, FF, EUE	English	Weight-for-age z-scores (WHO)	-	SR, SE	FF, EUE, FR, EF, DD, EOE
McPhie, 2011 [a] [59]	Australia	Community sample	175, 53.7% F	2-5 y (2.83 ±0.72)	FF	English	BMI z-scores (IOTF)	-	-	FF
Parkinson, 2010 [60]	UK	Gateshead Millennium Study	492 (T1), 583 (T2), 50% F	5-8 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI	FR, EF	SR, SE, EUE	DD, EOE, FF
Pesch, 2018 [61]	USA	Community sample	223, 47.5% F	4-8y	FR, EF, SR [k]	English	BMI z-scores	FR, EF	SR	-
Quah, 2017 [a, b] [62]	Singapore	GUSTO	636, 47.8% F	3.06 (±0.1)	SR, SE, DD, EUE, FF[l]	English	BMI z-scores (WHO 2006)	-	SR, SE, EUE	DD, FF
Roach, 2017 [63]	USA	The Healthy Family Study	64, 44.3% F	3-6 y	FR, EF, EOE, SR.	English	BMI z-scores (CDC)	FR, EOE, EF	SR	-
Rudy, 2016 [a] [64]	USA	Pre-school sample	181, 48.1% F	4-5 y	FR, SR, EF	English + Spanish [f]	BMI z-scores (CDC)	FR, EF	SR	-
Sanchez, 2016 [a, b] [65]	Chile	GOCS cohort	1058, 51% F	7-10 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Chilean-Spanish [f]	BMI z-scores (WHO)	EF, EOE, FR, DD	SR, SE, FF	EUE

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Silva Garcia, 2016 [a, b 66]	USA	Community sample	186, 47.6% F	4-5 y (4.34 ±0.48)	FR, EF, EOE, DD, SR, SE, FF, EUE	English & Spanish	BMI z-scores (CDC)	FR, EF	SR, SE	EOE, DD, FF, EUE
Sleddens, 2008 [a 67]	Netherlands	School-based sample	135, 49.6% F	6-7 y	EF, SR, SE, FF[m]	Dutch [f]	BMI z-scores (Dutch national data)	EF	SR, SE	DD, EUE
Somaraki, 2018 [68]	Sweden	Swedish Population Registry	Cohort 1: 876,	3-8 yrs	FR, EF, EOE, DD, SR, SE, FF, EUE	Swedish	BMI z-scores (IOTF)	Results stratified by country of origin (n = 74). See original paper for full details.		
		Community sample	Cohort 2: 353,	3-8 yrs						
		Childhood obesity RCT	Cohort 3: 147,	3-8 yrs						
Soussigan, 2012 [a, b 69]	France	Community sample	40, 45% F	6-11 y	FR, EOE, DD, SR, SE	French	BMI z-scores (IOTF)	FR, DD	SR, SE	EOE
Svensson, 2011 [70]	Sweden	Early STOPP cohort	174, 50% F	1-6 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Swedish [f]	BMI z-scores (French ref data)	-	-	FR, EF, EOE, DD, EUE, FF, SE, SR
Tay, 2016 [a, b 71]	Malaysia	SEANUTS	1782, 51.4% F	7-12 y	DD, EUE, FF, SE, SR[n]	Malaysian [f]	BMI z-scores (WHO)	DD	SR, SE, FF, EUE	-
Viana, 2008 [a 32]	Portugal	Convenience sample	240, 52% F	3-13 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Portuguese [f]	BMI z-scores (CDC)	FR, EF, EOE	SE, SR, EUE	DD, FF
Vollmer, 2015 [a, b 72]	USA	Preschool children	150, 45% F	3-5 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI z-scores (CDC)	FR, EOE	SR	EF, DD, SE, EUE, FF
Webber, 2009 [a, b 73]	UK	PEACHES	270, 49% F	7-9 y	FR, EF, EOE, DD, SR/SE, FF, EUE[g]	English	BMI z-scores (UK 1990 data)	FR, EOE, EF, DD	SR/SE, FF	EUE

Author, date	Country	Participants			CEBQ measure		Outcome: weight	CEBQ traits associated with adiposity measures		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
McCarthy, 2015[b, c] [74]	Ireland	The Cork BASELINE birth cohort	1189, 50% F	2 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI percentiles (WHO)			
Sanlier, 2016[c] [75]	Turkey	Community sample	520, 49% F	2-12 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Turkish	BMI z-scores (WHO)			

Abbreviations: N = Population; SD = Standard Deviation; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EOE = Emotional over-eating; DD = desire to drink; EF = Enjoyment of food; EUE = Emotional under-eating; SE = Slowness in eating; FF = Food fussiness; CDC = Centre for Disease Control; WHO = World Health Organisation; IOTF = International Obesity Task Force; CGF = Child Growth Foundation Reference curves 1996; NP = Not provided; N = Number; y = years. **Cohort acronyms:** Generation R = A population-based birth cohort in the Netherlands followed prospectively; PEACHES = Physical Exercise and Appetite in Children Study; TEDS = Twins Early Development Study; FBBT = Family Based Behavioural Treatment; NOURISH = Intervention/ Randomised Controlled Trial designed to educate paternal feeding practices and promote healthier food intake; The Cork BASELINE Birth Cohort Study = Babies After SCOPE: Evaluating the Longitudinal Impact on Neurological and Nutritional Endpoints Birth Cohort Study; GMS = Gateshead Millennium Study; GOCS = Growth and Obesity Chilean Cohort Study; TESS = Trondheim Early Secure Study; Healthy You! University of Minnesota Masonic Children's Hospital Pediatric Weight Management Clinic; ABCD = Amsterdam Born Children and their Development cohort.

[a] Indicates studies included in the meta-analysis

[b] Indicates studies for which authors provided additional data.

[c] Indicates studies where data were analysed using logistic regression, and the results were presented as odds ratios.

[Sanlier et al (2018) used multiple logistic regression models for the association between CEBQ scales and BMI z-scores, stratified by weight status: FF was significant negatively associated in the overweight (B = -.54, p=.01) and obese weight category (B = -.058, p<.01). EF was significantly positively associated (B = .65, p=.04) in the normal weight category. All other traits were null associations. McCartney et al. (2015) reported odds ratio (OR) for overweight/obesity by CEBQ traits; EF (OR =1.90, 95% confidence interval (CI)=1.46–2.48), FR (OR=1.73, 95% CI=1.47–2.03; all p<0.001), SR (OR=0.56, 95% CI = 0.43-0.73; p<.001), SE (OR = 0.57, 95% CI = 0.45, 0.73; p<.001), FF (OR = 0.70, 95% CI = 0.56-0.88; p=0.002). EUE, EOE, DD not significant.]

[d] Escobar et al (2014) data presented in the table are for baseline results at 48 months.

[e] Data reported in Mallan et al (2014) were taken from both the intervention and control groups of NOURISH. The intervention group received education sessions aimed to improve parental feeding practices and influence infants' food intake and eating habits. It is therefore important to note that the results presented could be influenced by the effect of intervention.

[f] Denotes validated translated versions of the CEBQ.

Modifications to CEBQ subscales (scales that were modified from original format were excluded from review)**

[g] SR + SE combined

[h] FR split into two scales. One SE item dropped. 3 FF items dropped. SR dropped.

[i] FF scale split into two

[j] FF split in two, with 2 SR items added in FF1

[k] SR reverse scored

[l] FR, EOE and EF subscales changed.

[m] EOE+FR combined to new EOE scale

[n] 1 item dropped from EOE & items moved from EOE, EF into FR

Table 6.2. Summary characteristics for cross-sectional studies comparing mean CEBQ scale scores across weight categories and testing for linearity of trends (n=19)

Author, date	Country	Participants			CEBQ measure		Outcome: weight	
		Cohort	N, Gender % F	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Weight categories used
Carnell & Wardle, 2008 [a, b]	UK	TEDS & Community sample	10364, 51.5% F; 572, 46.9% F	8-11 (9.9 ±0.86), 3-5 (4.4 ±0.62)	EF, SR/SE (combined)[e]	English	BMI z-scores (UK 1990 data)	Low-normal, mid-norm, high, very high
Boswell, 2018 [a, b]	Australia	Community sample	977, 50.6% F	2-4.9y (3.4 y)	FR, EF, SR, SE, FF	English	BMI z-scores (CDC)	UW, NW, OW, OB
Croker, 2011 [76]	UK	PEACHES & TEDS; FBBT sample	406, 54% F; 66, 68% F	7-12 y; 8-13 y	FR, EF, EOE, DD, SR/SE, FF, EUE[e]	English	BMI z-scores (UK 1990 data)	UW, NW, OW, OB, Clinically OB
de Groot, 2017 [77]	Netherlands	Community sample	44, 50%	12-16y	FR, SR, EF, EOE, DD	Dutch	BMI-SDS (NP)	NW, OW
dos Passos, 2015 [78]	Brazil	Community sample	335, 51.3% F	6-10 y (7.33 ±0.87)	FR, EF, EOE, DD, SR, SE, EUE, FF	English	BMI z-scores (WHO)	NW, OW, OB, Severe OB
Gardner, 2015 [79]	USA	Community sample	64, 49.4% F)	5-6 y	FR, EF, SR	English	BMI-for-age percentile (CDC 2000)	NW, OB
Ho-Urriola, 2014 [80]	Chile	Community sample	377, 51.3% F	6-12 y (10.1 ±2)	FR, EF, EOE, DD, SR, SE, EUE, FF	Chilean	BMI percentiles (CDC 2000)	NW, OB
Jahnke, 2008 [81]	Germany	Community sample	142, 36% F	3-6 y (4.2 ±1)	FR	German	BMI z-scores (German national data)	UW, NW, OW, OB
McCarthy, 2015 [a, b 74]	Ireland	The Cork BASELINE birth cohort	1189, 50% F	2 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI percentiles (WHO)	UW, NW, OW/OB
Mosli, 2015 [82]	USA	Community sample	274, 49.3% F	4-8 y	SR, SE, FF	English	BMI percentiles (CDC 2000)	NW (<85th), OW/OB (85th>)

Author, date	Country	Participants			CEBQ measure		Outcome: weight	
		Cohort	N, Gender % F	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Weight categories used
Obregon, 2017 [83]	Chile	Community sample	258, 44% F	8-14 y (11.4 ±1.6)	FR, EF, EOE, DD, SR, SE, EUE, FF	Chilean	BMI percentiles (CDC 2000 + WHO 2006)	NW, OW, OB
Parkinson, 2010 [a, b, c]	UK	Gateshead Millennium Study	492 (T1), 583 (T2), 50% F	5-8 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI	BMI centile lowest, middle, highest
Powers, 2006 [84]	USA	Community sample	296,48% F	2-5y	FR[f]	English	BMI z-scores (CDC)	UW, NW, at-risk for OW, OW
Sanchez, 2016[a, b] [65]	Chile	GOCS cohort	1058, 51% F	7-10 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Chilean-Spanish[d]	BMI z-scores (WHO)	NW, OW, OB
Soussigan, 2012 [a, b] [69]	France	Community sample	40, 45% F	6-11 y	FR, EOE, DD, SR, SE	French	BMI z-scores (IOTF)	NW, OW
Spence, 2011 [85]	Canada	Community sample	1730, 48.9% F	4-5 y	FR, EF, EOE, DD, SR, SE, FF, EUE	English	BMI (CDC + IOTF classification)	UW, NW, at-risk for OW, OW
Webber, 2009[a, b] [73]	UK	PEACHES	270, 49% F	7-9 y	FR, EF, EOE, DD, SR/SE, FF, EUE[e]	English	BMI z-scores (UK 1990 data)	Thinness grade 1/2, low NW 50th centile or less, mid normal weight >50th but not OW, OW/OB
Sandvik, 2018 [86]	Sweden	Swedish Registry sample	1272, 47% F	3.3-7.9y (4.9 ±0.8)	FR, EF, EOE, DD, SR, SE, FF, EUE	Swedish	BMI z-scores (IOTF)	Thinness (BMI <18.5kg/m^2), NW, OW, OB
Sanlier, 2016 [c] [75]	Turkey	Community sample	520, 49% F	2-12 y	FR, EF, EOE, DD, SR, SE, FF, EUE	Turkish	BMI z-score (WHO)	UW, NW, OW, OB

[a] Indicates studies also reporting continuous associations between CEBQ and adiposity; these are included in this section of the narrative review.
[b] Indicates studies included in the meta-analysis.
[c] Indicates the study also reporting prospective association between CEBQ and adiposity.
[d] Denotes validated translated versions of the CEBQ.
[e] SR + SE combined
Modifications to CEBQ subscales (scales that were modified from original format were excluded from review)**
[f] DD item dropped
Abbreviations: N = Population; SD = Standard Deviation; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EOE = Emotional over-eating; DD = desire to drink; EF = Enjoyment of food; EUE = Emotional under-eating; SE = Slowness in eating; FF = Food fussiness; CDC = Centre for Disease Control; WHO = World Health Organisation; IOTF = International Obesity Task Force; NP = Not provided; y = years;

Author, date	Country	Participants			CEBQ measure		Outcome: weight	
		Cohort	N, Gender % F	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Weight categories used

Cohort acronyms: TEDS = Twins Early Development Study; GOCS = Growth and Obesity Chilean Cohort Study; PEACHES = Physical Exercise and Appetite in Children Study; FBBT = Family Based Behavioural Treatment

Table 6.3. Summary characteristics for prospective studies examining associations between CEBQ scales at baseline and later adiposity (n=11)

Author, date	Country	Participants			CEBQ measure		Outcome: adiposity measure	Associations between CEBQ scales and later adiposity (CEBQ → adiposity)		
		Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Significant Positive	Significant Negative	Null
Mallan, 2016[a 87]	Australia	NOURISH	340, F 53.5%	14m - 3.7y	FF	English	BMI z-scores (WHO)	-	FF	-
Mallan, 2014[a 88]	Australia	NOURISH	37[f] (Control n=20, Intervention n =17), 57% F	2-4 y	FR, EF, SR, SE	English	BMI z-scores (WHO)	-	SR	FR, EF, SE
McPhie, 2012[b 89]	Australia	Community sample	117, F 53.8%	2-5 y	FF[i]	English	BMI z-scores (CDC)	-	-	FF
Quah, 2015[c 19]	Malaysia	GUSTO	210 (T2 = 205, T3 = 162, T4 = 179), F 49.5%	12-24m	SR, SE[j]	Malaysian[h]	BMI z-scores (WHO)	-	-	SR, SE
Steinsbekk, 2015 [90]	Norway	TESS	996 (T1=4y) 658 (T2=6y) 675 (T3=8y)	4-8 y	FR, EF, EOE, SR, SE	Norwegian[h]	BMI z-scores	FR, EF, EOE	SR, SE	-
Derks, 2018[d 20]	Netherlands	Generation R	3514, (T1- 4y) 3097, (T2- 6y) 3331, (T3- 9.8y), F 51.3%	4-10 y	FR, EOE, EF, SR/SE[k]	Dutch[h]	BMI z-scores, FMI, FFMI (Dutch growth reference curves)	EOE	-	FR, EF, SR

Steinsbekk, 2017[d, e] [33]	Norway	TESS	807, F 50.2%	6-10 y	FR, SR	Norwegian[h]	BF%, MM%	FR (BF%)	SR (BF%)	-
Bjorklund, 2018[e] [91]	Norway	TESS	797 (T1 - 6.7y) 699 (T2 - 8.8y) 702 (T4 - 10.5y), F 50.2%	6-10 y	FR	Norwegian[h]	BMI z-scores	FR	-	-
Bergmeier, 2014 [34]	Australia	Community sample	201, F 56.7%	2-5 y	FF, EF	English	BMI z-scores (CDC)	-	-	FF, EF
Escobar, 2014[e, f, g] [46]	Canada	MAVAN	340 (48m), 278 (60m), 221 (72m), F 54.1%	48-72m	FR, EOE, DD, EF, EUE, SE, SR, FF	English	BMI z-scores	FR, EF, DD, EOE	SR, SE	FF, EUE
Parkinson, 2010 [60]	UK	GMS	492 (5-6y) 583 (6-8y)	6-8 y	FR, EOE, DD, EF, EUE, SE, SR, FF	English	BMI percentiles (Cohort mean)	FR, EOE, EF, DD	SR, SE	EUE, FF

Abbreviations: N = Population; SD = Standard Deviation; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EOE = Emotional over-eating; DD = desire to drink; EF = Enjoyment of food; EUE = Emotional under-eating; SE = Slowness in eating; FF = Food fussiness; CDC = Centre for Disease Control; WHO = World Health Organisation; IOTF = International Obesity Task Force; NP = Not provided; y = years; FMI = Fat Mass Index, FFMI = Fat Free Mass Index.
Cohort acronyms: Generation R = A population-based birth cohort in the Netherlands followed prospectively; NOURISH = Intervention/ Randomised Controlled Trial designed to educate paternal feeding practices and promote healthier food intake GMS = Gateshead Millennium Study; TESS = Trondheim Early Secure study; ABCD = Amsterdam Born Children and their Development cohort

[a] Data for Mallan et al (2014, 2016) were taken from both the intervention and control groups of NOURISH. The intervention group received education sessions aimed to improve parental feeding practices and influence infants' food intake and eating habits. It is therefore important to note that the results presented could be influenced by the effect of intervention.
[b] EF subscale result reported in paper, but subscale coding was modified in McPhie et al (2012). Results for EF have been excluded. Association between FF and BMI z-score in this study are based on change in FF with change in BMI z-score.
[c] Quah et al (2015) merged the FR & EF subscales, these observations have been excluded from the table above.
[d] Indicates studies that reported on the bidirectional relationship between appetite and adiposity.
[e] When multiple time waves of data are presented at the individual study level, the longest time period is summarised in the table above.
[f] Authors provided additional data.
[g] Prospective associations presented for the MAVAN cohort (Escobar et al, 2014) are based on additional data obtained from the study authors for all CEBQ subscales (results presented are for BMI z-score at 48m to CEBQ measured at 72 m).
[h] Denotes validated translated versions of the CEBQ.
Modifications to CEBQ subscales (scales that were modified from original format were excluded from review)**
[i] EF item dropped from scale
[j] FR and EF subscales adapted

[k] SR/SE combined

Table 6.4. Summary characteristics for CEBQ prospective studies (n=5) reporting on relationship between adiposity and later appetite

Author, date	Country	Direction	Participants			CEBQ measure		Outcome: adiposity measure (reference data)	Adiposity associated with CEBQ		
			Cohort	N, gender %	Age range	Sub-scales	Language		Positive	Negative	None
Steinsbekk, 2015 [90]	Norway	**BMI → CEBQ**	TESS	996 (T1=4y) 658 (T2=6y) 675 (T3=8y)	4-8 y	FR, EF, EOE, SR, SE	Norwegian[c]	BMI z-score	FR	SR	EF, SE, EOE
Steinsbekk, 2016 [92]	Norway	**BMI → CEBQ**	TESS	797[k], 50.2% F	6-8 y	FR, EF, EOE, SR, SE	Norwegian[c]	BMI z-scores	FR	SR	EF, SE, EOE
Derks, 2018[d] [20]	Netherlands	**BMI → CEBQ**	Generation R	3514, (T1- 4y) 3097, (T2- 6y) 3331, (T3-9.8y), F 51.3%	4-10 y	FR, EOE, EF, SR/SE[f]	Dutch[c]	BMI z-scores, FMI, FFMI (Dutch growth reference curves)	FR, EOE, EF	SR	-
Steinsbekk, 2017[d] [93]	Norway	**BF% → CEBQ**	TESS	807, F 50.2%	6-10 y	FR, SR	Norwegian[c]	BF%, MM%	FR (BF%)	SR (BF%)	-
van Deutekom, 2016[a, b] [30]	Netherlands	**Δweight-for-age z-score → CEBQ**	ABCD	2227, F 48.7%	0-5 y	SR	Dutch[c]	Weight-for-age z-scores (Study population)	-	SR 0-1m, 1-3m, 3-6m, 6-12m, 12-5 y.	Birth weight

Abbreviations: N = Population; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EOE = Emotional over-eating; DD = desire to drink; EF = Enjoyment of food; EUE = Emotional under-eating; SE = Slowness in eating; FF = Food fussiness; y = years; FMI = Fat Mass Index, FFMI = Fat Free Mass Index.
Cohort acronyms: Generation R = A population-based birth cohort in the Netherlands followed prospectively; TESS = Trondheim Early Secure study; ABCD = Amsterdam Born Children and their Development cohort

[a] van Deutekom et al (2016) reported on the relationship of conditional weight gain to SR.
[b] Authors provided additional data.
[c] Denotes validated translated versions of the CEBQ.
[d] Indicates studies that reported on the bidirectional relationship between adiposity and appetite.
[f] SR/SE combined

Table 6.5. Summary characteristics for BEBQ cross-sectional and prospective studies (n = 5) included in the narrative review.

Author, date	Country	Design	Participants			BEBQ measure		Outcome: weight	BEBQ traits associated with weight		
			Cohort	N, gender %	Age range/ mean (SD±)	Sub-scales	Language	Measure (reference data)	Positive	Negative	None
Mallan, 2014	Australia	Prospective	New Beginnings: Healthy Mothers and Babies Study	467, F 50%	4 m (±0.6)	FR, EF, SE, SR	English	BMI, Weight-for -age z-score (WHO)	EF	SR, SE	FR
Quah, 2015	Singapore	Prospective	GUSTO	210, F 50.5%	0-24 m	EF, FR, SE/SR[a]	English	BMI z-scores (WHO)	FR	SE/SR	EF
Shepard, 2015	USA	Prospective	Community	31, F 39%	0.5-5 m	EF, FR, SE, SR, GA	English	BMI z-scores (WHO)	EF, FR, GA	SE	SR
van Jaarsveld, 2011	UK	Prospective	Gemini	4804, F 50.3%	3-15 m/8.2 m (±2.2)	EF, FR, SE, SR, GA	English	BMI z-scores (UK 1990 data)	EF, FR, GA	SR, SE	-
Patel, 2018	UK	Cross-sectional	UPBEAT	353	6 m	SE, FR, EF, GA	English	BMI z-scores (WHO)	GA	-	SE, FR, EF

Abbreviations: N = Population; SD = Standard Deviation; BMI = Body Mass Index; F = female; FR = Food responsiveness; SR = Satiety responsiveness; EF = Enjoyment of food; SE = Slowness in eating; GA = General Appetite; WHO = World Health Organisation; m = months
Cohort acronyms: GUSTO = Growing Up in Singapore Toward healthy Outcomes, UPBEAT = UK Pregnancies Better Eating and Activity Trial.

[a] SR + SE combined

6.4.3 Meta-analyses of cross-sectional CEBQ studies (n=27)

In a random effects meta-analysis model, mean bivariate correlation coefficients for associations between the eight CEBQ scales and BMIz were combined (n=19 maximum). All estimates were significant and in expected directions; food approach scales (FR, EF, EOE, DD) were correlated positively, and food avoidant scales (SR, SE, FF, EUE) were negatively, with BMIz. All associations were small in size[94]. The largest associations were observed between FR and BMIz r=0.22 (95% CI: 0.16, 0.29; I^2=88.0%; n=9463), and between SR and BMIz r= -0.21 (95% CI: -0.24, -0.17; I^2=56.7%; n=9854). Detailed summaries of the pooled effect estimates and their 95% CIs, for each CEBQ scale, are shown in **Table 6.6** and **Figure 6.2.**

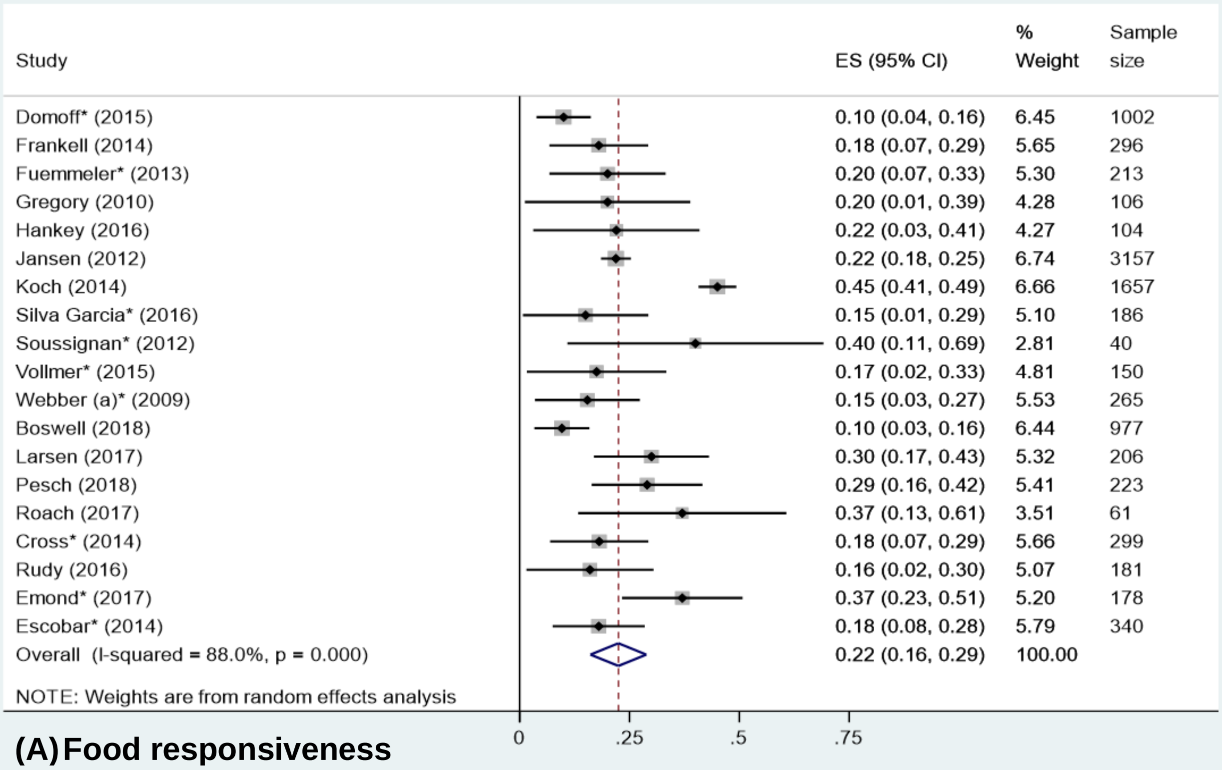
Table 6.6. Results from random effects meta-analysis of studies examining correlation of CEBQ scales with BMI z-scores (only unadjusted correlation coefficients[a])

CEBQ scale	r	95 % CI	I^2 (%)	P-value for heterogeneity	Sub-cohorts (n)	n
FR	**0.22**	(0.16, 0.29)	88.0	0.00	19	9463
EF	**0.17**	(0.14, 0.20)	49.4	0.00	19	20416
EOE	**0.15**	(0.08, 0.22)	82.9	0.00	11	7038
DD	**0.10**	(0.04, 0.15)	82.9	0.00	10	9219
SR	**-0.21**	(-0.24, -0.17)	56.7	0.00	17	9854
SE	**-0.15**	(-0.21, -0.10)	64.8	0.00	8	5192
FF	**-0.08**	(-0.10, -0.06)	0.00	0.99	11	8855
EUE	**-0.09**	(-0.11, -0.06)	8.00	0.37	7	7330

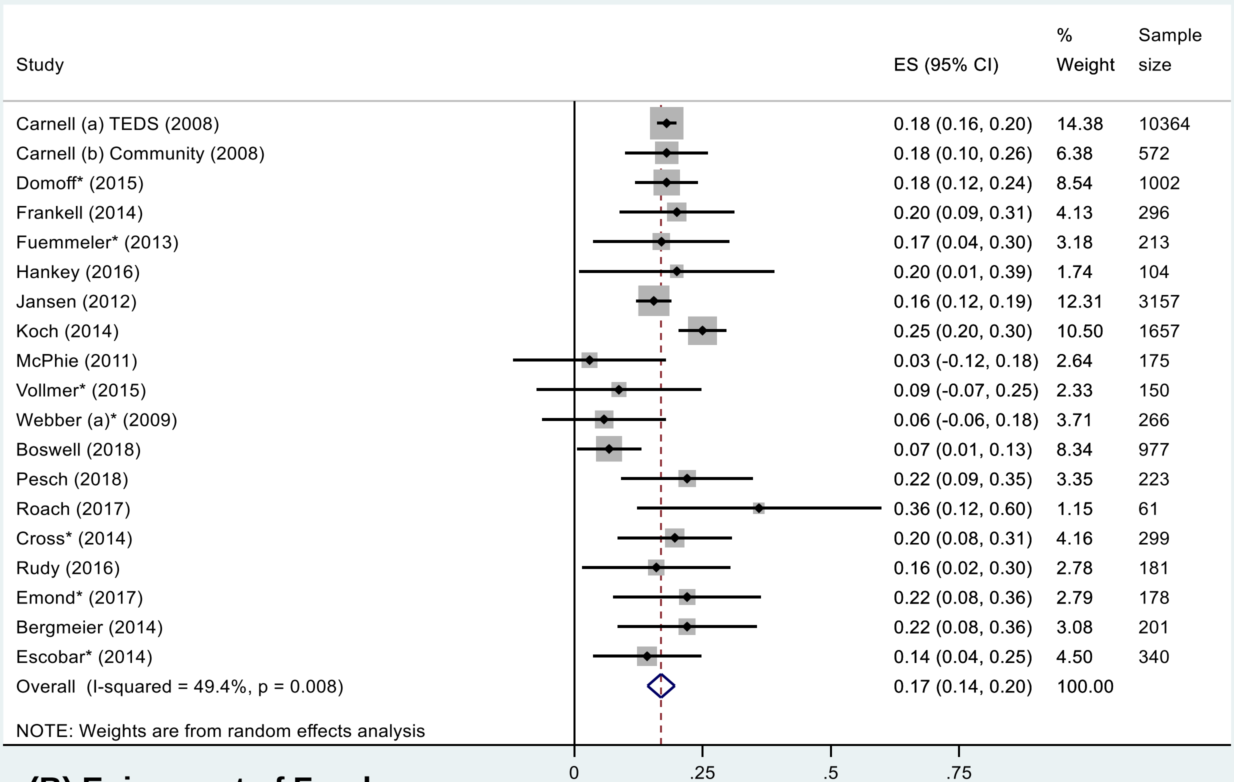
[a]Data for Haycraft et al (2011) were reported as adjusted in the original study. Authors provided raw data to calculate the unadjusted correlation coefficients, and these were subsequently were pooled in the model presented above.

Statistically significant estimates have been **bolded.**

Figure 6.2. Pooled effect estimates for unadjusted correlation coefficients for with BMI z-scores, by Child Eating Behaviour Questionnaire (CEBQ) scale. (Parts A-H).

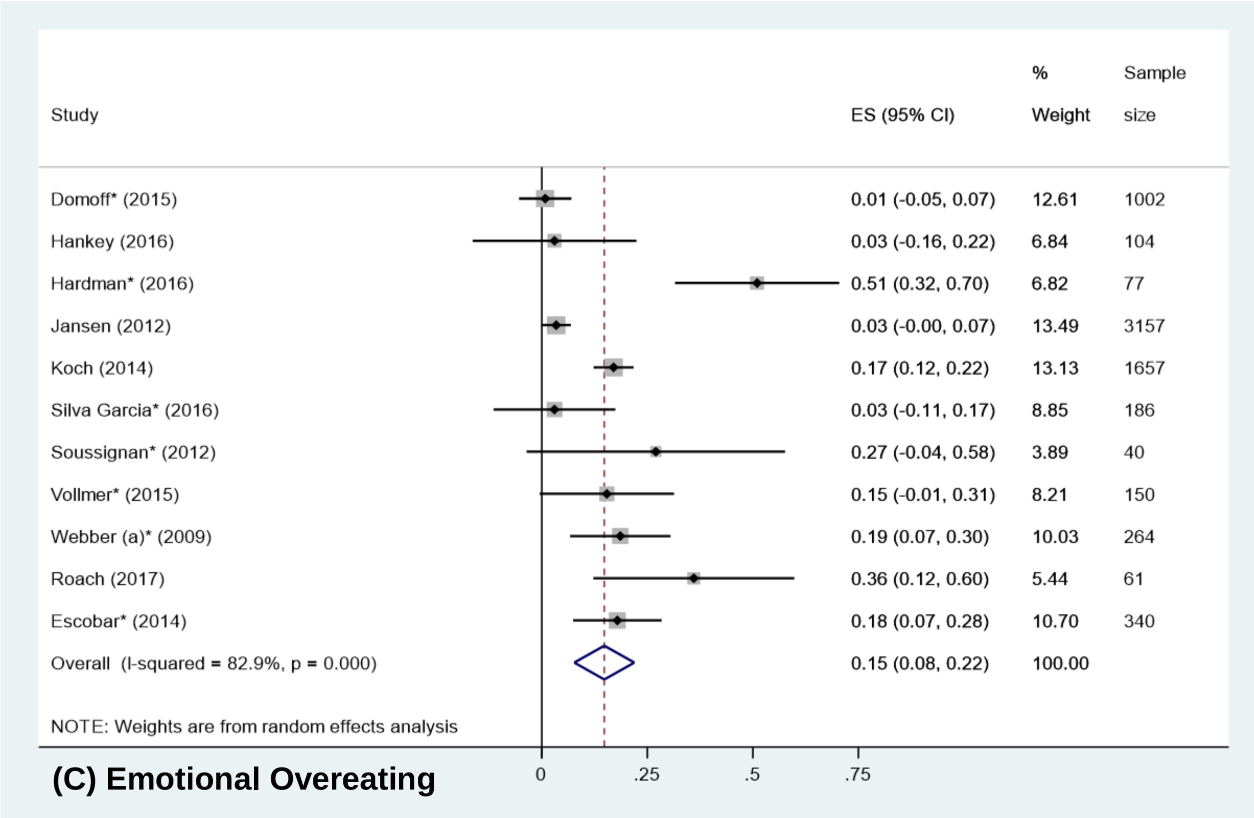


(A) Food responsiveness



(B) Enjoyment of Food

Figure 6.2. Pooled effect estimates for unadjusted correlation coefficients for with BMI z-scores, by Child Eating Behaviour Questionnaire (CEBQ) scale. (continued)



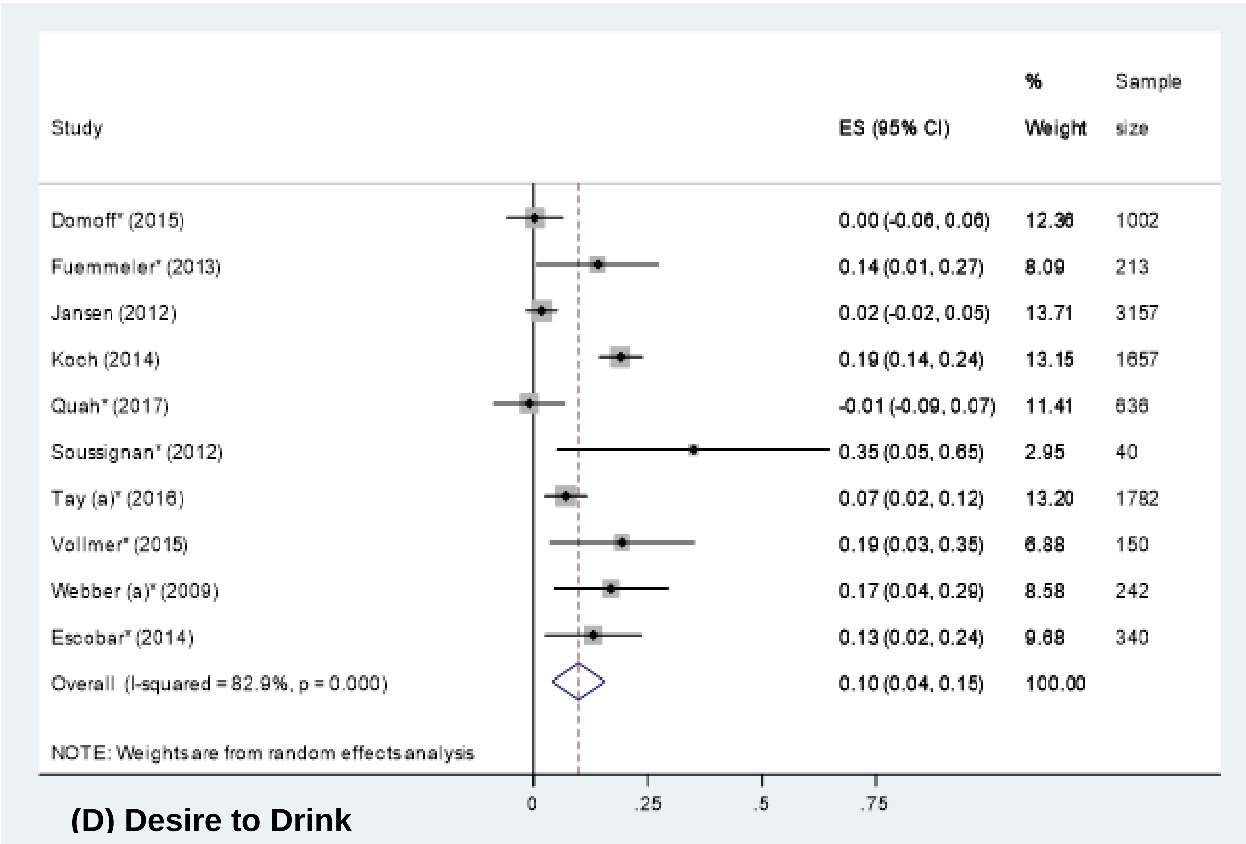
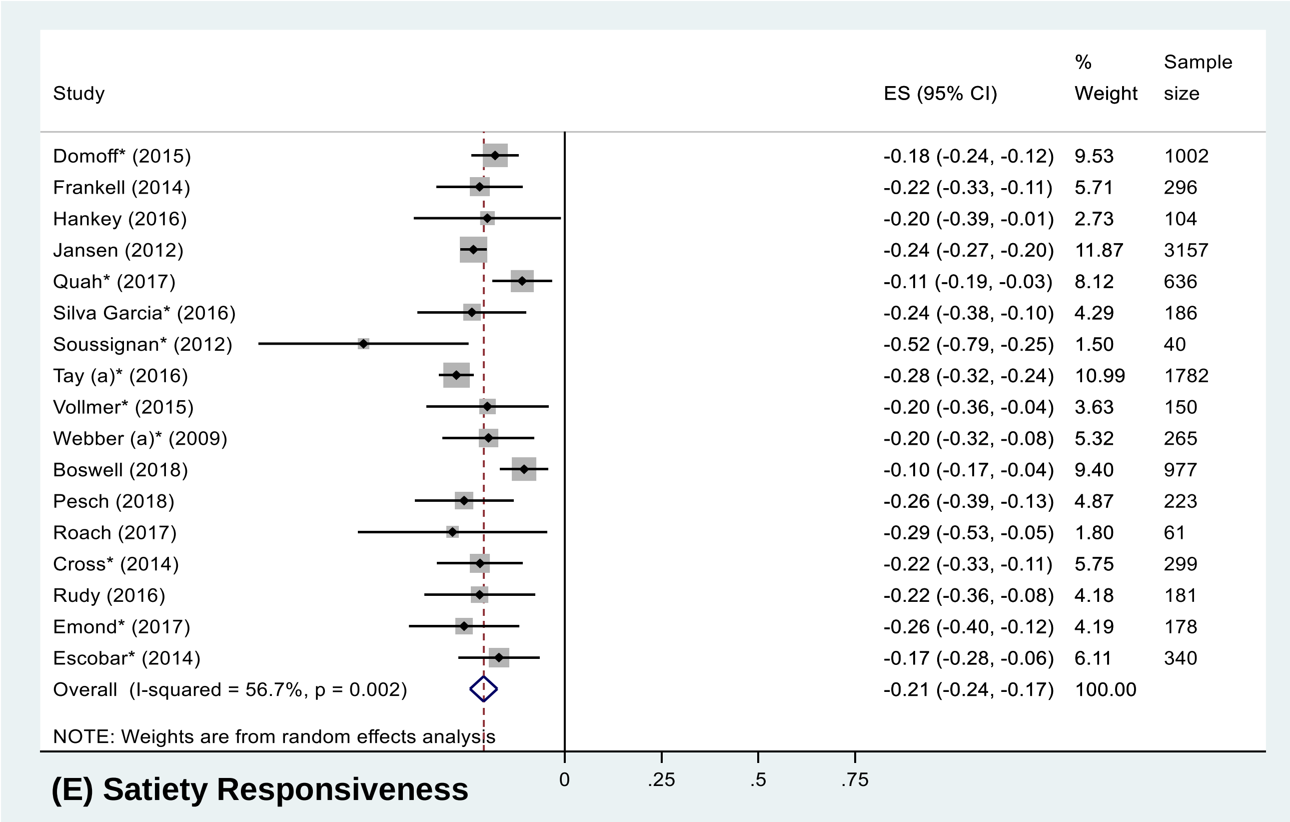
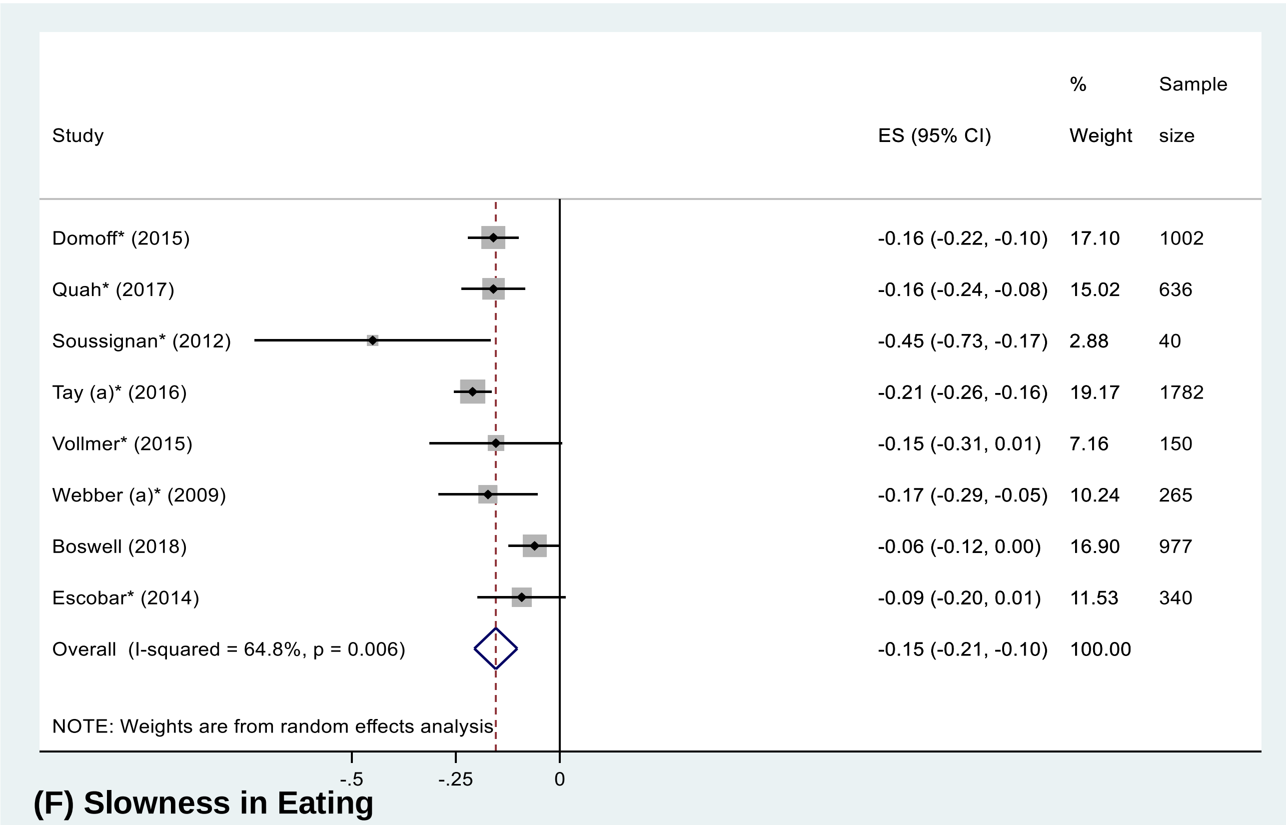


Figure 6.2. Pooled effect estimates for unadjusted correlation coefficients for with BMI z-scores, by Child Eating Behaviour Questionnaire (CEBQ) scale. (continued)

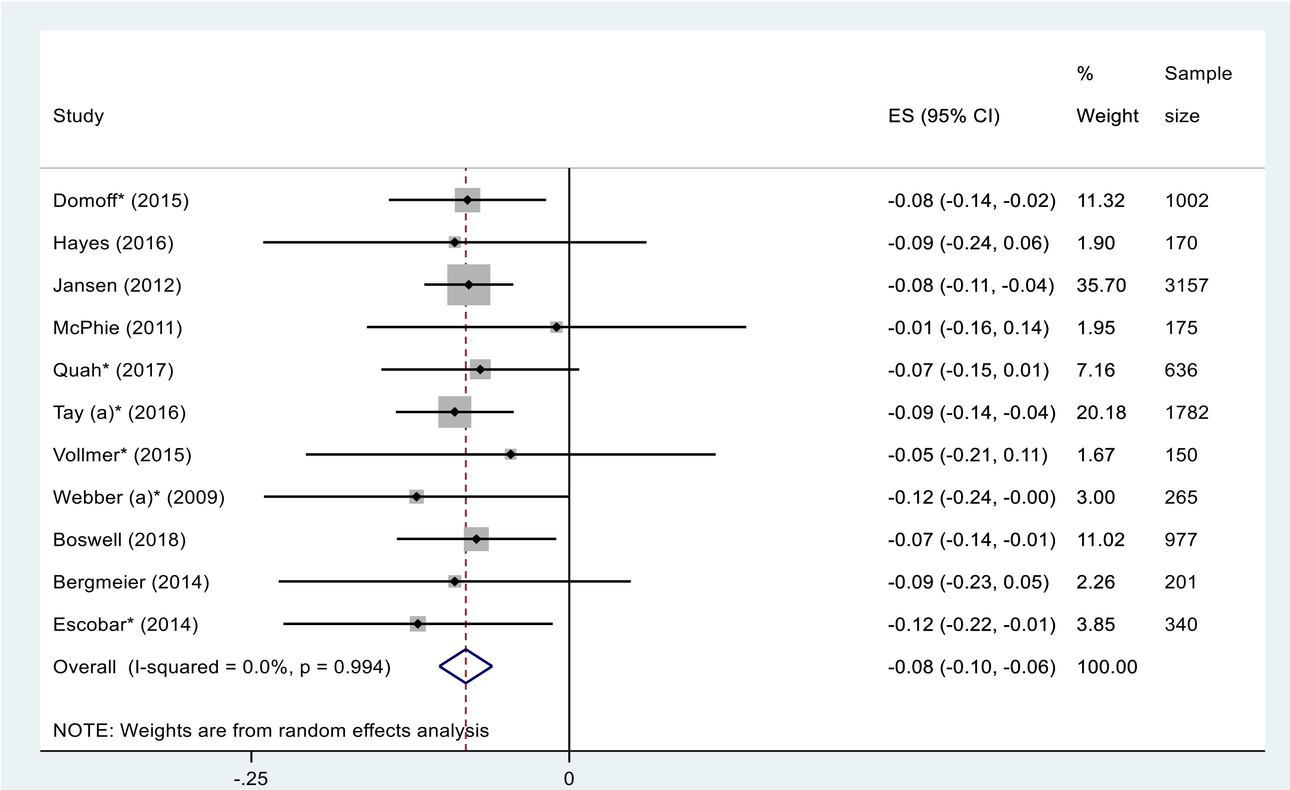


(E) Satiety Responsiveness

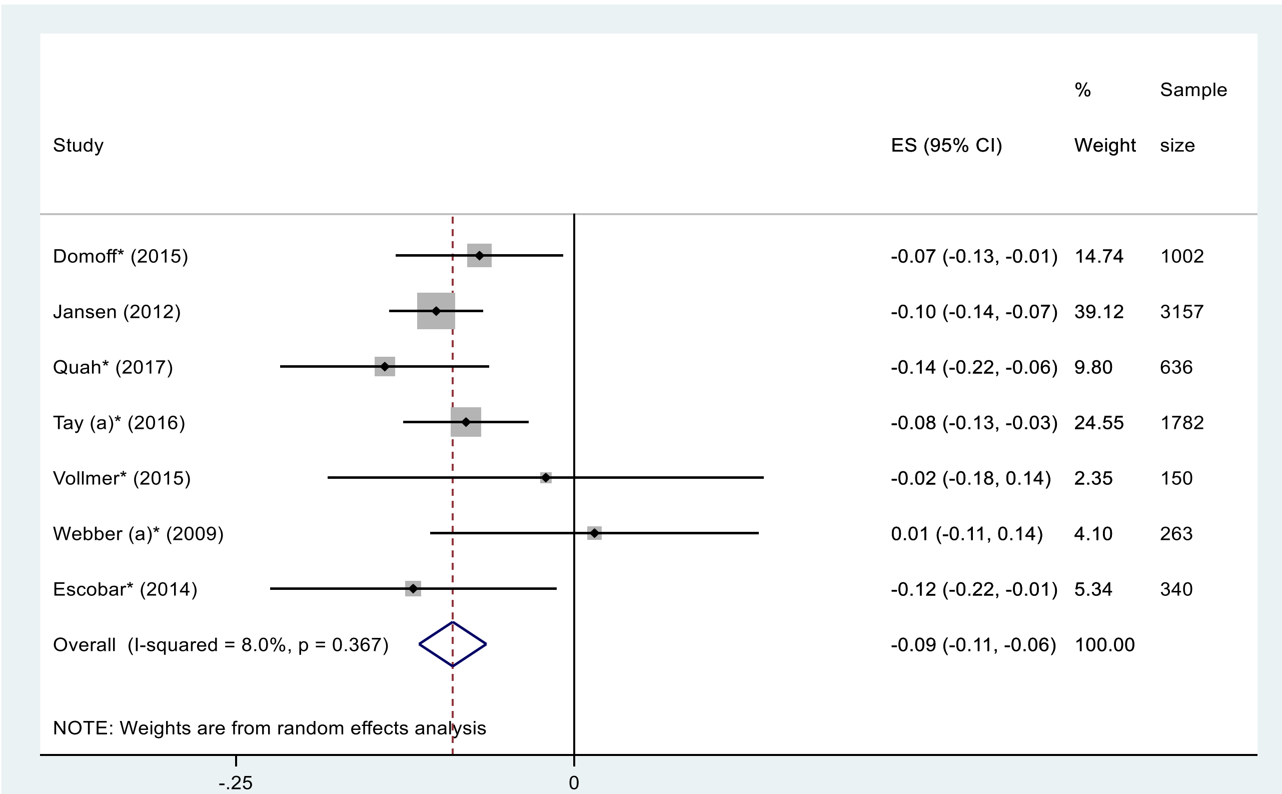


(F) Slowness in Eating

Figure 6.2. Pooled effect estimates for unadjusted correlation coefficients for with BMI z-scores, by Child Eating Behaviour Questionnaire (CEBQ) scale. (continued)



(G) Food Fussiness



(H) Emotional Undereating

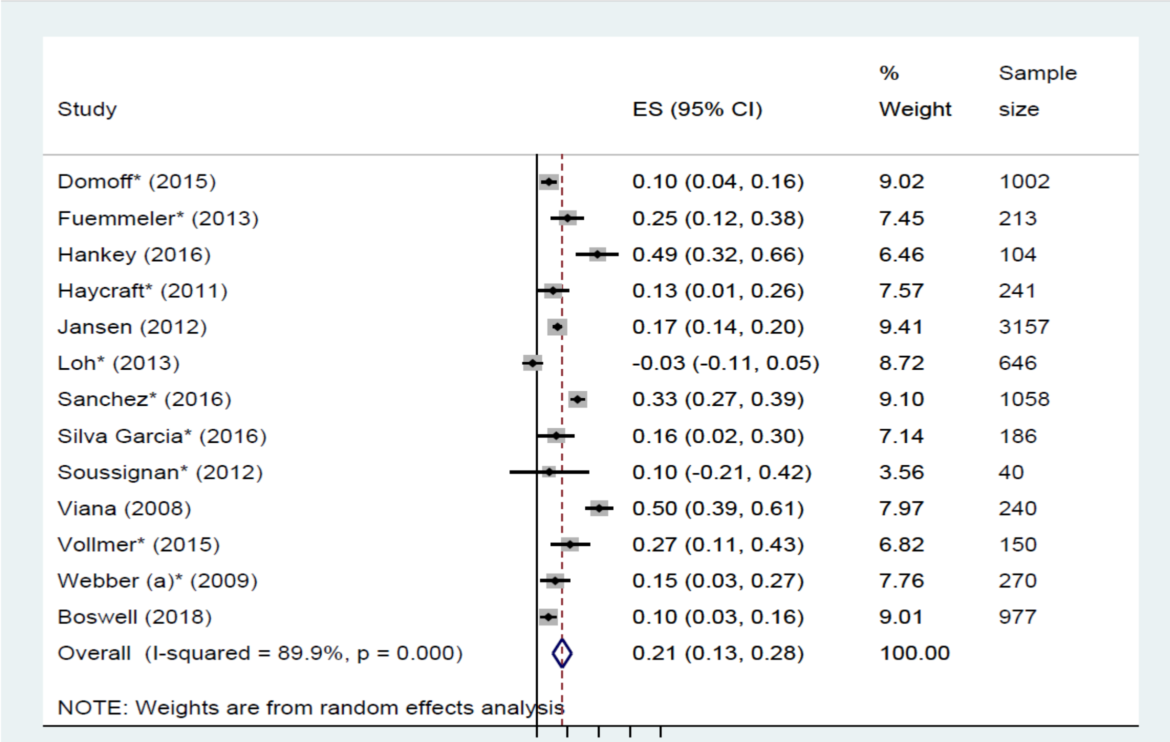
In an overall random effects model pooling data from all eligible studies presenting regression coefficients between CEBQ scales and BMIz (n=13), the maximally adjusted standardized effect estimates (β) were prioritised. If unavailable, the crude estimates (i.e. equivalent to a Pearson's correlation coefficient) were taken forward. Six out of eight scales were significantly associated with BMIz in the adjusted estimates in expected directions. Strongest associations were observed for SR β=-0.31 (95% CI: -0.40, -0.23; I^2=94.0%; n=9800) and FR β=0.22 (95% CI: 0.11, 0.34; I^2=93.2%; n=5707) with BMIz. FF and DD were not significantly associated with BMIz. Full results for the overall pooled models, as well as the adjusted only and crude only meta-analyses are shown in **Table 6.7** and **Figure 6.3.**

Table 6.7. Results from random effects meta-analysis of studies examining regression of BMI z-scores on CEBQ scales, stratified by level of adjustment

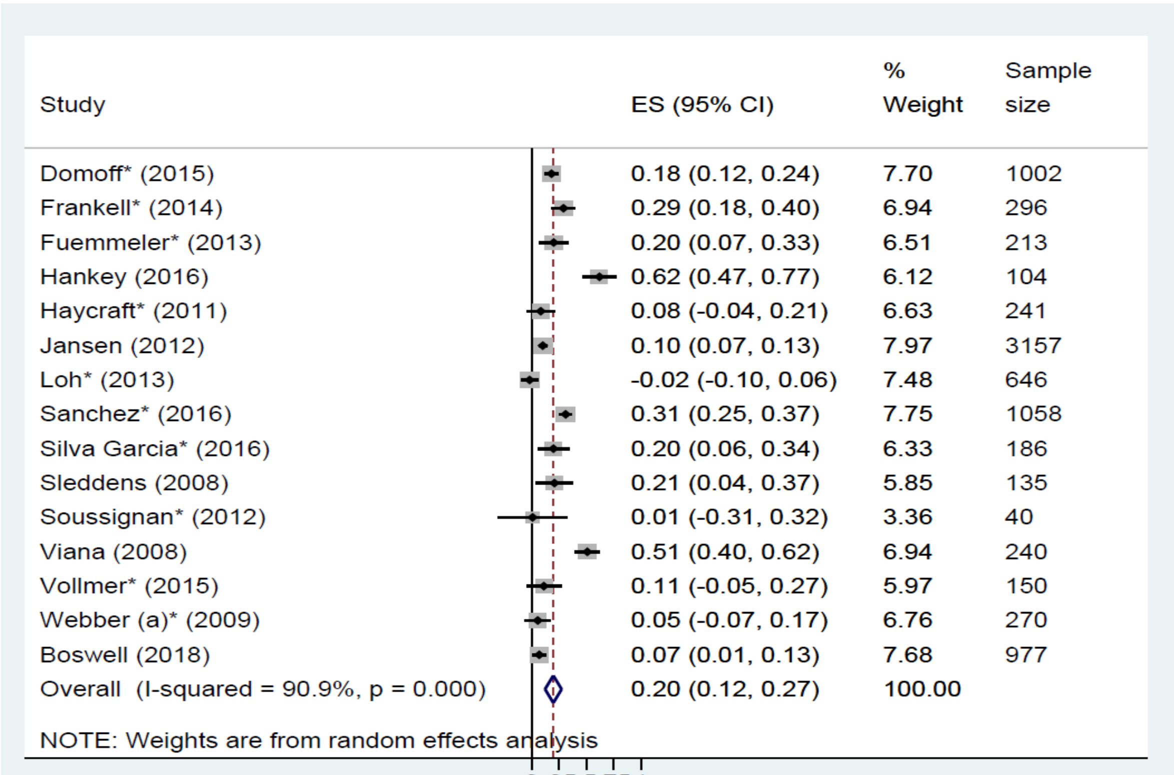
CEBQ scale	β	95 % CI	I^2 (%)	P-value for heterogeneity	Sub-cohorts (n)	n
Overall						
FR	**0.21**	(0.13, 0.28)	89.9	0.00	13	8284
EF	**0.20**	(0.12, 0.27)	90.9	0.00	15	8715
EOE	**0.22**	(0.13, 0.31)	87.2	0.00	12	4149
DD	0.03	(-0.03, 0.08)	73.4	0.00	11	6020
SR	**-0.33**	(-0.40, -0.23)	94.0	0.00	14	9800
SE	**-0.19**	(-0.25, -0.12)	85.6	0.00	12	6889
FF	-0.04	(-0.08, 0.01)	76.0	0.00	15	10053
EUE	**-0.04**	(-0.08, -0.01)	48.0	0.03	13	9339
Crude-only						
FR	**0.19**	(0.11, 0.27)	83.4	0.00	7	5734
EF	**0.20**	(0.12, 0.28)	86.8	0.00	8	6030
EOE	**0.20**	(0.08, 0.32)	88.9	0.00	6	4621
DD	-0.07	(-0.28, 0.14)	96.8	0.00	5	4653
SR	**-0.30**	(-0.42, -0.17)	94.5	0.00	7	5817
SE	**-0.13**	(-0.20, -0.06)	51.0	0.00	4	2260
FF	-0.04	(-0.10, 0.02)	67.1	0.01	6	5630
EUE	**-0.05**	(-0.12, 0.03)	68.9	0.02	4	4440
Adjusted-only						
FR	**0.22**	(0.11, 0.34)	93.2	0.00	7	5707
EF	**0.18**	(0.07, 0.30)	93.1	0.00	8	5842
EOE	**0.20**	(0.09, 0.32)	88.1	0.00	7	2685
DD	0.04	(-0.03, 0.11)	78.1	0.00	7	4524
SR	**-0.31**	(-0.41, -0.22)	93.3	0.00	8	7140
SE	**-0.21**	(-0.31, -0.11)	89.5	0.00	8	4629
FF	-0.05	(-0.11, 0.01)	79.6	0.00	10	7580
EUE	**-0.05**	(-0.09, -0.02)	45.7	0.06	10	8056

Pooled effect estimates are presented by level of study adjustment reported at the individual study level.
The ‘Overall’ pooled model exclusively includes observations from the maximum number of studies, primarily including adjusted estimates for studies that provided such data. If not available, then unadjusted data were included.
The ‘Crude-only’ model exclusively includes observations from any study that provided unadjusted data.
The ‘Adjusted-only’ model exclusively includes observations from any study that provided unadjusted data.
Statistically significant estimates have been **bolded.**

Figure 6.3. Pooled effect estimates for regression coefficients with BMI z-scores, by Child Eating Behaviour Questionnaire (CEBQ) subscales. (Parts A-H).



(A) Food Responsiveness



(B) Enjoyment of Food

Figure 6.3. Pooled effect estimates for regression coefficients with BMI z-scores, by Child Eating Behaviour Questionnaire (CEBQ) subscales. (continued)

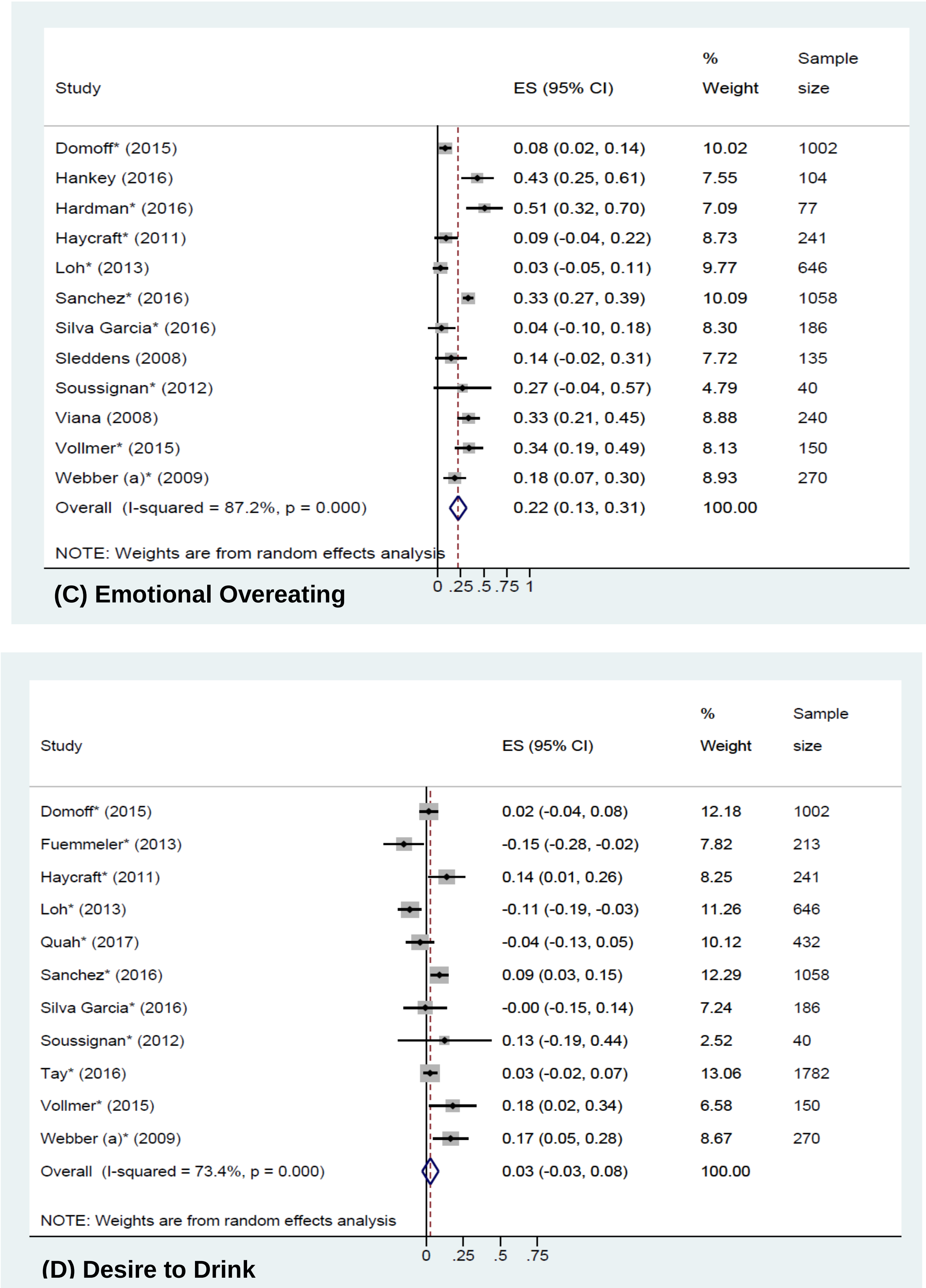
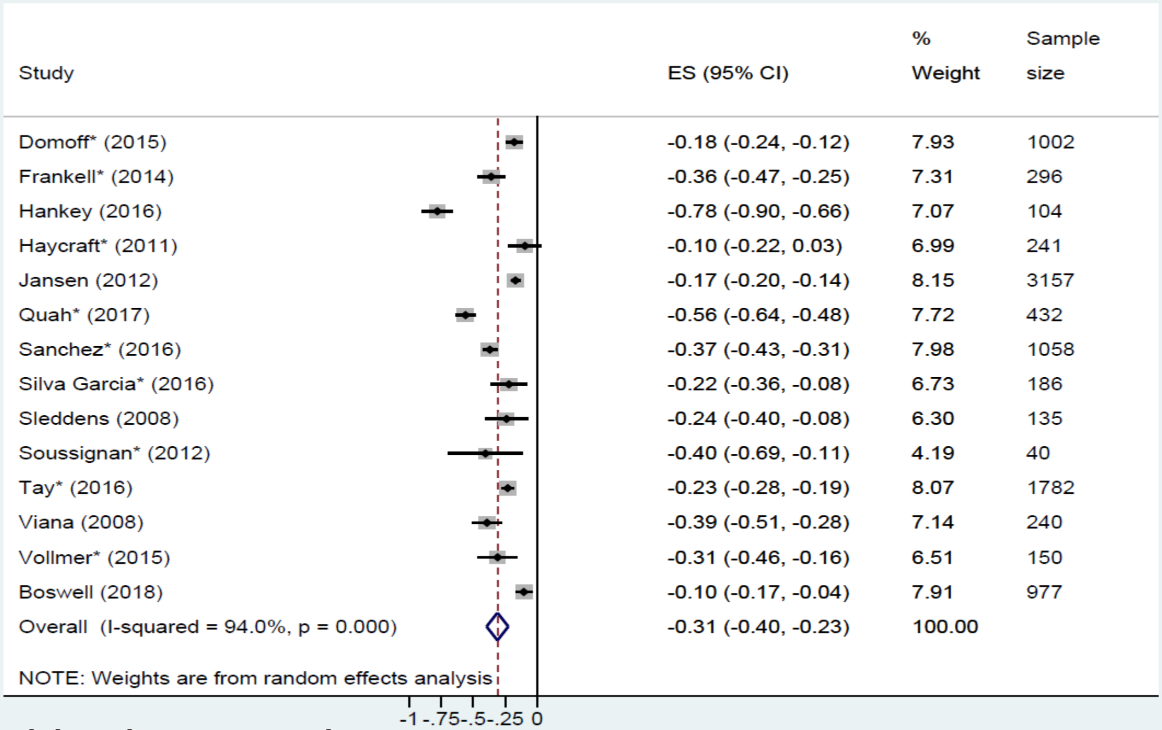
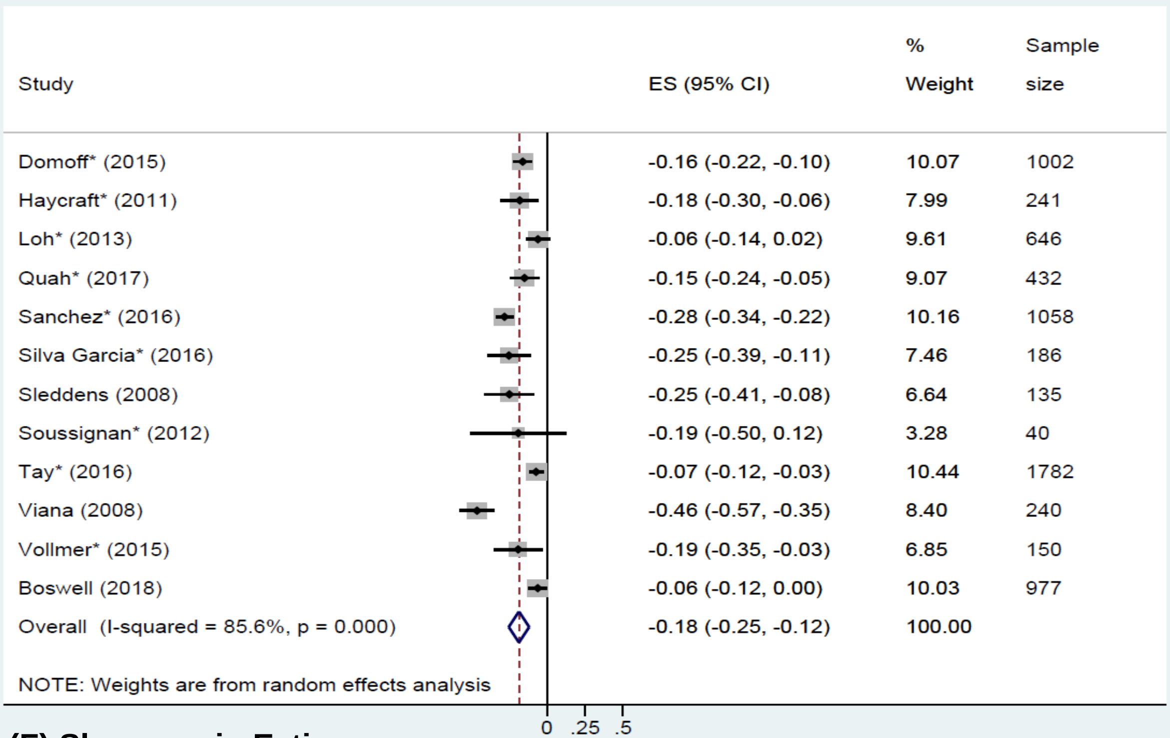


Figure 6.3. Pooled effect estimates for regression coefficients with BMI z-scores, by Child Eating Behaviour Questionnaire (CEBQ) subscales. (continued)

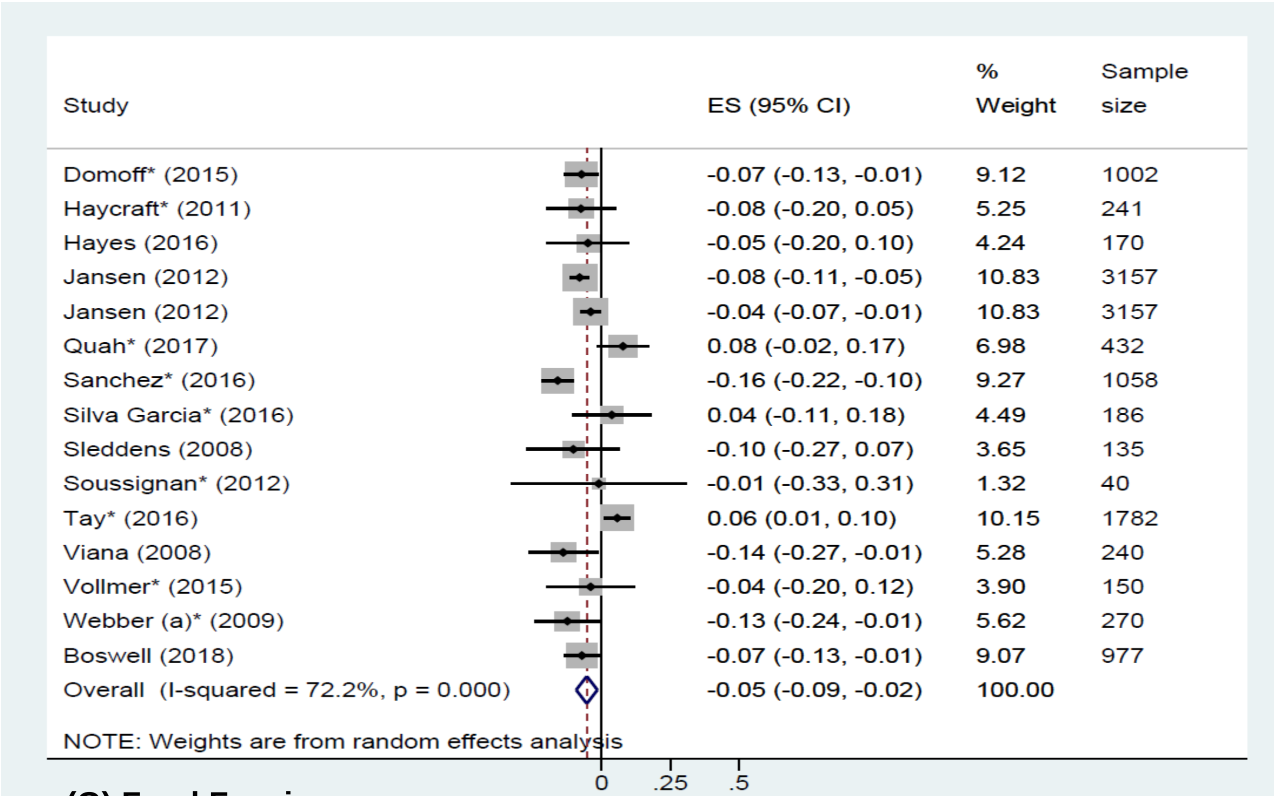


(E) Satiety Responsiveness

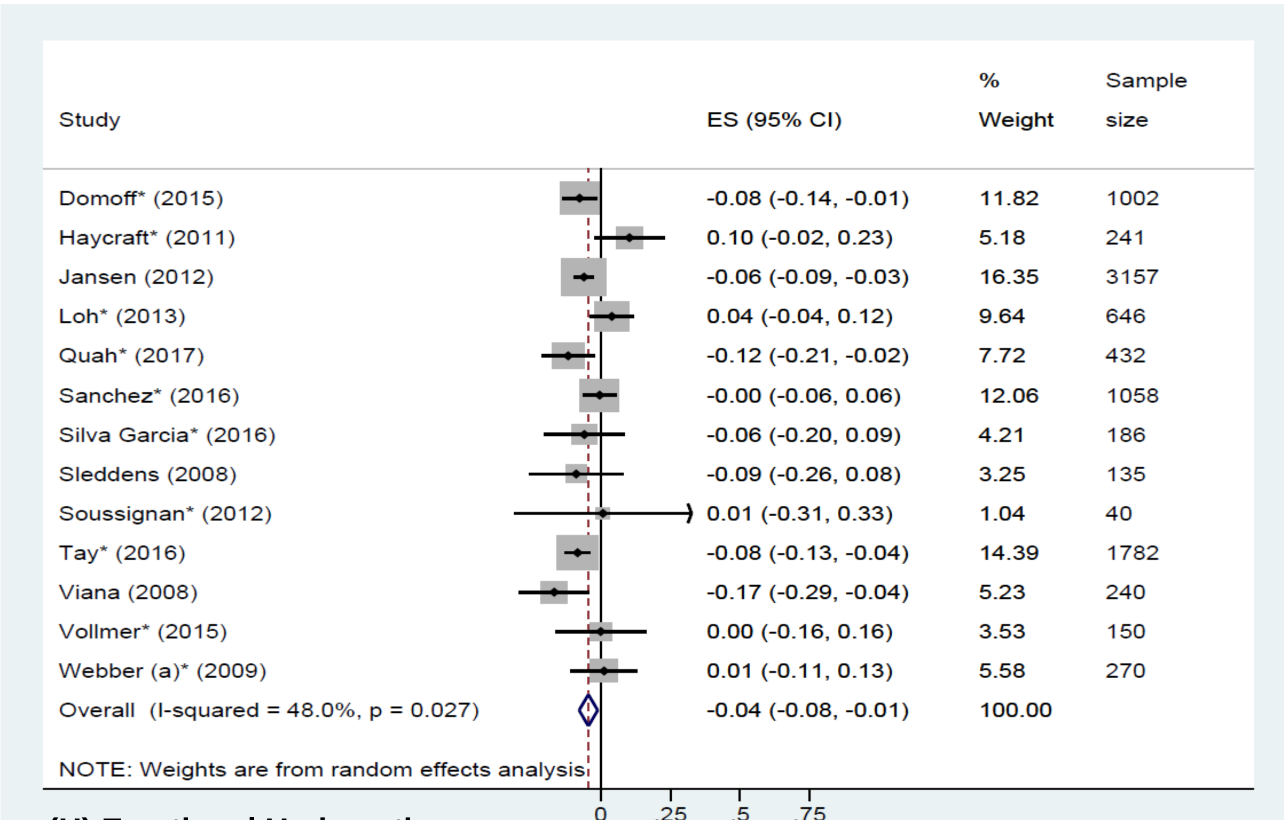


(F) Slowness in Eating

Figure 6.3. Pooled effect estimates for regression coefficients with BMI z-scores, by Child Eating Behaviour Questionnaire (CEBQ) subscales. (continued)



(G) Food Fussiness



(H) Emotional Undereating

6.4.4 Narrative Review of CEBQ studies

6.4.4.1 Cross-sectional CEBQ studies

In the 54 studies reporting on cross-sectional associations between the CEBQ and measures of adiposity, five appetitive traits were consistently associated with child adiposity in expected directions. Positive associations were reported for FR (24/29 studies), EF (21/28) and EOE (12/22), and negative associations for SR (22/25), SE (12/19) and SR/SE combined (2/2). Null associations were reported for EUE (10/17), FF (12/19) and DD (15/22). Descriptive summaries of these relationships are presented in **Appendix E.3.**

Nineteen cross-sectional studies reported data on differences in mean CEBQ scale scores by weight categories. There were substantial variability in number of categories (ranging from 2 to 5), and the adiposity thresholds and reference data used to define them (see Table 2). Just over half (11/19) of studies tested for trends of linearity in scale scores across adiposity categories. Positive linear trends were observed for FR (10/10), EF (9/10), EOE (8/8) and DD (6/7), and negative linear trends for SR (7/7), SE (4/4), FF (4/7), and SR/SE (3/3). No association was observed for EUE (5/6). Findings are summarised in see **Appendix E.4.**

6.4.4.2 Prospective CEBQ studies

Only 11 studies explored prospective associations between the CEBQ and adiposity, all adjusting for baseline adiposity[19,20,33,34,46,88,89,95–98]. Most studies used BMIz (n=9), but BMI percentile (n=1), and multiple other indicators (n=1) were also reported. Six appetitive traits were consistently associated with child adiposity in expected directions, with positive associations for FR (6/8 studies), EF (5/7), EOE (5/5) and DD (3/3), and negative associations for SR (5/7) and SE (3/5). Null associations were reported for FF (4/5) and EUE (2/2). Studies reporting the opposite direction of influence (n=5), showed consistent positive associations between adiposity and later FR (4/5), EF (2/3) and EOE (2/3), and negative associations for SR (4/5). Of these, five studies also reported on the reverse relationships, from baseline CEBQ scores to later adiposity[20,30,90,93,99]. Only one study explored prospective relationships from adiposity to later appetitive traits, but did not examine bidirectionality[92]. Results are summarised in **Appendix E.3**.

6.4.4.3 BEBQ studies (n=5)

Four of five identified studies explored prospective relationships between BEBQ scales and adiposity (Patel et al., 2017). Only two studies reported cross-sectional associations (Patel 2018; Quah 2015), so meta-analysis for the BEBQ estimates was not undertaken. Positive associations with adiposity were reported for FR (3/5), EF (4/5) and GA (3/3), and negative associations for SR (2/4) and SE (3/3). A descriptive summary of the direction of the observed relationships in these papers is presented in **Appendix E.3.**

6.5 Discussion

The CEBQ and BEBQ were designed to capture individual differences in appetitive traits hypothesised to contribute to the development of overweight and underweight. These questionnaires have been used extensively since their inception, but this is the first systematic examination of relationships between appetitive traits, and measures of adiposity across childhood.

Pooled estimates based on 27 eligible studies for inclusion in the meta-analysis demonstrated that six CEBQ scales were associated with BMI z-scores in hypothesised directions. Three food approach scales (FR, EF, EOE) were consistently positively associated with adiposity, with the largest association observed for FR ($r=.22$, $\beta=.21$). Three food avoidant scales (SR, SE, EUE) were consistently negatively associated with adiposity, with the largest association observed for SR ($r=-.21$, $\beta=-.33$). In contrast, associations of DD and FF with BMI-z scores were mixed, with only studies reporting correlations yielding significant pooled estimates. Findings were broadly consistent across relationships evaluated in the narrative review and for the fewer BEBQ studies. For studies examining linearity of associations across weight categories, results were graded in the expected direction for all CEBQ scales except EUE, which was unrelated to weight status. The small number of studies reporting prospective relationships between appetite and adiposity suggested bidirectional associations.

Together these findings support the central hypothesis of behavioural susceptibility theory – that appetitive traits are a key behavioural mechanism that help to explain an individual's susceptibility to gain excess weight (or not) in response to the obesogenic environment. However, findings also indicate that adiposity itself may lead to changes in appetite over time, such that children of higher adiposity develop increasingly avid appetites. Although future prospective studies are needed to reveal the direction of influence, this impact of weight on appetite is potentially problematic for weight loss interventions targeting eating behaviour and highlights the importance of obesity prevention and management of appetite from infancy.

The CEBQ was originally developed as a multi-dimensional measure of the appetitive traits implicated in the development of body weight in children. Most traits captured by the CEBQ were conceptualised based on existing literature examining dimensions of eating behaviour[15]. For example, FR and SR were developed from experimental laboratory studies which identified clusters of behaviours (e.g. eating without hunger, palatability responsiveness) linked to increased obesity risk[15,100,101]. Early work revealed differences in these traits, with greater responsiveness to food cues, and lower responsiveness to internal cues of satiety, observed in individuals with obesity, compared to those with a healthy weight [15,101–103]. However, two traits, EUE and DD, were added following open-ended parent interviews and these scales showed less clear adiposity relationships, possibly due to ambiguity in what they assess. For example, DD assesses general wanting for drinks, without specifying beverage types. Distinguishing between the preference for water versus a caloric beverage (e.g. sugar-sweetened drinks or milk) may be necessary to clarify associations with energy intake and therefore weight[104]. There were also inconsistencies in the EUE-adiposity relationship. EUE was commonly excluded from studies, resulting in a smaller analysis sample, so the inconsistency may have resulted from lower statistical power. Additionally, EUE scores may partly capture occurrence of a ‘state’, i.e. how often a child gets upset around mealtimes. For example, parents who pressure their children to eat may trigger a state of food anxiety, resulting in the expression of EUE behaviours regardless of their appetitive trait[105,106].

The unclear relationship between FF and adiposity revealed is unsurprising. Food fussiness characterises two aspects: eating a limited range of foods, and refusal of unfamiliar foods (‘food neophobia’). Both behaviours contribute to lower dietary variety, which is associated with poorer diet quality. Parents worry about fussy eating because it could lead to a child eating too little, or consuming insufficient variety for optimal development[107]. FF *has* been associated with under-eating and failure to thrive in children[108] but also with overconsumption of energy dense foods[109–111]. FF may not confer risk of underweight if adequate quantities of food are consumed, even if diet quality remains poor.

The small number of studies (n=11) reporting prospective relationships between appetite and adiposity, limits our ability to draw conclusions regarding the likely direction of influence between appetitive traits and weight development. Even fewer studies (n=5) examined bidirectional relationships, but all were supportive of bidirectional associations. While tentative evidence supports the hypothesis that an avid appetite predisposes to weight gain, it is possible the influence of appetite on weight development is greater during infancy, with adiposity level becoming more important in shaping appetite later in childhood.

6.5.1 Limitations

Heterogeneity in reporting and in adiposity measures (e.g. BMI z-score versus BMI percentiles) prevented the inclusion of more studies in the meta-analytic model, and meta-analysis of prospective effect estimates. Additionally, we were unable to include several studies that modified the CEBQ from its original, validated form (n=18) – e.g. studies that dropped items from scales, moved items into other scales, split scales, or created new scores for scales.

While the focus of this review was all measures of child adiposity, the majority of studies utilised BMI z-scores as the primary outcome and thus it was only possible to include BMI z-score in the meta-analytic model. There are a number of limitations to using BMI as an indicator of adiposity. BMI only acts a surrogate measure and cannot differentiate between weight attributable to fat mass or lean mass and thus misclassification of weight status can occur at an individual level, especially during childhood when maturation occurs at differing rates [112–114]. Furthermore, studies have highlighted the specific measurement used, e.g. BMI vs BMI z-scores vs BMI percentiles, may provide different results when examining changes in adiposity over time[113,115]. While BMI z-score is a valuable screening tool, it is not recommended as an appropriate diagnostic method for clinically assessing adiposity and should be used in conjunction with other measures of body composition in clinical practice[113]. However, BMI measures continue to be commonly employed in population research because they offer a practical and affordable method for assessment at scale, thus representing the best available indicator for this investigation.

Studies examining appetite in relation to weight status primarily focused on differences between children with healthy weight and overweight, rather than relationships between appetitive traits across the weight spectrum. Research in children with underweight is necessary to uncover how appetitive traits influence under-eating and the development of disordered eating behaviours, for example, to identify the age at which children might start to express active food restriction or excess consumption.

Only CEBQ and BEBQ-measured appetitive traits were included in this review. Other existing validated psychometric measures such as the DEBQ and Three Factor Eating Behaviour Questionnaire (TFEQ)[103] were not specifically developed for children, and capture a narrower range of appetitive traits. Confining our analysis to the CEBQ and BEBQ facilitates future comparisons across the life course via the Adult Eating Behaviour Questionnaire (AEBQ), which matches the appetitive trait factor structure of the CEBQ[116].

There were only a small number of bidirectional studies and those identified varied widely in period of follow-up, age-range, and frequency of assessment. Further analysis of prospective data from birth are needed to understand dynamic changes in direction and strength of the appetite-adiposity relationship across childhood. Future studies should also consider methods for disentangling between-person from within-person effects and discounting effects of all time-invariant confounders (e.g. sex or ethnicity), thereby separating the within-person level from confounding group-level association and moving closer to true causation of the appetite-adiposity relationship[117]. Research examining the impact on child adiposity of interventions that effectively modify appetitive traits could also inform on causality.

6.5.2 Implications

Notwithstanding these limitations, our findings suggest interventions targeting appetitive traits may provide a novel opportunity in obesity prevention and treatment, with potential implications for clinical practice and population health. Tailoring interventions to individuals' problematic appetitive traits may encourage behaviour change, influencing efficacy of lifestyle interventions (e.g. reducing emotional eating as a stress coping mechanism)[118]. E-health interventions show small positive effects of tailoring based on factors such as dietary intake, on weight loss success[119,120]. Preliminary research tailoring treatment targeting food-cue reactivity and satiety responsiveness in adults with binge eating demonstrated clear reductions in episodes of overeating, and BMI over a 4 month treatment period, with results maintained at 3-month follow-up[121]. Future work aims to apply this approach to children[122]. Establishing optimal BEBQ or CEBQ scale cut-off values for prediction of the development of overweight would support this work by helping to identify children at risk, informing algorithms to support clinical decision-making, and highlighting the most effective appetitive traits to target to support healthy weight management. At a population health level, even if tailoring is not possible, incorporating individual variation in appetitive traits with known adiposity impacts could improve models aiming to assess or predict impacts of environmental interventions to prevent child obesity[123,124].

6.5.3 Conclusion

The studies reviewed provide preliminary support for the hypothesis that a more avid appetite – higher scores on CEBQ and BEBQ food approach traits and lower scores on food avoidant traits – predisposes to excess weight gain and increased risk of overweight during childhood. However, evidence remains weak; most studies were cross-sectional, precluding conclusions about causal directions, and there were too few bidirectional prospective studies to detect effects reliably. More prospective research from birth is needed to establish causality, and to investigate bidirectional relationships between appetite and adiposity which may change in direction and strength throughout development. Nevertheless, this is the most comprehensive synthesis of published evidence on the relationship between appetitive traits and adiposity in childhood to date. Results provide a foundation for future prospective research to understand how appetitive traits mediate the influence of the obesogenic environment on body weight trajectories.

6.6 References

1. Carnell S, Haworth CMA, Plomin R, Wardle J. Genetic influence on appetite in children. *Int J Obes (Lond)*. 2008;32(10):1468-1473. doi:10.1038/ijo.2008.127
2. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*. 2008;88(1):22-29.
3. Llewellyn C, Wardle J. Behavioral susceptibility to obesity: Gene–environment interplay in the development of weight. *Physiol Behav*. 2015;152:494-501. doi:https://doi.org/10.1016/j.physbeh.2015.07.006
4. Elks CE, den Hoed M, Zhao JH, et al. Variability in the Heritability of Body Mass Index: A Systematic Review and Meta-Regression. *Front Endocrinol (Lausanne)*. 2012;3(FEB):29. doi:10.3389/fendo.2012.00029
5. Silventoinen K, Jelenkovic A, Sund R, et al. Genetic and environmental effects on body mass index from infancy to the onset of adulthood: An individual-based pooled analysis of 45 twin cohorts participating in the COllaborative project of Development of Anthropometrical measures in Twins (CODATwins). *Am J Clin Nutr*. 2016;104(2):371-379. doi:10.3945/ajcn.116.130252
6. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*. 2008;88(1):22-29.

http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105791809&site=ehost-live

7. Llewellyn CH, van Jaarsveld CHM, Johnson L, Carnell S, Wardle J. Nature and nurture in infant appetite: analysis of the Gemini twin birth cohort. *Am J Clin Nutr*. 2010;91(5):1172-1179. doi:10.3945/ajcn.2009.28868

8. Llewellyn C, van Jaarsveld CHM, Plomin R, Fisher A, Wardle J. Inherited behavioral susceptibility to adiposity in infancy: a multivariate genetic analysis of appetite and weight in the Gemini birth cohort. *Am J Clin Nutr*. 2012;95(3):633-639. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108164473&site=ehost-live

9. Jacob R, Drapeau V, Tremblay A, Provencher V, Bouchard C, Pérusse L. The role of eating behavior traits in mediating genetic susceptibility to obesity. *Am J Clin Nutr*. 2018;108:445-452. doi:10.1093/ajcn/nqy130

10. Llewellyn C, Trzaskowski M, van Jaarsveld CH, Plomin R, Wardle J. Satiety mechanisms in genetic risk of obesity. *JAMA Pediatr*. 2014;168(4):338-344. doi:https://dx.doi.org/10.1001/jamapediatrics.2013.4944

11. Wardle J, Guthrie CA, Sanderson S, Rapoport L. Development of the Children’s Eating Behaviour Questionnaire. *J Child Psychol Psychiatry Allied Discip*. 2001;42(7):963-970. doi:10.1017/S0021963001007727

12. Carnell S, Wardle J. Measuring behavioural susceptibility to obesity: Validation of the child eating behaviour questionnaire. *Appetite*. 2007;48(1):104-113. doi:10.1016/j.appet.2006.07.075

13. Kral TVE, Faith MS. Child eating patterns and weight regulation: a

developmental behaviour genetics framework. *Acta Paediatr*. 2007;96(SUPPL. 454):29-34. doi:10.1111/j.1651-2227.2007.00167.x

14. Faith MS, Carnell S, Kral TVE. Genetics of food intake self-regulation in childhood: Literature review and research opportunities. *Hum Hered*. 2013;75(2-4):80-89. doi:10.1159/000353879

15. Schachter S. Obesity and eating. *Science (80-)*. 1968;161(3843):751-756. doi:10.1126/science.161.3843.751

16. Llewellyn C, van Jaarsveld CH, Johnson L, Carnell S, Wardle J. Development and factor structure of the Baby Eating Behaviour Questionnaire in the Gemini birth cohort. *Appetite*. 2011;57(2):388-396. doi:https://dx.doi.org/10.1016/j.appet.2011.05.324

17. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*. 2008;88(1):22-29. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105791809&site=ehost-live

18. Horan M, Gibney E, Molloy E, McAuliffe F. Methodologies to assess paediatric adiposity. *Ir J Med Sci*. 2015;184(1):53-68. doi:10.1007/s11845-014-1124-1

19. Quah PL, Chan YH, Aris IM, et al. Prospective associations of appetitive traits at 3 and 12 months of age with body mass index and weight gain in the first 2 years of life. *BMC Pediatr*. 2015;15:153. doi:https://dx.doi.org/10.1186/s12887-015-0467-8

20. Derks IPM, Sijbrands EJG, Wake M, et al. Eating behavior and body composition across childhood: a prospective cohort study. *Int J Behav Nutr Phys Act*. 2018;15(1):1-9. doi:10.1186/s12966-018-0725-x

21. van Jaarsveld CH, Llewellyn CH, Johnson L, Wardle J. Prospective associations between appetitive traits and weight gain in infancy. *Am J Clin Nutr*. 2011;94(6):1562-1567. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108207259&site=ehost-live

22. van Strien T, Frijters JER, Bergers GPA, Defares PB. The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *Int J Eat Disord*. 1986;5(2):295-315. doi:10.1002/1098-108X(198602)5:2<295::AID-EAT2260050209>3.0.CO;2-T

23. World Health Organisation. *WHO Definition of Key Terms*.; 2013. Accessed July 10, 2020. https://www.who.int/hiv/pub/guidelines/arv2013/intro/keyterms/en/

24. Wells G, Shea B, Robertson J, et al. *The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomized Studies in Meta-Analysis*.

25. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials*. 1986;7(3):177-188. doi:10.1016/0197-2456(86)90046-2

26. Valentine JC, Pigott TD, Rothstein HR. How Many Studies Do You Need? *J Educ Behav Stat*. 2010;35(2):215-247. doi:10.3102/1076998609346961

27. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ*. 2003;327(7414):557-560. doi:10.1136/bmj.327.7414.557

28. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple , graphical test measures of funnel plot asymmetry. *Bmj*. 1997;315(7109):629-634. doi:10.1136/bmj.315.7109.629

29. Mallan KM, Nambiar S, Magarey AM, Daniels LA. Satiety responsiveness

in toddlerhood predicts energy intake and weight status at four years of age. *Appetite*. 2014;74:79-85. doi:https://doi.org/10.1016/j.appet.2013.12.001

30. van Deutekom AW, Chinapaw MJ, Vrijkotte TG, Gemke RJ. The association of birth weight and postnatal growth with energy intake and eating behavior at 5 years of age-A birth cohort study. *Int J Behav Nutr Phys Act Vol 13 2016, ArtID 15*. 2016;13. doi:http://dx.doi.org/10.1186/s12966-016-0335-4

31. Loh DA, Moy FM, Zaharan NL, Mohamed Z. Eating behaviour among multi-ethnic adolescents in a middle-income country as measured by the self-reported Children's Eating Behaviour Questionnaire. *PLoS ONE [Electronic Resour*. 2013;8(12):e82885. doi:https://dx.doi.org/10.1371/journal.pone.0082885

32. Viana V, Sinde S, Saxton JC. Children's Eating Behaviour Questionnaire: associations with BMI in Portuguese children. *Br J Nutr*. 2008;100(2):445-450. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105669370&site=ehost-live

33. Steinsbekk, Llewellyn CH, Fildes A, Wichstrøm L. Body composition impacts appetite regulation in middle childhood. A prospective study of Norwegian community children. 2017;14(1):70.

34. Bergmeier H, Skouteris H, Horwood S, Hooley M, Richardson B. Child temperament and maternal predictors of preschool children's eating and body mass index. A prospective study. *Appetite*. 2014;74:125-132. doi:https://dx.doi.org/10.1016/j.appet.2013.12.006

35. Mallan KM, Liu WH, Mehta RJ, Daniels LA, Magarey A, Battistutta D.

Maternal report of young children's eating styles. Validation of the Children's Eating Behaviour Questionnaire in three ethnically diverse Australian samples. *Appetite*. 2013;64:48-55. doi:https://dx.doi.org/10.1016/j.appet.2013.01.003

36. Shepard DN, Chandler-Laney PC. Prospective associations of eating behaviors with weight gain in infants. *Obesity*. 2015;23(9):1881-1885. doi:https://dx.doi.org/10.1002/oby.21168

37. van Jaarsveld CH, Llewellyn CH, Johnson L, Wardle J. Prospective associations between appetitive traits and weight gain in infancy. *Am J Clin Nutr*. 2011;94(6):1562-1567. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108207259&site=ehost-live

38. Cao YT, Svensson V, Marcus C, Zhang J, Zhang JD, Sobko T. Eating behaviour patterns in Chinese children aged 12-18 months and association with relative weight - factorial validation of the Children's Eating Behaviour Questionnaire. *Int J Behav Nutr Phys Act*. Published online 2012:5. doi:http://dx.doi.org/10.1186/1479-5868-9-5

39. Boswell N, Byrne R, Davies PSW. Eating behavior traits associated with demographic variables and implications for obesity outcomes in early childhood. *Appetite*. 2018;120:482-490. doi:10.1016/j.appet.2017.10.012

40. Braden A, Rhee K, Peterson CB, Rydell SA, Zucker N, Boutelle K. Associations between child emotional eating and general parenting style, feeding practices, and parent psychopathology. *Appetite*. 2014;80:35-40. doi:https://dx.doi.org/10.1016/j.appet.2014.04.017

41. Brown A, Lee M. Breastfeeding during the first year promotes satiety responsiveness in children aged 18-24 months. *Pediatr Obes*.

2012;7(5):382-390. doi:https://dx.doi.org/10.1111/j.2047-6310.2012.00071.x

42. Cross MB, Hallett AM, Ledoux TA, O'Connor DP, Hughes SO. Effects of children's self-regulation of eating on parental feeding practices and child weight. *Appetite*. 2014;81:76-83. doi:https://dx.doi.org/10.1016/j.appet.2014.06.014

43. Demir D, Bektas M. The effect of childrens' eating behaviors and parental feeding style on childhood obesity. *Eat Behav*. 2017;26:137-142. doi:https://dx.doi.org/10.1016/j.eatbeh.2017.03.004

44. Domoff SE, Miller AL, Kaciroti N, Lumeng JC. Validation of the Children's Eating Behaviour Questionnaire in a low-income preschool-aged sample in the United States. *Appetite*. 2015;95:415-420. doi:https://dx.doi.org/10.1016/j.appet.2015.08.002

45. Emond JA, Tovar A, Li Z, Lansigan RK, Gilbert-Diamond D. FTO genotype and weight status among preadolescents: Assessing the mediating effects of obesogenic appetitive traits. *Appetite*. 2017;117:321-329. doi:http://dx.doi.org/10.1016/j.appet.2017.07.009

46. Escobar RS, O'Donnell KA, Colalillo S, et al. Better quality of mother-child interaction at 4 years of age decreases emotional overeating in IUGR girls. *Appetite*. 2014;81:337-342. doi:https://dx.doi.org/10.1016/j.appet.2014.06.107

47. Frankel LA, O'Connor TM, Chen TA, Nicklas T, Power TG, Hughes SO. Parents' perceptions of preschool children's ability to regulate eating. Feeding style differences. *Appetite*. 2014;76:166-174. doi:https://dx.doi.org/10.1016/j.appet.2014.01.077

48. Fuemmeler BF, Lovelady CA, Zucker NL, Ostbye T. Parental Obesity

Moderates the Relationship Between Childhood Appetitive Traits and Weight. *Obesity*. 2013;21(4):815-823. doi:10.1002/oby.20144

49. Gregory JE, Paxton SJ, Brozovic AM. Maternal feeding practices, child eating behaviour and body mass index in preschool-aged children: A prospective analysis. *Int J Behav Nutr Phys Act Vol 7 2010, ArtID 55*. 2010;7. doi:http://dx.doi.org/10.1186/1479-5868-7-55

50. Hankey M, Williams NA, Dev D. Uninvolved maternal feeding style moderates the association of emotional overeating to preschoolers' body mass index z-scores. *J Nutr Educ Behav*. 2016;48(8):530-537. doi:http://dx.doi.org/10.1016/j.jneb.2016.06.006

51. Hardman CA, Christiansen P, Wilkinson LL. Using food to soothe: Maternal attachment anxiety is associated with child emotional eating. *Appetite*. 2016;99:91-96. doi:https://dx.doi.org/10.1016/j.appet.2016.01.017

52. Haycraft E, Farrow C, Meyer C, Powell F, Blissett J. Relationships between temperament and eating behaviours in young children. *Appetite*. 2011;56(3):689-692. doi:https://dx.doi.org/10.1016/j.appet.2011.02.005

53. Hayes JF, Altman M, Kolko RP, et al. Decreasing food fussiness in children with obesity leads to greater weight loss in family-based treatment. *Obesity*. 2016;24(10):2158-2163. doi:https://dx.doi.org/10.1002/oby.21622

54. Jansen PW, Roza SJ, Jaddoe VW, et al. Children's eating behavior, feeding practices of parents and weight problems in early childhood: Results from the population-based Generation R Study. *Int J Behav Nutr Phys Act Vol 9 2012, ArtID 130*. 2012;9. doi:http://dx.doi.org/10.1186/1479-5868-9-130

55. Koch A, Pollatos O. Interoceptive sensitivty, body weight and eating behavior in children: a prospective study. *Front Psychol*. 2014;5. doi:10.3389/fpsyg.2014.01003

56. Larsen JK, Sleddens EFC, Vink JM, van den Broek N, Kremers SPJ. The sex-specific interaction between food responsiveness and sleep duration explaining body mass index among children. *Sleep Med*. 2017;40:106-109. doi:10.1016/j.sleep.2017.09.025

57. Lipowska M, Lipowski M, Jurek P, Jankowska AM, Pawlicka P. Gender and body-fat status as predictors of parental feeding styles and children's nutritional knowledge, eating habits and behaviours. *Int J Environ Res Public Health*. 2018;15(5). doi:10.3390/ijerph15050852

58. Lora KR, Hubbs-Tait L, Ferris AM, Wakefield D. African-American and Hispanic children's beverage intake: Differences in associations with desire to drink, fathers' feeding practices, and weight concerns. *Appetite*. 2016;107:558-567. doi:http://dx.doi.org/10.1016/j.appet.2016.09.012

59. McPhie S, Skouteris H, McCabe M, et al. Maternal correlates of preschool child eating behaviours and body mass index: a cross-sectional study. *Int J Pediatr Obes*. 2011;6(5-6):476-480. doi:https://dx.doi.org/10.3109/17477166.2011.598937

60. Parkinson KN, Drewett RF, Le Couteur AS, Adamson AJ. Do maternal ratings of appetite in infants predict later Child Eating Behaviour Questionnaire scores and body mass index? *Appetite*. 2010;54(1):186-190. doi:http://dx.doi.org/10.1016/j.appet.2009.10.007

61. Pesch MH, Appugliese DP, Miller AL, Rosenblum KL, Lumeng JC, Bauer KW. Approaches to restrictive feeding: Associations with child weight and eating behavior. *Eat Behav*. 2018;31:74-79.

doi:10.1016/J.EATBEH.2018.08.006

62. Quah PL, Cheung YB, Pang WW, et al. Validation of the Children's Eating Behavior Questionnaire in 3 year old children of a multi-ethnic Asian population: The GUSTO cohort study. *Appetite*. 2017;113:100-105. doi:http://dx.doi.org/10.1016/j.appet.2017.02.024

63. Roach E, Viechnicki GB, Retzloff LB, Davis-Kean P, Lumeng JC, Miller AL. Family food talk, child eating behavior, and maternal feeding practices. *Appetite*. 2017;117:40-50. doi:http://dx.doi.org/10.1016/j.appet.2017.06.001

64. Rudy E, Bauer KW, Hughes SO, et al. Interrelationships of child appetite, weight and snacking among Hispanic preschoolers. *Pediatr Obesity*. Published online 2016. doi:http://dx.doi.org/10.1111/ijpo.12186

65. Sanchez U, Weisstaub G, Santos JL, Corvalan C, Uauy R. GOCS cohort: Children's eating behavior scores and BMI. *Eur J Clin Nutr*. 2016;70(8):925-928. doi:http://dx.doi.org/10.1038/ejcn.2016.18

66. Silva Garcia K, Power TG, Fisher JO, O'Connor TM, Hughes SO. Latina mothers' influences on child appetite regulation. *Appetite*. 2016;103:200-207. doi:http://dx.doi.org/10.1016/j.appet.2016.04.013

67. Sleddens EFC, Kremers SPJ, Thijs C. The Children's Eating Behaviour Questionnaire: Factorial validity and association with body mass index in Dutch children aged 6-7. *Int J Behav Nutr Phys Act Vol 5 2008, ArtID 49*. 2008;5. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2014-47912-001

68. Somaraki M, Eli K, Sorjonen K, et al. Perceived child eating behaviours and maternal migrant background. *Appetite*. 2018;125:302-313.

doi:10.1016/j.appet.2018.02.010

69. Soussignan R, Schaal B, Boulanger V, Gaillet M, Jiang T. Orofacial reactivity to the sight and smell of food stimuli. Evidence for anticipatory liking related to food reward cues in overweight children. *Appetite*. 2012;58(2):508-516. doi:https://dx.doi.org/10.1016/j.appet.2011.12.018

70. Svensson V, Lundborg L, Cao Y, Nowicka P, Marcus C, Sobko T. Obesity related eating behaviour patterns in Swedish preschool children and association with age, gender, relative weight and parental weight - factorial validation of the Children's Eating Behaviour Questionnaire. *Int J Behav Nutr Phys Act*. Published online 2011:134. doi:http://dx.doi.org/10.1186/1479-5868-8-134

71. Tay CW, Chin YS, Lee ST, Khouw I, Poh BK, Group SMS. Association of Eating Behavior With Nutritional Status and Body Composition in Primary School-Aged Children. *Asia-Pacific J Public Heal*. 2016;28(5 Suppl):47S-58S. doi:https://dx.doi.org/10.1177/1010539516651475

72. Vollmer RL, Adamsons K, Foster JS, Mobley AR. Association of fathers' feeding practices and feeding style on preschool age children's diet quality, eating behavior and body mass index. *Appetite*. 2015;89:274-281. doi:https://dx.doi.org/10.1016/j.appet.2015.02.021

73. Webber L, Hill C, Saxton J, Van Jaarsveld CH, Wardle J. Eating behaviour and weight in children. *Int J Obes*. 2009;33(1):21-28. doi:https://dx.doi.org/10.1038/ijo.2008.219

74. McCarthy EK, Chaoimh C, Murray DM, Hourihane JO, Kenny LC, Kiely M. Eating behaviour and weight status at 2 years of age: data from the Cork BASELINE Birth Cohort Study. *Eur J Clin Nutr*. 2015;69(12):1356-1359. doi:https://dx.doi.org/10.1038/ejcn.2015.130

75. Sanlier N, Arslan S, Buyukgenc N, Toka O. Are eating behaviors related with by body mass index, gender and age? *Ecol Food Nutr*. 2018;57(4):372-387. doi:10.1080/03670244.2018.1493470

76. Croker H, Cooke L, Wardle J. Appetitive behaviours of children attending obesity treatment. *Appetite*. 2011;57(2):525-529. doi:https://dx.doi.org/10.1016/j.appet.2011.05.320

77. de Groot CJ, van den Akker ELT, Rings E, Delemarre-van de Waal HA, van der Grond J. Brain structure, executive function and appetitive traits in adolescent obesity. *Pediatr Obes*. 2017;12(4):e33-e36. doi:https://dx.doi.org/10.1111/ijpo.12149

78. dos Passos DR, Gigante DP, Maciel F V, Matijasevich A. [Children's eating behaviour: comparison between normal and overweight children from a school in Pelotas, Rio Grande do Sul, Brazil]. *Rev Paul Pediatr*. 2015;33(1):42-49. doi:https://dx.doi.org/10.1016/j.rpped.2014.11.007

79. Gardner KR, Sapienza C, Fisher JO. Genetic and epigenetic associations to obesity-related appetite phenotypes among African-American children. *Pediatr Obes*. 2015;10(6):476-482. doi:https://dx.doi.org/10.1111/ijpo.12010

80. Ho-Urriola J, Guzman-Guzman IP, Smalley S V, et al. Melanocortin-4 receptor polymorphism rs17782313: association with obesity and eating in the absence of hunger in Chilean children. *Nutrition*. 2014;30(2):145-149. doi:https://dx.doi.org/10.1016/j.nut.2013.05.030

81. Jahnke DL, Warschburger PA. Familial transmission of eating behaviors in preschool-aged children. *Obesity*. 2008;16(8):1821-1825. doi:https://dx.doi.org/10.1038/oby.2008.255

82. Mosli RH, Lumeng JC, Kaciroti N, et al. Higher weight status of only and

last-born children. Maternal feeding and child eating behaviors as underlying processes among 4-8 year olds. *Appetite*. 2015;92:167-172. doi:https://dx.doi.org/10.1016/j.appet.2015.05.021

83. Obregon AM, Valladares M, Goldfield G. Association of the dopamine D2 receptor rs1800497 polymorphism and eating behavior in Chilean children. *Nutrition*. 2017;35:139-145. doi:https://dx.doi.org/10.1016/j.nut.2016.11.005

84. Powers SW, Chamberlin LA, van Schaick KB, Sherman SN, Whitaker RC. Maternal feeding strategies, child eating behaviors, and child BMI in low-income African-American preschoolers. *Obesity*. 2006;14(11):2026-2033. doi:https://dx.doi.org/10.1038/oby.2006.237

85. Spence JC, Carson V, Casey L, Boule N. Examining behavioural susceptibility to obesity among Canadian pre-school children: the role of eating behaviours. *Int J Pediatr Obes*. 2011;6(2-2):e501-7. doi:https://dx.doi.org/10.3109/17477166.2010.512087

86. Sandvik P, Ek A, Somaraki M, Hammar U, Eli K, Nowicka P. Picky eating in Swedish preschoolers of different weight status: Application of two new screening cut-offs. *Int J Behav Nutr Phys Act*. 2018;15(1). doi:10.1186/s12966-018-0706-0

87. Mallan K, Fildes A, Magarey A, Daniels L. The Relationship between Number of Fruits, Vegetables, and Noncore Foods Tried at Age 14 Months and Food Preferences, Dietary Intake Patterns, Fussy Eating Behavior, and Weight Status at Age 3.7 Years. *J Acad Nutr Diet*. 2016;116(4):630-637. doi:10.1016/j.jand.2015.06.006

88. Mallan K, Nambiar S, Magarey A, Daniels L. Satiety responsiveness in toddlerhood predicts energy intake and weight status at four years of age.

Appetite. 2014;74:79-85. doi:10.1016/j.appet.2013.12.001

89. McPhie S, Skouteris H, Fuller-Tyszkiewicz M, et al. Maternal predictors of preschool child-eating behaviours, food intake and body mass index: A prospective study. *Early Child Dev Care*. 2012;182(8):999-1014. doi:http://dx.doi.org/10.1080/03004430.2012.678595

90. Steinsbekk S, Wichstrom L. Predictors of Change in BMI From the Age of 4 to 8. *J Pediatr Psychol*. 2015;40(10):1056-1064. doi:https://dx.doi.org/10.1093/jpepsy/jsv052

91. Bjørklund O, Belsky J, Wichstrøm L, Steinsbekk S. Predictors of eating behavior in middle childhood: A hybrid fixed effects model. *Dev Psychol*. 2018;54(6):1099-1110. doi:10.1037/DEV0000504

92. Steinsbekk S, Belsky J, Wichstrom L. Parental feeding and child eating: An investigation of reciprocal effects. *Child Dev*. 2016;87(5):1538-1549. doi:http://dx.doi.org/10.1111/cdev.12546

93. Steinsbekk S, Llewellyn CH, Fildes A, Wichstrom L. Body composition impacts appetite regulation in middle childhood. A prospective study of Norwegian community children. *Int J Behav Nutr Phys Act Vol 14 2017, ArtID 70*. 2017;14. doi:http://dx.doi.org/10.1186/s12966-017-0528-5

94. Chen H, Cohen P, Chen S. How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies. *Commun Stat Simul Comput*. 2010;39(4):860-864. doi:10.1080/03610911003650383

95. Parkinson KN, Drewett RF, Le Couteur AS, Adamson AJ. Do maternal ratings of appetite in infants predict later Child Eating Behaviour Questionnaire scores and body mass index? *Appetite*. 2010;54(1):186-190. doi:10.1016/j.appet.2009.10.007

96. Mallan KM, Fildes A, Magarey AM, Daniels LA. The Relationship between

Number of Fruits, Vegetables, and Noncore Foods Tried at Age 14 Months and Food Preferences, Dietary Intake Patterns, Fussy Eating Behavior, and Weight Status at Age 3.7 Years. *J Acad Nutr Diet*. 2016;116(4):630-637. doi:10.1016/j.jand.2015.06.006

97. Steinsbekk, Wichstrøm L, Wichstrom L. Predictors of Change in BMI From the Age of 4 to 8. *J Pediatr Psychol*. 2015;40(10):1056-1064.
98. Bjørklund, O. Belsky, J., Wichstrøm, Lars. & Steinsbekk S. Predictors of eating behavior in middle childhood: A hybrid fixed effects model. *Dev Psychol*. 2018;54(6):1099-1110.
99. Koch A, Pollatos O. Interoceptive sensitivty, body weight and eating behavior in children: a prospective study. *Front Psychol*. 2014;5. doi:10.3389/fpsyg.2014.01003
100. Barkeling B, Ekman S, Rossner S. Eating behaviour in obese and normal weight 11-year-old children. *Int J Obes*. 1992;16(5):355-360.
101. Nisbett RE. Taste, deprivation, and weight determinants of eating behavior. *J Pers Soc Psychol*. 1968;10(2):107-116. doi:10.1037/h0026283
102. Saelens BE, Epstein LH. *Reinforcing Value of Food in Obese and Non-Obese Women*. Vol 27.; 1996.
103. Stunkard AJ, Messick S. The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *J Psychosom Res*. 1985;29(1):71-83. doi:10.1016/0022-3999(85)90010-8
104. Webber L, Hill C, Saxton J, Jaarsveld C, Wardle J. *Eating Behaviour and Weight in Children*. Vol 33.; 2008. doi:10.1038/ijo.2008.219
105. Webber L, Cooke L, Hill C, Wardle J. Child adiposity and maternal feeding practices: a longitudinal analysis. *Am J Clin Nutr*.

2010;92(6):1423-1428. doi:10.3945/ajcn.2010.30112

106. Ventura AK, Birch LL. Does parenting affect children's eating and weight status? *Int J Behav Nutr Phys Act*. 2008;5:15. doi:10.1186/1479-5868-5-15

107. Mascola AJ, Bryson SW, Agras WS. Picky eating during childhood: a longitudinal study to age 11 years. *Eat Behav*. 2010;11(4):253-257. doi:10.1016/j.eatbeh.2010.05.006

108. Wright C, Birks E. Risk factors for failure to thrive: a population-based survey. *Child Care Health Dev*. 2000;26(1):5-16. doi:10.1046/j.1365-2214.2000.00135.x

109. Galloway AT, Lee Y, Birch LL. Predictors and consequences of food neophobia and pickiness in young girls. *J Am Diet Assoc*. 2003;103(6):692-698. doi:10.1053/jada.2003.50134

110. Gibson EL, Cooke L. Understanding Food Fussiness and Its Implications for Food Choice, Health, Weight and Interventions in Young Children: The Impact of Professor Jane Wardle. *Curr Obes Rep*. 2017;6(1):46-56. doi:10.1007/s13679-017-0248-9

111. Hayes JF, Altman M, Kolko RP, et al. Decreasing food fussiness in children with obesity leads to greater weight loss in family-based treatment. *Obesity*. 2016;24(10):2158-2163. doi:https://dx.doi.org/10.1002/oby.21622

112. Freeman J V, Cole TJ, Chinn S, Jones PR, White EM, Preece MA. Cross sectional stature and weight reference curves for the UK, 1990. *Arch Dis Child*. 1995;73(1):17. http://adc.bmj.com/content/73/1/17.abstract

113. Mei Z, Grummer-Strawn LM, Pietrobelli A, Goulding A, Goran MI, Dietz WH. Validity of body mass index compared with other body-composition

screening indexes for the assessment of body fatness in children and adolescents. *Am J Clin Nutr*. 2002;75(6):978-985. doi:10.1093/ajcn/75.6.978

114. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: International survey. *Br Med J*. Published online 2000. doi:10.1136/bmj.320.7244.1240

115. Cole TJ, Faith MS, Pietrobelli A, Heo M. What is the best measure of adiposity change in growing children: BMI, BMI %, BMI z-score or BMI centile? *Eur J Clin Nutr*. 2005;59(3):419-425. doi:10.1038/sj.ejcn.1602090

116. Hunot C, Fildes A, Croker H, Johnson F, Beeken RJ. Development of a brief Appetitive Trait Tailored Intervention (ATTI) in a sample of overweight and obese adults. In: *34th Annual Scientific Meeting of The Obesity Society*. ; 2016. Accessed April 9, 2020. https://www.researchgate.net/publication/309720102_Development_of_a_brief_Appetitive_Trait_Tailored_Intervention_ATTI_in_a_sample_of_overweight_and_obese_adults

117. Hamaker EL, Kuiper RM, Grasman RPPP. A critique of the cross-lagged panel model. *Psychol Methods*. 2015;20(1):102-116. doi:10.1037/a0038889

118. Hunot C, Fildes A, Croker H, Llewellyn CH, Wardle J, Beeken RJ. Appetitive traits and relationships with BMI in adults: Development of the Adult Eating Behaviour Questionnaire. *Appetite*. 2016;105:356-363. doi:10.1016/j.appet.2016.05.024

119. Ryan K, Dockray S, Linehan C. A systematic review of tailored eHealth interventions for weight loss. *Digit Heal*. 2019;5:205520761982668. doi:10.1177/2055207619826685

120. Helle C, Hillesund ER, Wills AK, Øverby NC. Evaluation of an eHealth intervention aiming to promote healthy food habits from infancy -the Norwegian randomized controlled trial Early Food for Future Health. *Int J Behav Nutr Phys Act*. 2019;16(1):1. doi:10.1186/s12966-018-0763-4

121. Boutelle KN, Knatz S, Carlson J, Bergmann K, Peterson CB. An Open Trial Targeting Food Cue Reactivity and Satiety Sensitivity in Overweight and Obese Binge Eaters. *Cogn Behav Pract*. 2017;24(3):363-373. doi:10.1016/j.cbpra.2016.08.003

122. Boutelle KN, Kang Sim DE, Manzano M, Rhee KE, Crow SJ, Strong DR. Role of appetitive phenotype trajectory groups on child body weight during a family-based treatment for children with overweight or obesity. *Int J Obes*. 2019;43(11):2302-2308. doi:10.1038/s41366-019-0463-4

123. Department of Health U, Services H, for Disease Control C. Preventing Chronic Disease, Public Health Research, Practice, and Policy,. doi:10.5888/pcd14.170491

124. Dooyema CA, Belay B, Foltz JL, Williams N, Blanck HM. The childhood obesity research demonstration project: A comprehensive community approach to reduce childhood obesity. *Child Obes*. 2013;9(5):454-459. doi:10.1089/chi.2013.0060

Introduction to Chapter Seven

Previous research conducted in Gemini revealed the heritability of child BMI is higher among children living in higher-risk (86%) home environments compared to those living in lower-risk (39%) home environments[1]. These findings suggest gene-environment interactions, whereby the expression of genetic risk is dependent on environmental exposure. In other words, the more obesogenic the environment, the stronger the genetic effect on body weight. Chapter Six demonstrated a robust relationship between appetite and weight in childhood, cross-sectionally and longitudinally, and many appetitive traits have previously been shown to have a moderate-to-strong heritable component, however, there is little research exploring gene-environment interactions with child appetitive traits. Paper five, presented in Chapter Seven, aims to test BST's hypothesis that individuals who inherit genes promoting a more avid appetite are more vulnerable to overeating and developing obesity in response to exposure to the 'obesogenic' environment.

Chapter 7

Variation in the heritability of child appetite based on the obesogenic risk in the Home Environment.

Chapter type:	Journal Article
Journal:	*International Journal of Behavioral Nutrition and Physical Activity*
Submission date:	To be submitted.

Note. *As this paper is due to be submitted, the formatting and layout are consistent with the requirements for International Journal of Behavioral Nutrition and Physical Activity, references will not follow the APA style and will be placed at the end of the chapter rather than at the end of the thesis.*

7.1 Abstract

Background: Behavioural Susceptibility Theory of obesity (BST) hypothesises that genes promoting a more avid appetite (i.e. higher responsiveness to food cues) are more potently expressed in an 'obesogenic' environment in which food cues are more prominent and there is greater opportunity to eat. This study aims to test BST by examining whether the heritability of food responsiveness varies by obesogenic risk in the home environment. It is hypothesised that the heritability of food responsiveness will be higher among children living in 'higher-risk' home environments.

Methods: Primary caregivers from the Gemini cohort completed the Home Environment Interview (HEI), a comprehensive measure of the home environment, via telephone when their twins were 4 years old. The HEI comprises four standardized composite scores: one for each domain (food, physical activity, and media) of the environment, as well as a score for the overall obesogenic home environment. The four composite scores were dichotomised based on the mean of zero, to create lower-risk (≤0) and higher-risk (>0) food, activity, media and overall home environment composites. Primary caregivers additionally completed the Food responsiveness (FR) subscale of the Child Eating Behaviour Questionnaire (CEBQ). Quantitative genetic model fitting was used to estimate the heritability of FR for children living in lower-risk and higher-risk home environments. Fit statistics were used to identify if the best-fitting model combined estimates of genetic and environmental influence across lower and higher risk HE groups or allowed them to vary.

Results: A total of 770 twin pairs (1540 individual twins; 757 [49.2%] male; mean [SD] age, 4.12 [0.4] years at HEI) were included in the analytic sample. The best-fitting model allowed estimates of genetic and environmental influence to vary

across higher and lower risk groups for the media, PA and overall home environment. For children living in a higher-risk media environment, the heritability of FR was higher (80%; 95% CI, 61-91%) than for those living in a lower-risk environment (48%; 95% CI 36-61%). In contrast, in the lower-risk home media environments the shared environmental influence on FR was significantly higher (41%; 95% CI, 28%-52%) compared to in higher-risk media environments (8%; 95% CI, 0%-27%). For the PA and overall home environment, the unique environmental influences were significantly higher in the higher risk groups, but the difference was small (11% and 8% respectively). The best-fitting model for the food environment had the same estimates of genetic and environmental influence across both lower and higher risk groups.

Discussion: The findings provide partial support for BST by suggesting that the shared environmental influence on appetite was higher in lower-risk home media environments and that obesity-related genes may be more strongly associated with child appetite in higher-risk media environments. Modifying the media environment children are exposed to in the family home could help to protect those predisposed to a more avid appetite.

Key words: Home Environment, Food Responsiveness, Children, Media, Obesity, Appetite

7.2 Background

Rates of obesity have risen dramatically in the past centuries. However, despite wide-spread exposure to the ‘obesogenic’ environment in western countries, there are still considerable individual differences in human body weight and twin and family studies estimate that up to 70% of the variation is attributable to genetic differences between people[2–4]. The consensus is that obesity develops from a combination of genetic susceptibility and exposure to an ‘obesogenic’ environment. Behavioural Susceptibility Theory of obesity (BST) provides a possible explanation for how genes and environments interact to determine individual variation in body weight. BST proposes that inherited differences in appetite avidity influence why some people eat more, in response to environmental cues and opportunity, and therefore are more likely to gain weight [2,3].

A burgeoning research base has demonstrated that the heritability of body mass index (BMI)[5,6] varies substantially by population and socio-environmental characteristics and, in particular, by broad-level metrics of an ‘obesogenic’ environment such as socioeconomic status (SES), country-level wealth, and year-of-birth. For example, a large twin study in the Netherlands (n=33,338 children) reported that the heritability of BMI was significantly higher among children living in lower SES households, compared to those living in more affluent homes[7]. Similar findings have been observed in countries with higher gross domestic product (GDP)[6] and in populations born after the onset of modern ‘obesogenic’ environment[5,8–10]. Comparatively less is known about the mechanisms and behavioural pathways driving this variation in individuals' response to environmental exposure.

A large body of evidence has identified food responsiveness (i.e. wanting to eat in response to the sight, smell or taste of palatable food) as a key appetitive trait implicated in an individual's risk for excess weight gain[2,11,12]. Since the 1960s, evidence for the role of food responsiveness has amassed from behavioural studies conducted in both children and adults[13,14], as well as studies of biomarkers (e.g. salivary responses, brain activation) in adults[15–17]. Early experimental research demonstrated that individuals with obesity were more responsive to food cues and consumed more palatable foods[13,18], compared to individuals with a healthy weight. More recently, the parent-report Child Eating Behaviour Questionnaire was developed to measure food responsiveness (among other eating behaviours) psychometrically in large numbers of children. Studies using the CEBQ have reported that children who score higher on the food responsiveness scale consume more total energy, eat at a faster rate[14] and have greater preference for energy-dense foods[19]. A comprehensive systematic review and meta-analysis of 72 studies of the CEBQ (n=27 meta-analysis) revealed that food responsiveness was consistently associated with higher BMI in childhood, both cross-sectionally and longitudinally[20].

BST suggests gene-environment interactions, whereby the genetic and environmental influences underlying a trait increase or decrease depending on environmental exposure. Like human body weight, appetite has a moderate-to-strong heritable component[21–25], with 59% of the variance in food responsiveness attributable to additive genetic influences in infancy[26] and 75% in school-aged children (8-11 year olds)[4]. Alongside the evidence for a relationship between appetite and weight, these findings provide preliminary support for BST. This suggests that individuals with genes predisposing them to a more avid appetite – expressed behaviourally as higher food responsiveness - are more likely to overeat and gain excessive weight in response to an ‘obesogenic’ environment characterised by greater prominence of food cues and increased opportunity to eat.

The home environment has been identified as an important influence on the development of eating behaviours and risk of excess weight gain in early childhood[27–31]. The ‘obesogenic’ home environment can be conceptualised in terms of three separate domains; the food, physical activity and media domains[31–33]. Recent findings from a large twin study of 1850 children (mean [SD] age=4.2 [0.4] years) demonstrated that the heritability of BMI was significantly higher for children living in ‘higher-risk’ (more obesogenic) home environments, compared to those living in ‘lower-risk’ homes (heritability 86% vs 36%, respectively)[1]. These findings indicate that the genetic influence on weight is more potently expressed in more obesogenic home environments[1]. However, to date no research has examined appetite as the mediating mechanism for gene-environment interaction - i.e. whether the genetic influence on appetite is also more strongly expressed in an obesogenic environment. Therefore, this study aims to test BST by examining whether the heritability of food responsiveness varies by obesogenic risk in the home environment. In accordance with BST, it is hypothesised that the heritability of food responsiveness will be higher among children living in ‘higher-risk’ (more obesogenic) home environments compared to those living in ‘lower-risk’ home environments.

7.3 Methods

7.3.1 Sample

Participants were from the Gemini study, a longitudinal birth cohort of families with twins born in England and Wales between March and December 2007. In total, 2,402 families with monozygotic (identical) and dizygotic (non-identical) twins (n=4804) consented to take part and completed the baseline questionnaire when their children were a mean (±SD) of 8.2 (±2.2) months old [34]. The Home Environment Interview (HEI) was completed by 1113 of the 2402 families (46% of the total sample) when the children were 4.2 (±0.4) years of age. Parents were also asked to complete the Food Responsiveness scale of the Child Eating Behaviour Questionnaire (CEBQ) when the children were 5.15 (±0.13) years of age. The study sample comprised 770 twin pairs (1540 children; 757 [49.2%] male and 783 [50.8%] female) with data on all study variables. Ethical approval was granted by the University College London Committee for the Ethics of non-National Health Service Human Research.

7.3.2 Measures

7.3.2.1 Zygosity

Parents were asked to report whether their twins were the same-sex or opposite-sex. Opposite-sex twins were classified as dizygotic (DZ). Parents of same-sex twins were asked to complete a previously validated 20-item questionnaire to establish zygosity[35]. The questionnaire assesses the twins' physical likeness, blood type, parents' and health professionals' opinions about the twins' zygosity, and how easily friends and family members can tell the twins apart. The questionnaire has been previously validated against DNA markers, and showed

100% agreement with DNA samples of 81 randomly selected Gemini twin pairs (43 mono-zygotic [MZ] and 38 DZ twins) at 29 months of age[36].

7.3.2.2 Measurement of Food responsiveness

Child food responsiveness was assessed using a 5-item scale from the Child Eating Behaviour Questionnaire (CEBQ)[37]. The CEBQ is a parent-reported psychometric measure of eight appetitive traits, which consists of 35 items and has been validated using behavioural measures of food intake[14]. Food Responsiveness (FR) measures a child's drive to eat in response to external food cues, i.e. the sight, smell or taste of palatable food (e.g. 'Even if my child is full up s/he finds room to eat his/her favourite food'). Items are rated using a 5 point Likert-Scale (1=Never, 2=Rarely, 3=Sometimes, 4=Often, 5=Always) and were averaged to create a food responsiveness total score. At least three of five items needed to be scored to calculate the mean total score. The original development paper reported high test-retest reliability for the FR subscale over a two week period (r=0.83) and high Cronbach's alpha (0.80-0.82) indicating good internal reliability [37].

7.3.2.3 Home Environment

Primary caregivers completed the HEI by telephone when their twins were 4 years of age. A total of 32 home environment constructs were included in the composites. Constructs identified as being associated with decreased risk for weight gain were reverse-scored so that a higher total score on each composite would reflect higher risk for weight gain. Each variable was then standardized using z-scores. Missing values were recoded to 0 (the mean value for a standardized variable). There were few missing cases on home environment variables: 15 (1.4% of the total sample) for garden play equipment; 39 (3.6%) for emotional feeding, instrumental feeding, encouragement, and modelling of healthy eating; 40 (3.6%) for monitoring and covert restriction; and 42 (3.8%) for restriction. The only variable with more than 5% missing was partner TV viewing (these cases did not have a partner), and data were missing in just 73 cases (6.7% of the analytic sample). Statistical analyses may be biased when more than 10% of data are missing[38], but none of the home environment variables reached this level of missing data. The missing cases were assigned the mean score because this approach has been shown to provide a more accurate estimate of association than other methods of handling missing data[39]. Results were checked by undertaking sensitivity analyses which included families with complete data only. The standardized variables (z-scores) were then summed to create three composites: one for the home food environment (the sum of 21 food environment variables), one for the home activity environment (the sum of 6 activity environment variables), and one for the home media environment (the sum of 5 media environment variables). The food, activity, and media composites were then summed to create an overall home environment composite, dividing by the number of variables per composite so that each domain contributed equally to the overall score (food composite/21 + activity composite/6 + media composite/5).

Test-retest reliability of the home environment composites over the course of 7 to 19 days (mean [SD], 9.6 [3.4] days) was acceptable to high. The intraclass correlation coefficients were 0.71 (95% CI, 0.52–0.83) for food, 0.83 (95% CI, 0.72–0.91) for activity, 0.92 (95% CI, 0.85–0.95) for media, and 0.92 (95% CI, 0.86–0.96) overall.

7.3.2.4 Statistical Analyses

7.3.2.4.1 Phenotypic associations with home environment composites

Complex samples general linear models were used to examine associations between the domain-specific composite scores (food, media, activity, as well as the overall composite) and the appetitive trait food responsiveness. For the purpose of these models, the home environment composite scores were kept as continuous variables for the full variation in scores to be taken into account. For each model the dependent variable was food responsiveness, with the domain-specific composite score (e.g. home food composite) as the predictor. Child sex, and age at measurements were included as covariates in the model. Higher scores on the composite means a higher-risk environment within the home. Complex samples analyses were used to account for clustering of twins within families. The alpha level was set at <0.05.

7.3.2.4.2 Heritability Analyses

Genetic and environmental contributions to variation in a trait can be estimated by comparing similarity between MZ twins (who share 100% of their genes) with DZ twins (who share on average 50% of their genes). Comparing within-pair correlations between MZ and DZ pairs allows for the variation in a trait to be decomposed into 3 latent factors (the ACE model): additive genetic effects (i.e., heritability; A); shared environmental influence (shared experiences that contribute to twin-pair similarity; C); and non-shared environmental influence (experiences unique to an individual that make twins within a pair different; E), which also includes random measurement error. Mono-zygotic (MZ) twins share 100% of their genes and di-zygotic (DZ) twins share approximately 50% of their genes, therefore the genetic correlation within MZ and DZ pairs were fixed at 1.0 and 0.5, respectively. It is assumed that shared environmental influences are equal for MZ and DZ twins, therefore the shared environmental correlation was fixed at 1.0 for both zygosities.

Two methods were used to estimate heritability of food responsiveness: twin correlations and maximum likelihood structural equation modelling (MLSEM). Twin correlations are conducted in the first instance to derive an indication of genetic and environmental contributions to variation in a trait. If similarity of MZ twin pairs is greater than the correlation of DZ twin pairs for the trait of interest, it indicates a significant effect of genetics, as the only assumed difference between the two types of twins is that MZ twin pairs are twice as similar genetically as DZ twin pairs. Whereas, if correlations between MZ and DZ twin pairs are similar, it indicates that environmental influences shared between twin pairs in one family are important in explaining individual differences in the observed trait. The model-fitting was then used to provide precise estimates of A, C, and E with 95% confidence intervals and goodness-of-fit statistics. Initially, the univariate model was fitted to the data to produce reliable parameter estimates for the whole sample with 95% confidence intervals (CIs) and Goodness-of-Fit statistics. Then a heterogeneity model was run to test for differences in estimates of A, C and E between lower-risk and higher-risk groups. For each method, child food responsiveness scores were residualized for age at measurement and sex effects using linear regression. This was done as age and sex is completely correlated within twin pairs, and might therefore inflate the twin pair similarity (and the shared environmental effect). The analyses were repeated using food responsiveness scores additionally residualized for gestational age using linear regression, which is also correlated within twin pairs.

Heritability estimates for food responsiveness scores were calculated for the total sample and for home environment groups separately (food, activity, media and overall home environment), which were dichotomized based on the mean of zero. Lower-risk (≤0) and higher-risk (>0) food, activity, media and overall home environments.

7.3.2.4.3 Twin Correlations

Intraclass correlations were calculated for each zygosity (MZ and DZ) and for each zygosity by each home environment group (e.g. MZs living in a higher-risk overall home environment) in R[40] using the structural equation modelling software OpenMx, version 2.19.1[41].

7.3.2.4.4 Model fitting

Univariate twin models (including all twins together regardless of risk group) were created in R[40] for each home environment domain, using the structural equation modelling software OpenMx, version 2.19.1.[41]. First, a common effects model was fitted to compare parameter estimates in lower-risk and higher-risk home environment groups. This is the fullest model allows both the variances to differ and the magnitude of A, C, and E to differ between groups. The second model (the scalar model) constrains the magnitudes of A, C and E to be the same but allows the variances to differ. The final model (the null model) constrains all parameters to be the same across the two groups. The fit of the sub-model was then compared with the previous model using likelihood ratio tests (i.e. the scalar is compared to the common effects model, and the null model is compared to the scalar model). A significant difference between the negative log-likelihood indicates a deterioration in model fit. Statistical significance was set at 0.05.

7.3.2.4.5 Statistical power

Following statistical advice from a lecturer in behavioural genetics at Kings College London, a sample size calculation was not conducted as this is not common practice post-hoc (i.e. following data collection) in genetics research. Evidence suggests that ~600 twin pairs are required to confidently reject other models and determine the best fitting model[42], the sample size in this study was 770 twin pairs. Furthermore, the sample size was similar to that of previous twin research with the same methodological approach[1].

7.4 Results

7.4.1 Sample characteristics

Of the 1113 families (n=2226 twins) that took part in the HEI, 12 twin-pairs had unknown zygosity, and 331 families (29.7%) had missing appetite data. This left a sample of 770 twin pairs (1540 twin children); 260 twin pairs (33.8%) were MZ. The characteristics for the sample by higher-risk and lower-risk home environments (based on the overall HE composite) are shown in **Table 7.1.** There were no significant differences between the analysis sample and the total HEI sample with respect to the study variables, except for maternal age which was higher in the analysis sample and the home media composite (see Appendix F.1 in supplementary material).

Table 7.1. Characteristics of the Study Sample by Overall Home Environment Risk, mean (SDs or range) for continuous variables and percentage (N) for categorical variables.

	Overall higher-risk home environment (n= 328)	Overall Lower-risk Home environment (n=442)	P Value Difference
Age of child at HEI (years)	4.10 (0.43)	4.14 (0.37)	.393
Age of child at CEBQ (years)	5.16 (0.14)	5.15 (0.12)	.160
Gestation (weeks)	36.34 (2.32)	36.30 (2.54)	.944
Sex of twin pair			
Male	35.7 (117)	32.8 (145)	
Female	37.2 (122)	34.6 (153)	.081
Opposite	27.1 (89)	32.6 (144)	
Zygosity			
MZ pairs	39.3 (129)	29.6 (131)	.006
DZ pairs	60.7 (199)	70.4 (311)	
Maternal age at twin's birth (years)	33.69 (4.78)	34.41 (4.29)	.078
SES composite score[1]	4.29 (1.30 to 6.90)	4.90 (1.80 to 6.96)	<.001
Overall Home Environment composite score	0.82 (0.00 to 3.94)	-0.70 (-2.45 to 0.00)	<.001
Food composite score	3.51 (-11.75 to 25.10)	-3.06 (-19.24 to 9.41)	<.001
Activity composite score	1.94 (-4.94 to 15.73)	-1.43 (-4.94 to 5.51)	<.001
Media composite score	1.95 (-5.81 to 18.11)	-1.83 (-7.00 to 5.70)	<.001

HEI = Home Environment Interview (HEI); MZ = monozygotic; DZ = dizygotic; SD = standard deviation.

[1]Missing data for 34 families (n=736)

7.4.2 Phenotypic associations with home environment composites

The associations between the home environment composites and food responsiveness are shown in **Table 7.2.** Food responsiveness was positively associated with the home environment (the food, activity, media, and overall home environment composite), indicating that higher-risk (a one unit increase in SD of HE risk score) home environments were associated with higher food responsiveness in children.

Table 7.2. Complex samples general linear model: associations between the home environment composites (food, activity, media, and overall) and food responsiveness.

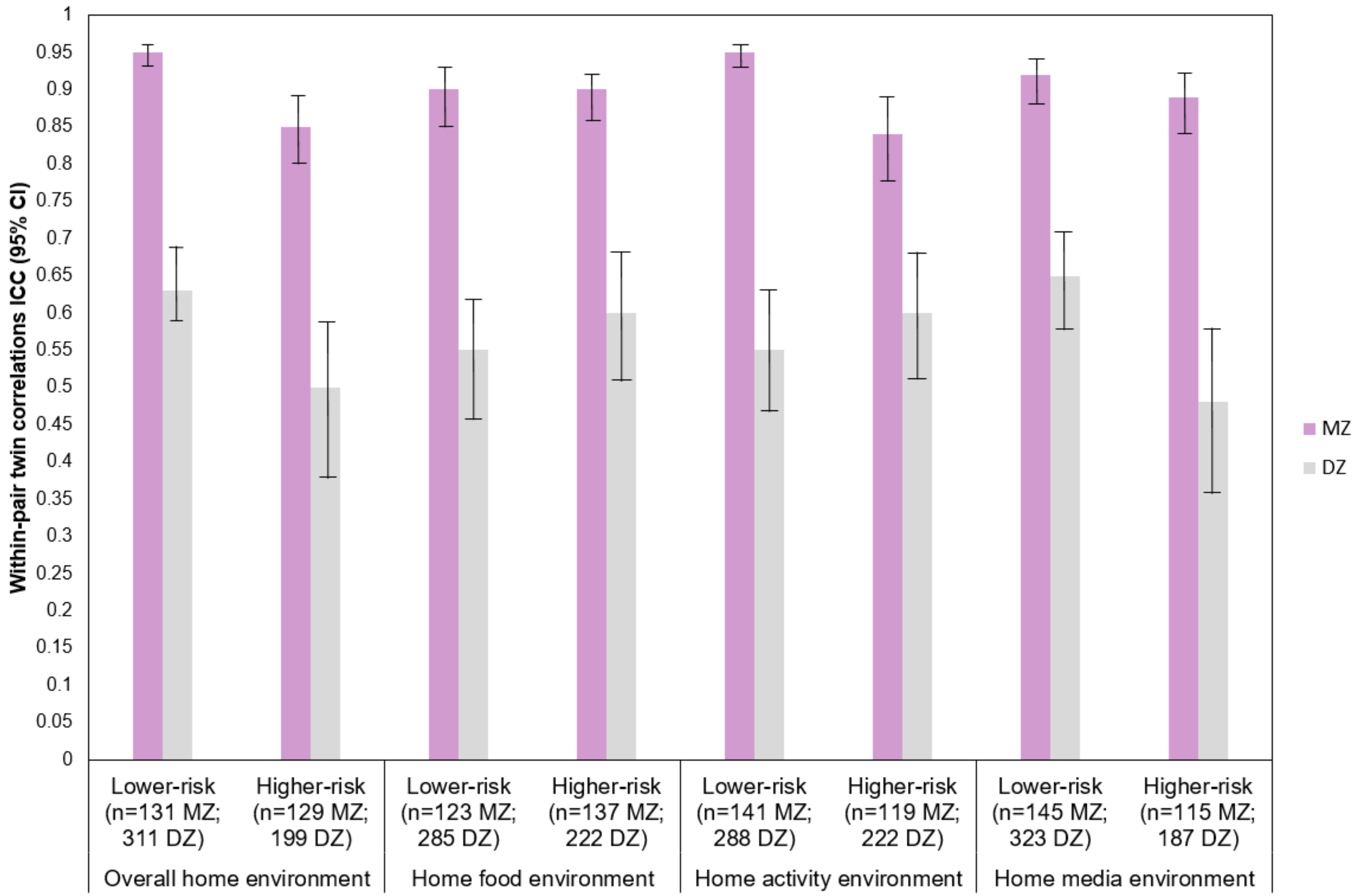
	Food responsiveness	
	Standardized β (±SE)	**R^2**
Overall home environment composite	**0.21 (0.04)****	**.04**
Food environment composite	**0.02 (0.01)****	**.02**
PA environment composite	**0.04 (0.01)****	**.02**
Media environment composite	**0.04 (0.01)****	**.02**

[1]Adjusting for clustering within families (complex samples analyses), the child's age at time of home environment interview, child sex. *p<.01, **p<.001. Abbreviations: PA=Physical activity

7.4.3 Twin correlations

The intraclass correlation coefficients for the trait scores (adjusted for age and sex) by zygosity and home environment groups are shown in **Figure 7.1.** Correlations were higher within MZ than DZ pairs (ranges, ICC=0.85-0.95 vs ICC=0.50-0.63), indicating additive genetic influence on food responsiveness. The results remained when additionally adjusting for gestational age.

Figure 7.1. Intraclass Correlations of Child food responsive scores by Zygosity and Home Environment risk group.



Abbreviations: MZ, monozygotic twins; DZ, dizygotic twins; 95% CI, Confidence Interval, N, Number; ICC, Intraclass correlations

7.4.4 Maximum Likelihood Structural Equation Modelling

For the total sample combined, the variance in food responsiveness was largely attributable to additive genetic factors (62%; 95% CI, 49%-74%), moderately attributed to shared environmental factors (27%; 95% CI, 15%-37%), with a small contribution from non-shared environmental factors (11%; 95% CI, 9%-14%). Parameter estimates for the higher-risk and lower-risk home environments are summarised in **Table 7.3.** For the overall home environment, the media and the physical activity environment, the common effects model provided the best fit for the data, which allowed A, C and E to vary across higher and lower risk groups. For the overall home environment, the unique environmental influence differed significantly across the groups, with a slightly higher contribution in the higher- vs the lower-risk group (15% versus 7% respectively). There was also a sizeable difference between the groups in the magnitude of the shared environmental influence, with a greater influence in the lower- vs higher-risk group (35% vs 14%). Although the 95% CIs overlapped, the point estimates in each group were outside the 95% CIs of the other group. The heritability of food responsiveness was higher in the higher-risk home media environments (80%; 95% CI, 61-91% vs 48%; 95% CI, 36-61%), although again the 95% confidence intervals overlapped slightly, with the point estimates for the lower- and higher-risk groups were outside the 95% CIs for the other respective group. The shared environmental influence on food responsiveness was significantly stronger in the lower vs the higher-risk home media environment; 41% for lower-risk and 8% for higher-risk home media environments. Estimates for the home physical activity environment also indicated differences between higher-risk and lower-risk environments but in the opposite direction, with higher heritability in lower-risk home environments, and higher shared environmental influence in the higher risk environment. Again, the confidence intervals overlapped, but the point estimates for each group sat outside the 95% CIs of the other respective group for both A and C. For the home food environment, the scalar model fitted the data best, indicating that there were no significant differences in the magnitudes of A, C or E across the groups, and only significant differences in the variances for Food Responsiveness. These results were replicated when additionally adjusting food responsiveness score for gestational age.

Table 7.3. Parameter Estimates and Goodness-of-Fit Statistics for Home Environment Interaction Models that examined the heritability of food responsiveness at 4 years of age.

Home environment model[a]	Estimate for Food responsiveness				
	Additive Genetic	Environment Shared	Unique/non-shared[b]	Change in AIC	P value
Overall (home)					
Common effects					
Lower risk	0.58 (0.47, 0.72)	0.35 (0.21, 0.46)	0.07 (0.05, 0.09)	NA	NA
Higher risk	0.71 (0.52, 0.88)	0.14 (0.00, 0.32)	0.15 (0.11, 0.20)	NA	NA
Scalar	0.62 (0.51, 0.74)	0.27 (0.15, 0.37)	0.11 (0.09, 0.14)	51.07	<.001
Null	0.61 (0.50, 0.73)	0.28 (0.25, 0.38)	0.11 (0.09, 0.14)	15.07	<.001
Food					
Common effects					
Lower risk	0.67 (0.52, 0.84)	0.22 (0.05, 0.36)	0.11 (0.09, 0.15)	NA	NA
Higher risk	0.55 (0.41, 0.72)	0.34 (0.17, 0.48)	0.11 (0.09, 0.15)	NA	NA
Scalar	0.61 (0.50, 0.73)	0.28 (0.16, 0.38)	0.11 (0.09, 0.14)	3.30	0.05
Null	0.61 (0.50, 0.73)	0.28 (0.25, 0.38)	0.11 (0.09, 0.14)	-5.02	<.01
Activity					
Common effects					
Lower risk	0.76 (0.62,0.93)	0.17 (0.01, 0.32)	0.06 (0.05, 0.08)	NA	NA
Higher risk	0.44 (0.28, 0.62)	0.39 (0.21, 0.53)	0.17 (0.13, 0.23)	NA	NA
Scalar	0.61 (0.50, 0.69)	0.28 (0.16, 0.38)	0.11 (0.09, 0.14)	35.64	<.001
Null	0.61 (0.50, 0.73)	0.28 (0.25, 0.38)	0.11 (0.09, 0.14)	-1.79	0.04
Media					
Common effects					
Lower risk	0.48 (0.36, 0.61)	0.41 (0.28, 0.52)	0.11 (0.08, 0.14)	NA	NA
Higher risk	0.80 (0.61, 0.91)	0.08 (0.00, 0.27)	0.12 (0.09, 0.16)	NA	NA
Scalar	0.62 (0.51, 0.74)	0.27 (0.21, 0.37)	0.11 (0.09, 0.14)	46.49	<.001
Null	0.61 (0.50, 0.73)	0.28 (0.25, 0.38)	0.11 (0.09, 0.14)	7.317	<.01

Abbreviations: AIC, Akaike Information criterion; NA, not applicable.
[a]Statistical analyses: standard ACE model-fitting analyses for continuous data were used to model food responsiveness score at 4 years of age.
[b]Includes measurement error
[c]*P* values were based on the likelihood ratio test and AIC. A better-fitting sub-model showed a change in χ^2 that did not represent a significant worsening of fit designated by the P value.

7.5 Discussion

This is the first study to test the BST hypothesis that appetite is more heritable among children who live in higher-risk home environments compared to those living in lower-risk home environments. Our study only partly supported this hypothesis. The heritability of food responsiveness was higher among children living in higher-risk home media environments (80%; 95% CI, 61-91%) compared to those living in lower-risk home media environments (48%; 95% CI 36-61%), although the confidence intervals overlapped marginally but the point estimates for each group sat outside the 95% CIs for the other respective group. Nonetheless, the proportion of variance in food responsiveness attributable to shared environmental factors was significantly greater in lower-risk home media environments (41%; 95% CI, 28-52%) compared to higher-risk home media environments (8%; 95% CI, 0-27%, respectively). These findings suggest that lower-risk home media environments may be protective against the expression of food responsiveness, an eating behaviour which has been linked to greater risk of overweight. However, we observed the opposite pattern for the home physical activity environment - higher heritability of Food Responsiveness in the lower- vs higher-risk group (76%; 95% CI, 62-93% vs 44%; 95% CI, 28-62%, although again with marginally overlapping intervals) – and no significant differences across the home food environment or the composite home environment score. We did, however, observe that children living in higher-risk home environments (food, activity, media and overall) exhibited higher food cue responsiveness, indicated by significant phenotypic associations between each of the home environment domain scores and Food Responsiveness.

Our findings provide partial support for the BST's hypothesis that individuals who inherit genes promoting a more avid appetite (i.e. higher responsiveness to food cues) are more vulnerable to overeating, if they are reared in a more 'obesogenic' environment characterised by greater media exposure specifically[2,3]. Higher-risk home media environments are characterised by greater availability and access to electronic devices, greater parental modelling of screen-based sedentary behaviours and fewer rules around devices. A recent systematic review of 62 observational studies observed robust relationships between aspects of the media environment and weight in childhood[31]. Research conducted in the same sample as the current study demonstrated children living in higher-risk media environments engaged in more screen-viewing behaviour[30,32] and displayed greater increases in weight from ages 4 to 12[43].

Screen-time and poorer dietary intake are behaviours that co-occur[44], and greater exposure to food cues via food advertisements may be one mechanism driving this[45]. Evidence suggests food advertisements are effective at influencing children's food choices and their intake of foods and beverages[45–48]. Children who are exposed to food advertisements are more likely to pester their parents to purchase energy-dense food products or purchase energy-dense snack foods and beverages themselves[49]. Existing research has also shown that individuals respond differently to food advertisements, with susceptible individuals (classified based on weight status) consuming more in the presence of food cues[50–54].

Children who inherit an avid appetite (e.g. high food responsiveness) may be more susceptible to expressing these appetitive behaviours in response to greater exposure to on-screen foods advertisements. Our finding that the shared environmental influence on variance in food responsiveness was greater in lower-risk media environments, suggests that aspects of a less obesogenic home media environment may offer some protection against the expression of this behaviour. These may include parental rules and policies around screen-time and parental modelling of activities other than screen-time, which result in less overall exposure to food advertising via limited media use among children.

In contrast to our hypothesis, the heritability of food responsiveness was higher among children living in *lower-risk* physical activity environments compared to those in higher-risk physical activity environments (76% vs 44% for variance attributed to additive genetic factors), although the confidence intervals marginally overlapped. These findings appear counter-intuitive, especially when considering previous literature examining the heritability of BMI in relation to physical activity[55–57]. However, previous research conducted in this sample demonstrated that children living in lower-risk physical activity environments engaged in more physical activity than children living in higher-risk activity environments[32]. Evidence from adults has shown that increased physical activity is associated with higher caloric intake[58,59], but data surrounding the effect of exercise on appetite is limited in children[60]. In adults it has been hypothesised that physical activity may influence appetite control through a dual-process action which increases an individual’s drive to eat but also post-meal satiety[61,62]. Engaging in physical activity may influence appetite by altering hedonic response to foods[63]. Experimental studies found individuals reported greater pleasure from food consumed following physical activity[64], and rated high-carbohydrate foods as more palatable following exercise[63,65]. Additionally, studies have indicated individuals may seek out particular foods (e.g. high-carbohydrate foods) in response to physical activity to replenish short-term energy stores[66]. Of note, all studies have shown large individual difference in the appetite response to physical activity, which may be partly genetically determined. Taken together, these findings suggest that engaging in more physical activity may allow greater genetic expression of an individual's responsiveness to foods (i.e. the drive to eat when see, smell or taste palatable foods) – that is, in an environment with greater opportunity for physical activity, differences between individuals' appetitive responses to physical activity will emerge more clearly. Future research in larger, more diverse samples with greater variation in the obesogenic risk in the physical activity environment will help to clarify the interplay between genes, physical activity, and appetite regulation.

There was an indication of greater shared environmental influence on food responsiveness among children living in a lower-risk environment, according to the overall HE score (14% vs 35%). Again, the confidence intervals overlapped, but the point estimates for each group sat outside the 95% CIs for the other respective group. The overall home environment composite is a combined score which includes the food, activity and media environments. What we observe for the overall home environment score combines the conflicting findings for the media and physical activity composites, reducing the observed difference in parameter estimates between the higher-risk and lower-risk overall home environment groups.

The most surprising finding, contrary to our hypothesis, was that there was no difference in the heritability of Food Responsiveness across lower- and higher-risk home food environments. Rather, the best-fitting model estimating the same values for A, C and E across both groups. In accordance with BST, it was expected that the heritability of food responsiveness would be higher in higher-risk home food environments (i.e. with greater availability of and access to energy-dense foods, sugar-sweetened beverages, fewer rules and limit setting, fewer mealtimes, etc.). In other words, the genetic influence on food responsiveness was expected to be more potently expressed in higher-risk home food environments, with greater environmental opportunity to express such behaviour. It is possible this unanticipated finding results from measurement issues in accurately capturing the dynamic food environment, or biases in responding. Furthermore, it is possible that the lack of difference observed for the home food environment may be a consequence of a caregiver modifying the types of foods available within the home in response to a child's appetite. Previous research has shown that caregiver feeding practices are in part responsive to a child's appetite or weight status[67–70]. For example, a caregiver of a child who is highly responsive to food may limit the availability of energy dense snacks in the home, in an effort to moderate a child's intake and subsequently weight. In contrast, a caregiver of a child who is less responsive to food may not feel the need to modify food availability or accessibility within the home, or may even increase the availability of energy-dense foods to encourage their child to eat more.

7.5.1 Limitations

There are several limitations to this study that should be acknowledged. The heritability estimates were derived from parent-reported measures of appetite, which may be subject to desirability biases or parental biases due to the subjective nature of the assessment. For example, parental rating of their child's appetite may have been influenced by their own appetite. The CEBQ has however been shown to be a valid measure with good correspondence to objective measures of appetite[14].

Although a common issue of longitudinal cohort studies[71], the majority of families in this sample were of higher socioeconomic status and identified as White, meaning that the sample may not be fully representative of the general population[72]. As such, true population-representative variation in home environment obesogenic risk may not have been captured, and differences in the heritability estimates for appetite may be more pronounced in home environments with greater variation. Gene-environment effects are stronger in more extreme environments[73,74], therefore, further research is warranted to examine gene-environment effects in larger, more diverse samples to clarify the relative contributions of the home food, physical activity and media environments. It would be beneficial to replicate these findings in more ethnically and socioeconomically diverse samples, with greater variation in the obesogenic risk of home environments. Furthermore, replication of the study using larger sample sizes, with more power to detect differences in heritability by groups, would be beneficial as small sample sizes can result in imprecise estimates, with large confidence intervals.

The findings suggest gene-environment interactions, but it is possible that the findings may be explained to some extent by passive or evocative gene-environment correlations. Passive gene-environment correlations occur when parents pass on associated genes and create environments that nurture their child's behaviour, meaning a child may be raised in a home environment that is correlated with their genotype[75]. For example, a child who inherits genes predisposing them to be more responsive to food cues, may also grow up with a food responsive parent who creates an environment that nurtures expression of this trait. While evocative gene-environment correlations can occur if a child expresses genetically determined behaviours and these behaviours evoke specific responses from their parents[76]. For example, a parent may modify their feeding practices or the types of foods and beverages available in the home, if a child is particularly responsive to food cues. Statistical approaches have been developed to account for gene-environment correlations in twin studies[35], but larger sample sizes are required to conduct such analyses.

Finally, a key assumption of the twin method is the equal environments assumption (EEA), which states that MZ and DZ twins share equally similar environments[77]. However, there is some evidence that MZ twins share more similar environments than DZ twins[78,79], for example, parents may treat MZ twins as more similar than DZs, which may lead to inflated heritability estimates. The EEA has been explored in Gemini using the 'misclassification of zygosity' design to test for parental bias in ratings of children's appetite[36]. The findings indicated that parental perception of twins' zygosity did not bias ratings of children's appetite in this sample, and provides support for the EEA and the twin method[36].

7.5.2 Conclusion

This is the first study to test the hypothesis that the heritability of appetite varies according to the obesogenic risk in the home environment. Our findings partly align with BST insofar as genetic influence on appetite is more strongly expressed in higher-risk media environments during childhood. At the same time, the shared environmental influence (41% vs 8%) on food responsiveness was significantly higher in lower-risk media environments, suggesting that an environment with less access to media may buffer the genetic expression of food responsiveness. This study highlights that the early home media environment (availability of screens, rules around screen-based media use in the family home etc.) may be an important avenue to consider when developing childhood obesity prevention and treatment strategies and that interventions may benefit from being tailored to a child's individual appetite profile. Future research in more diverse, larger samples is required to replicate the findings.

Abbreviations

HEI: Home Environment Interview
BST: Behavioural Susceptibility Theory
DZ: Di-zygotic
MZ: Mono-zygotic
FR: Food Responsiveness
CEBQ: Child Eating Behaviour Questionnaire
PA: Physical Activity

Declarations

Ethical approval and consent to participate

Ethical approval was originally granted for the study in 2007 by the University College London (UCL) Committee for the Ethics of non-National Health Service

Human Research. Written informed consent was provided by all Gemini families. All aspects of data collection and storage complied with the standards specified by this body.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the Economic and Social Research Council Advanced Quantitative Methods Studentship (Project reference: 1948633) which was awarded to Alice Kininmonth. The funders had no role in any element of this research.

Authors' contributions

AK and AF, in collaboration with CHL and AS, were responsible for the conceptualisation and design of the study. AK conducted the data analysis and was responsible for creating the first draft of the manuscript and all revisions of the manuscript. AF, CHL, AS, SS & AF oversaw this process. All authors have read, contributed to and approved the final manuscript.

Conflicts of interest

None to disclose.

Acknowledgements

We would like to thank the Gemini families for their participation in the study.

7.6 References

1. Schrempft S, van Jaarsveld CM, Fisher A, et al. Variation in the heritability of child body mass index by obesogenic home environment. *JAMA Pediatr*. 2018;172(12):1153-1160. doi:10.1001/jamapediatrics.2018.1508

2. Wardle J, Carnell S. Appetite is a Heritable Phenotype Associated with Adiposity. *Ann Behav Med*. 2009;38(suppl_1):s25-s30. doi:10.1007/s12160-009-9116-5

3. Llewellyn C, Fildes A. Behavioural Susceptibility Theory: Professor Jane Wardle and the Role of Appetite in Genetic Risk of Obesity. *Curr Obes Rep*. 2017;6(1):38-45. doi:10.1007/s13679-017-0247-x

4. Carnell S, Haworth CMA, Plomin R, Wardle J. Genetic influence on appetite in children. *Int J Obes (Lond)*. 2008;32(10):1468-1473. doi:10.1038/ijo.2008.127

5. Reddon H, Guéant J-L, Meyre D. The importance of gene–environment interactions in human obesity. *Clin Sci*. 2016;130(18):1571-1597. doi:10.1042/CS20160221

6. Min J, Chiu DT, Wang Y. Variation in the heritability of body mass index based on diverse twin studies: a systematic review. *Obes Rev*. 2013;14(11):871-882. doi:10.1111/obr.12065

7. Silventoinen K, Huppertz C, Beijsterveldt CEM van, Bartels M, Willemsen G, Boomsma DI. The genetic architecture of body mass index from

infancy to adulthood modified by parental education. *Obesity*. 2016;24(9):2004-2011. doi:10.1002/OBY.21588

8. Rokholm B, Silventoinen K, Tynelius P, Gamborg M, Sørensen TIA, Rasmussen F. Increasing genetic variance of body mass index during the swedish obesity epidemic. *PLoS One*. 2011;6(11):e27135. doi:10.1371/journal.pone.0027135

9. Wardle J, Carnell S, Haworth CM, Plomin R. Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment. *Am J Clin Nutr*. 2008;87(2):398-404. doi:10.1093/ajcn/87.2.398

10. Rokholm B, Silventoinen K, Ängquist L, Skytthe A, Kyvik KO, Sørensen TIA. Increased genetic variance of BMI with a higher prevalence of obesity. *PLoS One*. 2011;6(6). doi:10.1371/journal.pone.0020816

11. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*. 2008;88(1):22-29. doi:10.1093/ajcn/88.1.22

12. Webber L, Hill C, Saxton J, Jaarsveld C, Wardle J. *Eating Behaviour and Weight in Children*. Vol 33.; 2008. doi:10.1038/ijo.2008.219

13. Schachter S. Obesity and eating. *Science (80-)*. 1968;161(3843):751-756. doi:10.1126/science.161.3843.751

14. Carnell S, Wardle J. Measuring behavioural susceptibility to obesity: Validation of the child eating behaviour questionnaire. *Appetite*. 2007;48(1):104-113. doi:10.1016/j.appet.2006.07.075

15. DelParigi A, Chen K, Salbe AD, Reiman EM, Tataranni PA. Sensory experience of food and obesity: A positron emission tomography study of the brain regions affected by tasting a liquid meal after a prolonged fast. *Neuroimage*. 2005;24(2):436-443. doi:10.1016/j.neuroimage.2004.08.035

16. DelParigi A, Pannacciulli N, Le DSNT, Tataranni PA. In pursuit of neural risk factors for weight gain in humans. *Neurobiol Aging*. 2005;26(1):50-55. doi:10.1016/J.NEUROBIOLAGING.2005.09.008

17. Epstein LH, Paluch R, Coleman KJ. Differences in salivation to repeated

food cues in obese and nonobese women. *Psychosom Med*. 1996;58(2):160-164. doi:10.1097/00006842-199603000-00011

18. Nisbett RE. Taste, deprivation, and weight determinants of eating behavior. *J Pers Soc Psychol*. 1968;10(2):107-116. doi:10.1037/h0026283

19. Fildes A, Mallan KM, Cooke L, et al. The relationship between appetite and food preferences in British and Australian children. *Int J Behav Nutr Phys Act*. 2015;12(1):116. doi:10.1186/s12966-015-0275-4

20. Kininmonth A, Smith A, Carnell S, Steinsbekk S, Fildes A, Llewellyn C. The association between childhood adiposity and appetite assessed using the Child Eating Behavior Questionnaire and Baby Eating Behavior Questionnaire: A systematic review and meta-analysis. *Obes Rev*. 2021;22(5). doi:10.1111/obr.13169

21. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*. 2008;88(1):22-29. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105791809&site=ehost-live

22. Klump KL, McGue M, Iacono WG. Age differences in genetic and environmental influences on eating attitudes and behaviors in preadolescent and adolescent female twins. *J Abnorm Psychol*. 2000;109(2):239. doi:10.1037/0021-843X.109.2.239

23. Klump KL, McGue M, Iacono WG. Differential heritability of eating attitudes and behaviors in prepubertal versus pubertal twins. *Int J Eat Disord*. 2003;33(3):287-292. doi:10.1002/EAT.10151

24. Llewellyn CH, van Jaarsveld CH, Boniface D, Carnell S, Wardle J. Eating rate is a heritable phenotype related to weight in children. *Am J Clin Nutr*. 2008;88(6):1560-1566. doi:10.3945/AJCN.2008.26175

25. Llewellyn CH, van Jaarsveld CHM, Plomin R, Fisher A, Wardle J. Inherited behavioral susceptibility to adiposity in infancy: a multivariate genetic analysis of appetite and weight in the Gemini birth cohort. *Am J*

Clin Nutr. 2012;95(3):633-639. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108164473&site=ehost-live

26. Llewellyn CH, van Jaarsveld CHM, Johnson L, Carnell S, Wardle J. Nature and nurture in infant appetite: analysis of the Gemini twin birth cohort. *Am J Clin Nutr*. 2010;91(5):1172-1179. doi:10.3945/ajcn.2009.28868

27. Davison KK, Birch LL. Childhood overweight: A contextual model and recommendations for future research. *Obes Rev*. 2001;2(3):159-171. doi:10.1046/j.1467-789x.2001.00036.x

28. Rosenkranz RR, Dzewaltowski DA. Model of the home food environment pertaining to childhood obesity. *Nutr Rev*. 2008;66(3):123-140. doi:10.1111/j.1753-4887.2008.00017.x

29. Golan M. Parents as agents of change in childhood obesity - From research to practice. *Int J Pediatr Obes*. 2006;1(2):66-76. doi:10.1080/17477160600644272

30. Kininmonth AR, Schrempft S, Smith A, et al. The Home Environment Interview and associations with energy balance behaviours and body weight in school-aged children – A feasibility, reliability, and validity study. *Int J Behav Nutr Phys Act*. Published online 2022. doi:10.1186/s12966-021-01235-3

31. Kininmonth A, Smith AD, Llewellyn CH, Dye L, Lawton CL, Fildes A. The relationship between the home environment and child adiposity: a systematic review. *Int J Behav Nutr Phys Act*. 2021;18(1):4. doi:10.1186/s12966-020-01073-9

32. Schrempft S, Van Jaarsveld CHM, Fisher A, Wardle J. The obesogenic quality of the home environment: Associations with diet, physical activity, TV viewing, and BMI in preschool children. *PLoS One*. 2015;10(8):e0134490. doi:10.1371/journal.pone.0134490

33. Gattshall ML, Shoup J, Marshall JA, Crane LA, Estabrooks PA. Validation of a survey instrument to assess home environments for physical activity

and healthy eating in overweight children. *Int J Behav Nutr Phys Act*. 2008;5(1):3. doi:10.1186/1479-5868-5-3

34. Jaarsveld C, Johnson L, Llewellyn C, Wardle J. *Gemini: A UK Twin Birth Cohort With a Focus on Early Childhood Weight Trajectories, Appetite and the Family Environment*. Vol 13.; 2010. doi:10.1375/twin.13.1.72

35. Purcell S. Variance Components Models for Gene–Environment Interaction in Twin Analysis. *Twin Res Hum Genet*. 2002;5(6):554-571. doi:10.1375/TWIN.5.6.554

36. Herle M, Fildes A, van Jaarsveld C, Rijsdijk F, Llewellyn CH. Parental Reports of Infant and Child Eating Behaviors are not Affected by Their Beliefs About Their Twins' Zygosity. *Behav Genet*. 2016;46(6):763-771. doi:10.1007/s10519-016-9798-y

37. Wardle J, Guthrie CA, Sanderson S, Rapoport L. Development of the Children's Eating Behaviour Questionnaire. *J Child Psychol Psychiatry Allied Discip*. 2001;42(7):963-970. doi:10.1017/S0021963001007727

38. Bennett DA. How can I deal with missing data in my study? *Aust N Z J Public Health*. 2001;25(5):464-469. doi:10.1111/J.1467-842X.2001.TB00294.X

39. Little RJA, Rubin DB. *Statistical Analysis with Missing Data*. wiley; 2002. doi:10.1002/9781119013563

40. R Core Team. RStudio: Integrated development Environment for R. Published online 2018. http://www.rstudio.org/

41. Boker S, Neale M, Maes H, et al. OpenMx: An Open Source Extended Structural Equation Modeling Framework. *Psychometrika*. 2011;76(2):306. doi:10.1007/S11336-010-9200-6

42. Martin NG, Eaves LJ, Kearsey MJ, Davies P. The power of the classical twin study. *Hered 1978 401*. 1978;40(1):97-116. doi:10.1038/hdy.1978.10

43. Kininmonth AR, Schrempft S, Smith A, et al. Associations between the obesogenic home environment and childhood weight: a cross-lagged panel analysis. *Int J Obes*.

44. Pearson N, Biddle SJH, Griffiths P, Johnston JP, Haycraft E. Clustering and correlates of screen-time and eating behaviours among young children. *BMC Public Health*. 2018;18(1):753. doi:10.1186/s12889-018-5698-9

45. Delfino LD, Tebar WR, Silva DAS, Gil FCS, Mota J, Christofaro DGD. Food advertisements on television and eating habits in adolescents: a school-based study. *Rev Saude Publica*. 2020;54. doi:10.11606/S1518-8787.2020054001558

46. Story M, French S. Food advertising and marketing directed at children and adolescents in the US. *Int J Behav Nutr Phys Act*. 2004;1. doi:10.1186/1479-5868-1-3

47. J U, R S, D S. Associations between television viewing and consumption of commonly advertised foods among New Zealand children and young adolescents. *Public Health Nutr*. 2006;9(5):606-612. doi:10.1079/PHN2005899

48. Harris JL, Bargh JA, Brownell KD. Priming Effects of Television Food Advertising on Eating Behavior. *Health Psychol*. 2009;28(4):404. doi:10.1037/A0014399

49. Boyland E, Whalen R, Christiansen P, et al. *SEE IT, WANT IT, BUY IT, EAT IT HOW FOOD ADVERTISING IS ASSOCIATED WITH UNHEALTHY EATING BEHAVIOURS IN 7-11 YEAR OLD CHILDREN REFERENCE ACKNOWLEDGEMENTS*.; 2018. Accessed April 17, 2020. http://www.cancerresearchuk.org/

50. Andreyeva T, Kelly IR, Harris JL. Exposure to food advertising on television: Associations with children's fast food and soft drink consumption and obesity. *Econ Hum Biol*. 2011;9(3):221-233. doi:10.1016/j.ehb.2011.02.004

51. Falciglia GA, Gussow JD. Television commercials and eating behavior of obese and normal-weight women. *J Nutr Educ*. 1980;12(4):196-199. doi:10.1016/S0022-3182(80)80161-0

52. Halford JCG, Boyland EJ, Hughes G, Oliveira LP, Dovey TM. Beyond-

brand effect of television (TV) food advertisements/ commercials on caloric intake and food choice of 5-7-year-old children. *Appetite*. 2007;49:263-267. doi:10.1016/j.appet.2006.12.003

53. Halford JCG, Gillespie J, Brown V, Pontin EE, Dovey TM. Effect of television advertisements for foods on food consumption in children. *Appetite*. 2004;42(2):221-225. doi:10.1016/J.APPET.2003.11.006

54. Halford JCG, Boyland EJ, Hughes GM, Stacey L, McKean S, Dovey TM. Beyond-brand effect of television food advertisements on food choice in children: the effects of weight status. *Public Health Nutr*. 2008;11(9):897-904. doi:10.1017/S1368980007001231

55. Mustelin L, Silventoinen K, Pietiläinen K, Rissanen A, Kaprio J. Physical activity reduces the influence of genetic effects on BMI and waist circumference: a study in young adult twins. *Int J Obes 2009 331*. 2008;33(1):29-36. doi:10.1038/ijo.2008.258

56. Guo G, Liu H, Wang L, Shen H, Hu W. The Genome-Wide Influence on Human BMI Depends on Physical Activity, Life Course, and Historical Period. *Demography*. 2015;52(5):1651-1670. doi:10.1007/S13524-015-0421-2

57. McCaffery JM, Papandonatos GD, Bond DS, Lyons MJ, Wing RR. Gene × environment interaction of vigorous exercise and body mass index among male Vietnam-era twins. *Am J Clin Nutr*. 2009;89(4):1011-1018. doi:10.3945/AJCN.2008.27170

58. Beaulieu K, Blundell JE, Baak MA van, et al. Effect of exercise training interventions on energy intake and appetite control in adults with overweight or obesity: A systematic review and meta-analysis. *Obes Rev*. 2021;22(S4):e13251. doi:10.1111/OBR.13251

59. Tucker LA. Objectively measured physical activity predicts subsequent energy intake in 300 women. *Public Health Nutr*. 2017;20(1):112-120. doi:10.1017/S1368980016001841

60. Thivel D, Aucouturier J, Doucet éric, Saunders TJ, Chaput JP. Daily energy balance in children and adolescents. Does energy expenditure

predict subsequent energy intake? *Appetite*. 2013;60(1):58-64. doi:10.1016/J.APPET.2012.09.022

61. King NA, Caudwell PP, Hopkins M, Stubbs JR, Naslund E, Blundell JE. Dual-process action of exercise on appetite control: increase in orexigenic drive but improvement in meal-induced satiety. *Am J Clin Nutr*. 2009;90(4):921-927. doi:10.3945/AJCN.2009.27706

62. Beaulieu K, Hopkins M, Blundell J, Finlayson G. Homeostatic and non-homeostatic appetite control along the spectrum of physical activity levels: An updated perspective. *Physiol Behav*. 2018;192:23-29. doi:10.1016/J.PHYSBEH.2017.12.032

63. Bellisle F. Food choice, appetite and physical activity. *Public Health Nutr*. 1999;2(3a):357-361. Accessed October 20, 2021. https://www.cambridge.org/core.

64. Lluch A, King N, Blundell J. Exercise in dietary restrained women: no effect on energy intake but change in hedonic ratings. *Eur J Clin Nutr 1998 524*. 1998;52(4):300-307. doi:10.1038/sj.ejcn.1600555

65. King NA, Snell L, Smith RD, Blundell JE. Effects of short-term exercise on appetite responses in unrestrained females. *Eur J Clin Nutr*. 1996;50(10):663-667. Accessed October 20, 2021. https://www.cochranelibrary.com/es/central/doi/10.1002/central/CN-00352085/full

66. King N, Blundell J. High-fat foods overcome the energy expenditure induced by high-intensity cycling or running. *Eur J Clin Nutr*. Published online 1995.

67. Eichler J, Schmidt R, Poulain T, Hiemisch A, Kiess W, Hilbert A. Stability, continuity, and bi-directional associations of parental feeding practices and standardized child body mass index in children from 2 to 12 years of age. *Nutrients*. 2019;11(8). doi:10.3390/nu11081751

68. Jansen PW, Tharner A, Van Der Ende J, et al. Feeding practices and child weight: Is the association bidirectional in preschool children? *Am J Clin Nutr*. 2014;100(5):1329-1336. doi:10.3945/ajcn.114.088922

69. Harris HA, Fildes A, Mallan: KM, Llewellyn CH. Maternal feeding practices and fussy eating in toddlerhood: a discordant twin analysis. *Int J Behav Nutr Phys Act*. Published online 2016. doi:10.1186/s12966-016-0408-4

70. Selzam S, McAdams TA, Coleman JRI, et al. Evidence for gene-environment correlation in child feeding: Links between common genetic variation for BMI in children and parental feeding practices. *PLoS Genet*. 2018;14(11). doi:10.1371/JOURNAL.PGEN.1007757

71. Hawkes D, Plewis I. Modelling non-response in the National Child Development Study. *J R Stat Soc Ser A Stat Soc*. 2006;169(3). doi:10.1111/j.1467-985X.2006.00401.x

72. van Jaarsveld CH, Johnson L, Llewellyn C, Wardle J. Gemini: a UK twin birth cohort with a focus on early childhood weight trajectories, appetite and the family environment. *Twin Res Hum Genet*. 2010;13(1):72-78. doi:10.1375/twin.13.1.72

73. Scarr S. Developmental theories for the 1990s: development and individual differences. *Child Dev*. 1992;63(1). doi:10.1111/j.1467-8624.1992.tb03591.x

74. Turkheimer E, Gottesman II. Individual Differences and the Canalization of Human Behavior. *Dev Psychol*. 1991;27(1). doi:10.1037/0012-1649.27.1.18

75. Knopik V, Neiderhiser J, DeFries JC, Plomin R. Chapter 8: The Interplay between genes and environment. In: Linsmeier C, Berger S, Rostek M, eds. *Behavioral Genetics*. 7th ed. Worth Publishers Macmillan Learning; 2017:111-130.

76. DiLalla LF, Mullineaux PY, Elam KK. Twins. *Curated Ref Collect Neurosci Biobehav Psychol*. Published online January 1, 2020:398-407. doi:10.1016/B978-0-12-809324-5.22704-1

77. Knopik V, Neiderhiser J, DeFries JC, Plomin R. *Behavioural Genetics*. Seventh Ed. Worth Publishers Macmillan Learning; 2017.

78. Guo S-W. Does Higher Concordance in Monozygotic Twins Than in Dizygotic Twins Suggest a Genetic Component? *Hum Hered*.

2001;51(3):121-132. doi:10.1159/000053333

79. Hettema JM, Neale MC, Kendler KS. Physical similarity and the equal-environment assumption in twin studies of psychiatric disorders. *Behav Genet 1995 254*. 1995;25(4):327-335. doi:10.1007/BF02197281

Chapter 8
General discussion

8.1 Introduction

Excess adiposity in childhood is a considerable public health concern in the UK and globally. Children spend a significant amount of their early life in the home; home is where most food is consumed, where they spend the majority of their free time and, importantly, where they learn behaviours by observing their parents, siblings and other family members. As such the home environment is thought to be particularly influential in shaping dietary and physical activity behaviours associated with excess weight gain. However, somewhat surprisingly, the role that the home environment plays in child weight is under-researched and therefore still poorly understood. In particular, there has been a lack of research examining how an individual's appetitive traits might interact with the obesogenic home environment to determine weight development.

This thesis had three overall aims: 1) measure the home environment comprehensively during childhood, 2) provide insight into the role of the obesogenic home environment in children's weight development; and 3) test Behavioural Susceptibility Theory's (BSTs) hypotheses that appetite plays a causal role in weight, and that genetic influence on appetite will be more strongly expressed in an obesogenic home environment. In the first paper (Chapter Three) of this thesis, a systematic review of peer-reviewed literature synthesised the evidence base for relationships between the home environment and child adiposity. The second paper (Chapter Four) updated and validated a comprehensive measure of the home environment, including the obesogenic quality of each of the three separate domains (food, activity and media) of the home environment, for use in school-aged children. This measure was utilised in the Gemini cohort to examine cross-sectional associations between the home environment, energy-balance behaviours and weight when the children were 12 years old. Paper Three (Chapter Five) built on this work by using data collected in the Gemini cohort at ages four and 12 to examine the stability and continuity of the home environment over time, as well as bi-directional associations between the home environment and child weight from ages four to 12. Paper Four (Chapter Six) explored the validity of Behavioural Susceptibility Theory (BST) by conducting a systematic review and meta-analysis of observational research to establish how appetite relates to children's body weight cross-sectionally, as well as prospectively, with an estimation of effect sizes. Finally, Paper Five (Chapter Seven) aimed to take this a step further by testing BST's hypothesis that the heritability of appetite will be higher among children who live in a more obesogenic home environment.

8.2 Summary of findings and contribution to the literature

The findings of this thesis in relation to the three overall aims and corresponding research questions are summarised below.

8.2.1 Can the obesogenic quality of the home environment be measured comprehensively in childhood?

Findings from Paper One (Chapter Three) highlighted that existing measures of the home environment are limited, with most focussing on individual features, such as availability and access to TV in the bedroom, access to garden space, or availability of sugar-sweetened beverages in the home, rather than assessing the overall obesogenic nature of the home environment. Single, individual aspects of the home environment likely have limited influence on children's weight and provide only narrow insight into the role of the obesogenic home environment as a whole. Only five of the 62 studies included in this review (Chapter Three) captured all three (food, activity, and media) domains of the home environment, and of these, only one study created composite scores to quantify the overall obesogenic quality of the home environment (Schrempft et al., 2015). Composite scores such as those described by Schrempft et al. (2015) allow for the quantification of the obesogenic quality of the home environment and thus enable more meaningful interpretation of the role of the overall home environment. Paper One (Chapter Three) also highlighted the dearth of longitudinal research and revealed that no previous studies have used comprehensive measures to capture the home environment at multiple points. Consequently, our understanding of how the home environment changes over time as children transition from early childhood to adolescence is poor.

To address this gap, Paper Two (Chapter Four) detailed the steps taken to update and validate a comprehensive measure of the home environment, called the Home Environment Interview (HEI), for use in parents with school-aged children. As described in Chapter Two and Chapter Four, the HEI was originally developed for use in pre-school children and was administered in the Gemini cohort when the twins were aged four (Schrempft et al., 2015). The HEI was updated for use in school-aged children in multiple phases. Following an initial update of the measure, piloting using cognitive interviews revealed good acceptability and comprehension (n=14 caregivers). The updated HEI was then administered in the Gemini sample when the twins were aged 12 (n=149 families; 298 children).

Expert consultation and the findings from Paper One (Chapter Three) highlighted the need to increase the scope of questions about the media environment, to reflect technological advances and changes in media consumption since the HEI's original development. Paper One also highlighted that existing measures of the media environment were limited in their scope and rarely captured the wide range of electronic devices currently available to children (Chassiakos et al., 2016). Therefore, it was important for the updated measure to capture the increasing diversity and overall number of electronic devices available in the home.

Consultation with 21 experts in the field of childhood obesity research allowed for consensus to be gained about the constructs from the HEI that should be included in the composite scores (i.e. those relevant to risk for child weight gain). This method of consulting with experts has previously been used in the development of measures of the home environment (Bryant et al., 2008; Golan & Weizman, 1998; Ihmels et al., 2009). This approach was preferred to other approaches such as pattern analytic techniques, which can be problematic if some variables do not load on to the latent factor(s) but are nevertheless relevant to body weight. For example, previous research which used principal component analysis (PCA) to determine variables to be included in a composite score to quantify household obesogenic risk and control (Grunseit et al., 2011) removed parental use of sweets to reward behaviour as it did not load onto the latent factors, even though this behaviour has been associated with increased consumption of energy-dense foods and beverages in other studies (Inhulsen et al., 2017; Kröller & Warschburger, 2008; Rodenburg et al., 2014; Sleddens et al., 2010).

Findings from Paper Two (Chapter Four) revealed that the updated HEI was feasible for administration via telephone interviews with primary caregivers (n=149 families; 298 children). The interview took on average 45 minutes to complete. Test-retest reliability over a two-week period for the composite scores (food, physical activity, media and overall home environment) were good to excellent. These findings were consistent with similar research in this cohort when the children were aged four (Schrempft et al., 2015). The home food environment composite was positively correlated with the home activity and media composites, indicating that ‘higher-risk’ home food environments tended also to be higher risk in terms of both activity and media environments and *vice versa.* In contrast, no association was observed between the home physical activity and media environment composites, indicating that ‘higher-risk’ in one domain is unrelated to risk in the other domain. For example, a home may have a ‘higher-risk’ media environment but a ‘lower-risk’ physical activity environment. These findings are supported by previous research (Schrempft et al., 2015) and highlight the importance of utilising composite measures of the overall obesogenic nature of the home environment as individual aspects or single domains (e.g. the physical activity environment) do not provide the full picture of the environment that a child is exposed to and interacts with.

Results from Paper Two (Chapter Four) also revealed good construct validity of the HEI, with clear cross-sectional associations between each of the home environment composites (food, activity, media, as well as the overall home environment) and corresponding energy-balance behaviours (food intake, physical activity and screen-based sedentary behaviours). These findings mirrored the earlier work undertaken in the same sample (Schrempft et al., 2015).

Building on this cross-sectional examination of the HEI, Paper Three (Chapter Five) utilised data collected previously in the Gemini cohort when the children were aged four, along with the newly collected data at age 12, to examine the stability and continuity of the home environment over time. Findings revealed moderate to strong tracking of the home environment (food, physical activity, media and overall home environment) from ages four to 12, indicating that children living in higher-risk home environments at age four tended to remain in higher-risk home environments at age 12. Although the findings indicated continuity at the individual level, stability analyses revealed that key aspects of the home environment became more obesogenic over time. Notable increases were observed for availability and access to energy-dense snacks and sugar-sweetened beverages and availability and access to electronic devices in the home and children's bedroom (between ages four and 12). Taken together, these findings indicate that while individual households tend to keep their relative position in terms of the obesogenic nature of their home environment, for all homes, aspects of the home environment became more obesogenic as the children got older. These findings are in line with previous research demonstrating age-related increases in the obesogenic nature of the home environment, such as increases in availability of and access to electronic devices (Ofcom, 2020) and reductions in family meal frequency as children reach adolescence (Harrison et al., 2015). This study is the first to measure the home environment comprehensively at two time points in a child's life, and explore how aspects of the home environment change across two key developmental phases

- from early childhood into adolescence. The tracking of the home environment over time highlights the importance of early intervention and preventative strategies to support families in establishing home environments that encourage healthy eating, physical activity and age-appropriate media use, as the obesogenic risk in the home environment tends to persist throughout childhood but also increases as children reach adolescence.

The findings from Paper Two and Paper Three (described in Chapters Four and Five respectively) indicate that the updated HEI is a reliable and valid comprehensive measure of the obesogenic home environment, which can be administered via telephone with parents of school-aged children, and used to quantify the obesogenic risk in the home environment (overall home environment, as well as the food, activity and media sub-domains).

8.2.2 To what extent is the home environment associated with weight in childhood?

Paper Two (Chapter Four) demonstrated cross-sectional associations between the overall obesogenic home environment (as well as individual composites: food, activity, and media) and dietary intake, activity levels and screen-based sedentary behaviours - key energy-balance behaviours associated with risk for weight gain. These findings are in line with previous research (Couch et al., 2014; Hales et al., 2013; Jago et al., 2008, 2014; Verloigne et al., 2012) and mirror findings observed in the same cohort when the children were four years old (Schrempft et al., 2015).

A review of the existing peer-reviewed literature highlighted that most consistent associations were observed between physical aspects of the home media environment and measures of adiposity in childhood (Paper One; Chapter Three). The relationships were less clear for the food and physical activity domains of the home environment. In accordance with these findings, Papers Two and Three also demonstrated the importance of the home media environment for child weight, while revealing less clear relationships between the food and activity domains with child weight. Positive cross-sectional associations were observed between the media environment and BMI-SDS at age 12, as well as positive associations between the overall home environment and BMI-SDS at age 12. These findings suggest that living in a more obesogenic home environment was associated with higher BMI-SDS at age 12 (Paper Two; Chapter Four). Contrary to this, no association was previously observed between the home environment or the media environment and child BMI-SDS at age four (Schrempft et al., 2015). Taken together, these findings suggested that relationships between the home environment and child weight may not manifest until later childhood, when a child has experienced longer environmental exposure and gained more autonomy over their behaviours.

Building on this, Paper Three (Chapter Five) found longitudinal associations between the home media environment at age four and child BMI-SDS at age 12. These findings indicated that living in a more obesogenic home media environment at age four predicted greater increases in child BMI-SDS from ages four to 12. The reverse path, from BMI-SDS at age four to the obesogenic home media environment at age 12, was not significant. Neither the cross-lagged path for the overall home environment, nor those for the food and activity composites were significant in either direction. The null associations observed for the food and activity environments concur with inconsistencies in the existing literature (Paper One; Chapter Three). This is the first time that the home environment has been comprehensively measured at two time points to examine bi-directional relationships between the obesogenic nature of the home environment and child BMI-SDS. The findings provide unique insight into the directionality of associations between the home environment and child weight. Taken together, the findings from Chapters 3-5 highlight the importance of the early home media environment for child weight development, and indicate that it may be an important avenue to explore when designing obesity prevention and treatment strategies.

There are a number of potential explanations as to why the media environment was found to be most consistently associated with child weight throughout the studies described in this thesis (Papers 1-3; Chapters 3-5). Firstly, the media environment within the family home is correlated with activity levels and sedentary behaviours that have been associated with risk of excess weight gain, which was observed in Paper Two (Chapter Four). Data from a large cross-sectional study of 9-11 year olds (n=5844, data pooled from 12 countries) revealed access to electronic devices in the bedroom were key correlates of not meeting physical activity guidelines and engaging in more screen-based sedentary behaviours (LeBlanc et al., 2015). These findings are supported by studies conducted in pre-school children (Spurrier et al., 2008) and school-aged children (Tandon et al., 2012a, 2014). The findings from Paper Two (Chapter Four) echoed this and demonstrated that children living in higher risk media environments spent more time engaged in screen-based sedentary behaviours

(TV and online viewing and video game use) and engaged in less physical activity.

Secondly, increased screen time and poorer dietary intake are behaviours that tend to co-occur (Pearson et al., 2018), and greater exposure to food advertisements when engaging in screen-viewing is one potential mechanism underpinning this clustering of behaviours. A large and consistent research base has shown that food advertisements are effective at influencing children's food choices and subsequently their intake of foods and beverages (Boyland et al., 2016, 2018; Boyland & Halford, 2013; Coates et al., 2019). Studies have shown that children are regularly exposed to food advertisements via traditional methods, such as TV (Kelly et al., 2019). A 2019 study which pooled data from 22 countries revealed that 23% of all advertisements shown during children's peak viewing times were for food or beverages, and the majority of adverts promoted unhealthy products (Kelly et al., 2019). Over recent years, technological advances have led to changes in the way that children consume media, with many spending more time engaged in online media (Ofcom, 2020). Consequently, this has led to an increase in digital food advertisements to children. Digital advertising brings a new level of complexity when it comes to capturing the types of food advertisements that children are exposed to, as exposure is largely tailored to an individual based on age, search history, and geo-locations, amongst other things (Boyland & Tatlow-Golden, 2017). However, studies have shown that the majority of food advertisements children are exposed to online are energy-dense snacks, sugar-sweetened beverages and fast foods (Boyland & Tatlow-Golden, 2017; Kelly et al., 2008; Tatlow-Golden et al., 2016). Cognitive research has shown that young children (less than eight years old) are particularly vulnerable to the effects of food advertising as they are unable to effectively recognise the ‘persuasive intent’ of advertisements and tend to view advertisements as entertaining and informative (Carter et al., 2011; Story & French, 2004; Strasburger, 2001). Moreover, experimental research conducted in US children (n=594; 4-12 years) has suggested that awareness of ‘persuasive intent’ may not emerge until later than previously thought, with understanding remaining low until ages 10-12 (Carter et al., 2011). As such, young children who are exposed to food advertisements are particularly vulnerable to their effects and are more likely to pester their parents to purchase energy-dense food products or purchase energy-dense snack foods and beverages themselves (Boyland et al., 2018). Further to the influence of food advertisements, a systematic review of the evidence demonstrated that children who watched TV while eating consumed more energy-dense snacks, sugar-sweetened beverages and fast foods, and fewer fruits and vegetables than those who did not watch TV while eating (Avery et al., 2017). Evidence from experimental and observational research also demonstrated that eating while watching TV leads to increases in food intake (Bellissimo et al., 2007; Braude & Stevenson, 2014; Wiecha et al., 2006). It has been suggested that this may be due to an individual’s attention being taken away from the food consumed, potentially reducing sensitivity to internal satiety signals (Braude & Stevenson, 2014; Smith & Ditschun, 2009), as well as food advertisements acting as a cue (Harris et al., 2009). These factors may be particularly detrimental for individuals predisposed to a more avid appetite – i.e. those with both high food cue responsiveness and weak sensitivity to satiety.

Thirdly, the observed relationships between the home media environment and child weight may partly reflect the fact the media domain is more stable, less complex and therefore easier to characterise and measure than the home food environment. Unlike the food environment, the media environment is unlikely to change from day-to-day or vary with seasonal changes to the same extent. It is also arguably easier to report the number and location of electronic devices in the home in comparison to food and beverage products which both fluctuate and are more varied in range and scope. Furthermore, the media environment may be less susceptible to social desirability biases, and therefore more accurately reported, when compared to the food or physical activity domains. Until recent years the role of the media in weight development has received less attention than either diet or physical activity. Evidence suggests that such biases may vary dependent on child weight status (Nepper & Chai, 2016), with parents of children with overweight more susceptible to desirability bias, which can make it difficult to disentangle the role of the home environment in child weight development.

8.2.3 In accordance with BST, are appetitive traits consistently associated with weight in childhood and does the heritability of appetite vary by the obesogenic quality of the home environment?

Paper Four (Chapter Six) details a systematic review and meta-analysis examining observational associations between CEBQ and BEBQ-measured appetitive traits and adiposity in childhood, and establishes the size and direction of these associations. Findings from the meta-analysis revealed six out of eight appetitive traits as measured by the CEBQ were associated with BMI z-scores in hypothesized directions (positive: Food Responsiveness (FR), Enjoyment of Food (EF), Emotional Overeating (EOE); negative: Satiety Responsiveness (SR), Slowness in Eating (SE), Emotional Undereating (EUE)), with the strongest associations observed for food responsiveness and satiety responsiveness. Studies ineligible for meta-analysis were narratively reviewed and findings were broadly consistent across CEBQ-adiposity relationships. Longitudinal data were limited (n=12), but findings suggested six of eight CEBQ appetitive traits were prospectively associated with child adiposity (positive: FR, EF, EOE, DD; negative: SR, SE). Five of these studies also suggested bidirectional associations. For the fewer BEBQ studies (n=5), all appetitive traits showed consistent cross-sectional relationships with infant weight or BMI.

Taken together, these findings support one of the central hypotheses of BST – that appetitive traits are a key behavioural mechanism that help to explain an individual's inherited susceptibility to excessive weight gain (or not) in response to the obesogenic environment. This study provides evidence for cross-sectional and prospective relationships between appetitive traits and adiposity in childhood. However, caution should be taken when interpreting these findings as the majority of studies were cross-sectional, limiting our ability to draw conclusions about causal directions. More prospective research from birth is needed to investigate bidirectional relationships between appetite and adiposity. Nevertheless, this is the most comprehensive synthesis of published evidence on the relationship between appetitive traits and adiposity in childhood to date. The confirmation of cross-sectional and prospective relationships between CEBQ- and BEBQ-assessed appetitive traits and adiposity supports the use of these questionnaires to investigate environmental as well as genetic influences on child eating behaviour (e.g. the home environment), within a behaviour genetics framework (Kral & Faith, 2009).

Building on this, Paper Five (Chapter Seven) examined whether the heritability of child appetite varies according to the obesogenic risk in the home environment. The findings indicated that the heritability of appetite (measured using food responsiveness as a proxy) was higher for children living in higher-risk home media environments, compared to those living in lower-risk home media environments (heritability 80%; 95% CI, 61-91% vs 48%; 95% CI, 36-61%). The findings provide partial support for BST, indicating that the genetic influence on appetite may be more potently expressed in more obesogenic home media environments, with greater exposure to food cues. Furthermore, in lower-risk home media environments the shared environmental influence on variance in food responsiveness was significantly higher than in higher-risk media environments, suggesting that lower-risk home media environments may be protective against the expression of food responsiveness. The findings for the home media environment suggest gene-environment interactions, whereby the genetic and environmental influences underlying food responsiveness increases or decreases depending on environmental exposure. The finding that heritability varied according to the media home environment should, however, be interpreted with caution because the confidence intervals for additive genetic influence overlapped, albeit marginally; nevertheless, the point estimate for each group was far outside the 95% CIs for the other respective group. On the other hand, the differences in shared environmental influence on food responsiveness by home media environment were large and significant, indicating that there was a high degree of confidence that shared environmental influences on variance in food responsiveness differ systematically across different levels of media risk. Estimates for the home physical activity environment also indicated differences between higher-risk and lower-risk environments but in the opposite direction, with higher heritability in lower-risk home environments, and higher shared environmental influence in the higher risk environment. Again, the confidence intervals overlapped, but the point estimates for each group sat outside the 95% CIs of the other respective group for both A and C. For the home food environment, the scalar model fitted the data best, indicating that there were no significant differences in the magnitudes of A, C or E across the groups, and only significant differences in the variances for Food Responsiveness. For the overall home environment, the unique environmental influence differed significantly across the groups, with a slightly higher contribution in the higher- vs the lower-risk group (15% versus 7% respectively). There was also a sizeable difference between the groups in the magnitude of the shared environmental influence, with a greater influence in the lower- vs higher-risk group (35% vs 14%). Although the 95% CIs overlapped, the point estimates in each group were outside the 95% CIs of the other group. It is possible that clearer differences in parameter estimates for heritability may have been observed in larger, more socioeconomically and ethnically diverse samples with greater variation in the obesogenic risk in the home environment and greater power to detect differences in estimates across groups. Therefore, future research in larger samples is required. Nonetheless, these findings offer an important step forward in our understanding of whether the genetic and environmental influences underlying appetite vary depending on environmental exposure.

8.3 Implications for theory and intervention

The findings of this thesis highlight the need for clearer and more consistent definitions of the home environment among researchers in the fields of public health, psychology, behavioural science and epidemiology. The current lack of consensus has resulted in substantial heterogeneity in measurements of the home environment making it challenging to draw conclusions about the role of the home environment in child weight development. This thesis has attempted to address these issues. Chapters Four and Five demonstrate that the home environment (the food, activity, media and overall home environment) can be comprehensively measured in childhood, using an interviewer-administered computer-assisted telephone interview. This highlights the importance of utilising composite measures of the home environment to understand the contribution of the overall home environment, as well as the relative contribution of the individual domains (food, activity and media), to children’s weight and weight-related behaviours.

The findings of this thesis have important implications for intervention and preventative strategies. As discussed in Chapter One, caregivers play a fundamental role in shaping both the physical and social aspects of the home environment deemed important for shaping children’s diet- and activity-related behaviours. Despite the importance of the home, many existing interventions have focussed on wider environments, for example community settings, schools and after-school programmes (Angawi & Gaissi, 2021). Interventions in these broader settings have the advantage of reaching a larger number of children simultaneously, providing a wider reach for a lower cost. However, as children consume most of their dietary intake at home (Chai & Nepper, 2015) and spend a significant amount of their free time at home, interventions targeting settings outside the family home may only influence a small portion of a child's energy-balance behaviours and subsequently weight outcomes. Thus, there is a need to focus intervention efforts at the level of the home and family environment as well. Existing evidence for the effectiveness of home-based interventions is limited (Angawi & Gaissi, 2021; Pamungkas & Chamroonsawasdi, 2019). Systematic reviews of the topic have demonstrated that there are few existing home-based interventions (Angawi & Gaissi, 2021), with most focussing on diet and physical activity (Ash et al., 2017; Knowlden & Sharma, 2012; Showell et al., 2013), with only limited effects on weight outcomes (Pamungkas & Chamroonsawasdi, 2019). The results of this thesis bring the home media environment into the spotlight (Chapters 3-5), highlighting its importance for child weight development (Chapter Five). The findings suggest home-based intervention efforts should target, as a priority, the home media environment using methods such as reducing the availability of electronic devices in the home and child's bedroom, and setting rules and limits around the use of electronic devices (e.g. time spent, not during mealtimes), with a particular focus towards the early years.

As discussed in Chapter One, stark socioeconomic inequalities in childhood obesity exist, with children living in areas of greatest deprivation more than twice as likely to have obesity compared to those living in the least deprived areas (NHS Digital, 2021). The findings of this thesis highlight that the home environment plays a key role in children's energy balance behaviours (Paper Two; Chapter Four) and subsequently, weight (Paper Three; Chapter Five). To date, few studies have examined SES-related differences in the home environment (Paper One; Chapter Three). In this thesis, lower SES was associated with 'higher-risk' home environments. These findings are in line with previous research which highlights that lower SES households had greater access to electronic devices in the child's bedroom (Adachi-Mejia et al., 2007; Borghese et al., 2015; Mihrshahi et al., 2017), less access to physical activity equipment and garden space (Schalkwijk et al., 2018; Tandon et al., 2012b; Umstattd Meyer et al., 2013), and less availability of fruits and vegetables (Boles et al., 2019; Grunseit et al., 2011; Schrempft et al., 2016). For lower SES families, decisions about food purchasing are largely dictated by price, ease of preparation and a product's shelf-life. Regular eating routines and family mealtimes are also harder to achieve for caregivers with limited resources and unpredictable working schedules (Bauer et al., 2012; Shift, 2018). These factors make it harder for families of lower SES to establish a healthier home environment and must be considered when developing home-based interventions. Future research should focus on developing strategies for modifying the home environment, which take into account the potential barriers (e.g. cost, time pressures, shift work, lack of resources) and facilitators (e.g. financial aid, food parcels) experienced by more deprived families.

The work included in this thesis demonstrated that most appetitive traits are consistently associated with weight in childhood, both cross-sectionally and longitudinally. These findings support the central hypothesis of BST – that appetitive traits are a key behavioural mechanism that help to explain an individual's susceptibility to gain excess weight (or not) in response to the obesogenic environment. Building on this, the findings of Paper Five (Chapter Seven) provide partial support for BST, indicating that the shared environmental influence on appetite was significantly greater in lower-risk home media environments and that genetic influence on appetite may be more potently expressed in higher-risk (more obesogenic) home media environments. These findings suggest that lower-risk home media environments, with fewer opportunities to eat energy-dense, palatable foods and less exposure to food cues, may be protective against expression of food responsiveness. The findings offer important insight into whether the genetic and environmental influences underlying child appetite varies depending on environmental exposure and suggest that the environment may be acting as a 'volume control', potentially increasing or decreasing a child's risk of overeating and developing obesity. If the environment is acting as a 'volume control' then children with greater genetic susceptibility to the obesogenic environment may benefit from interventions targeting modifiable aspects of the home environment, with a particular focus on the home media environment. Future research could focus on developing personalised preventative approaches or intervention strategies that first identifies children at risk of obesity based on their appetite (or parental obesity) and then works with families to modify the home environment to reduce risk. For example, creating a home environment with less exposure to food cues (i.e. via food advertisements), and fewer opportunities to eat energy-dense, palatable foods, may offer some protection for a child predisposed to a more avid appetite.

8.4 Limitations and directions for future research

8.4.1 Measurement issues

The use of parent-reported measures is a limitation of the research discussed in this thesis and will be explained in relation to each measure used. The Home Environment Interview (HEI) is a parent-reported measure and thus susceptible to social desirability and recall biases. For example, caregivers' might choose responses that suggest a ‘healthier’ home environments, because they are aware of what may be perceived as the ‘desirable’ answer. This is arguably even more problematic when the researcher asks participants direct questions, using interview-style methodologies, as this has been suggested to create more social ‘pressure’ than when participants provide responses by completing digital or paper-based questionnaires (Aquilino & Sciuto, 1990; Bowling, 2005; Hochstim, 1967). Furthermore, evidence has suggested such biases may vary dependent on child weight status (Bornstein et al., 2015; Bryant & Stevens, 2006; Hebert et al., 1995; King et al., 2016; Vesely & Klöckner, 2020), with parents of children with overweight more susceptible to social desirability bias, which can make it difficult to disentangle the role of the home environment in child weight development and should be taken into account when interpreting the results in this thesis. Nevertheless, previous research in Gemini when the children were age four has shown the HEI to have good to excellent validity when compared with images from wearable digital cameras (SenseCam[1]) of the home environment (Schrempft et al., 2017). In Gemini, families were visited at home seven to 24 days after completing the HEI and asked to wear the camera during waking hours while at home for four consecutive days (including at least one weekend day, to capture a representative picture of the home environment). The findings revealed good to excellent validity for key features within the home environment such as availability of foods and beverages (except sweet snacks, tinned and frozen vegetables), family meals, eating while watching TV, availability of electronic devices and physical activity equipment (Schrempft et al., 2017).

[1] SenseCam is a wearable digital camera designed to take pictures automatically, approximately every 20 seconds, when triggered by sensors. SenseCam has a long battery life (up to 16 hours), large strong capacity and each image is time-stamped to enable the duration of events or activities e.g. meals to be deduced.

Height and weight measurements were also parent-reported, which may introduce inaccuracies and bias. However, parent-reported anthropometrics corresponded well with researcher-reports with correlations of 0.90 reported in another population-based British twin cohort (Wardle et al., 2008) and more so when parents are provided with detailed instructions, electronic scales and height charts (Huybrechts et al., 2011), as was the case in Gemini.

In addition, appetite was measured using the CEBQ which is also a parent-reported measure. However, the CEBQ has been found to be a valid and reliable measure of children's appetite in socioeconomically and ethnically diverse populations (Domoff et al., 2015; Quah et al., 2017), with good correspondence to objective behavioural measures of appetite in children (Carnell & Wardle, 2007).

The use of BMI-SDS as the primary measure of adiposity is a limitation, as it cannot differentiate between weight attributable to fat mass or lean mass. This means misclassification of health risk based on weight status can occur at an individual level, especially during childhood when maturation occurs at differing rates. Thus, utilising other measures of adiposity such as waist circumference, skinfold thickness, or dual energy X-ray absorptiometry (DEXA) may be beneficial as they provide more accuracy in capturing adiposity. Nonetheless, BMI is commonly used in large population based studies such as Gemini, as it is a cost-effective way to collect information at scale (Burkhauser & Cawley, 2008). It was not feasible to collect other measures of adiposity such as skinfold thickness or

DEXA in Gemini as such measures would have been resource intensive and expensive to administer at scale (Brownbill & Ilich, 2005; Laskey, 1996).

8.4.1.1 Measurement of the home environment

The HEI is a comprehensive measure of physical and social aspects of the home food, activity and media environments, and was developed with input from experts in the field of childhood obesity research. However, it is possible that key features within the home environment were not measured or captured in an optimal way. For example, the measurement of home food availability was limited in that participants were asked to report on the types (e.g. confectionery, fruit, vegetables, salty snacks, sweet snacks, sugar-sweetened beverages) of particular food groups available in the home but not the amounts of each food group. Therefore, it was not possible to distinguish between households that had a greater quantity of the products, compared to those with only small amounts. Gaining more detailed food inventories would have allowed for more in-depth examination of food availability in the home. However, the need to ensure the interview was not too long or onerous for the participants to complete prevented inclusion of this level of detail.

When developing the composite measures of the home environment, the food, physical activity and media domains were all treated as contributing equally (unit weights) to the overall composite (by dividing by the number of variables in each domain). It could be argued that certain domains of the home environment are more important than others for determining overall obesogenic quality and, therefore, should carry more weight in the composite score. For example, if dietary intake and sedentary behaviour are most relevant to risk for weight gain, perhaps the food or media environments should carry more weight than the physical activity domain. However, there was not sufficient theoretical underpinning to support a differentially weighted composite. Although future research may benefit from clarifying the relative contribution of each domain, evidence has suggested that the use of unit weighting is empirically logical and that composite scores from unit weights generally correlate highly with differentially weighted composite scores (Bobko et al., 2007).

8.4.2 Representativeness of the sample

As discussed in Chapter Two, the families in the Gemini sample are fairly homogenous, with the majority of families identifying as White British and including a large proportion of higher SES families compared with the general population. The data collection detailed in Paper Two (Chapter Four) was conducted in a sub-sample of the Gemini cohort and due to the Covid-19 pandemic, data collection was ceased prematurely. The decision to cease data collection was taken when it became evident the home environment, and how families interact with it, was fundamentally changing as a consequence of the pandemic and lockdown restrictions. As such, the sample size in this thesis was smaller than originally planned and the families included at age 12 were of higher SES than the full Gemini sample at baseline. Therefore, the findings may not be generalizable to the wider population. The greater proportion of higher SES families in this sample is likely due to the fact that families of lower SES are harder to recruit, due to time constraints, conflicting priorities and frequent changes in contact information (Brannon et al., 2013; Cui et al., 2019). These factors may make it difficult to recruit and retain lower SES families in longitudinal studies such as Gemini, resulting in samples becoming increasingly of higher SES over time. If data collection and recruitment for Paper Two could have continued over a longer period, it may have been possible to increase the proportion of lower SES families recruited, however, there would have likely still been a bias towards mid-higher SES as this is the nature of the Gemini sample. It is important for future research to replicate these findings in larger, more ethnically and socioeconomically diverse samples, with potentially greater variation in the obesogenic nature of the home environment. At present the HEI is currently being administered to 1000 families from a wide range of SES, from four London boroughs, as part of an NIHR-funded project examining SES differences in family food cultures. This research will be an important step in moving understanding forward in this area.

The use of twins in research has been criticised as it is argued that twins are fundamentally different from singleton children and therefore lack generalisability to the wider population. Compared to singletons, twins generally have a lower birth weight, are born earlier and are at increased risk for perinatal complications than singletons (Grumbach et al., 1986; Van Dommelen et al., 2008). However, research has shown that twins do not differ from singletons on various physical, behavioural and personality traits, such as blood pressure, alcohol consumption, constraint, aggression, control, etc. (Andrew et al., 2001; Johnson et al., 2002). Additionally, although twins have a lower birth weight, they grow at a faster rate after birth, experiencing ‘catch up’ growth over the first 2 years of life, and achieve the same height and weight as singletons by about 2.5 years (Van Dommelen et al., 2008). There is also no evidence to suggest physical aspects of the home environment differ for households with twins compared to singletons. For example, the availability of electronic devices, foods and beverages, and physical activity equipment in the home may vary according to the number of children, but this would also occur for families with both multiples and singletons.

8.4.3 Equal environments assumption

As previously discussed in Chapter Two, a key assumption of the twin method is the ‘equal environments assumption’ (EEA), which states that environmental exposure influencing similarity within twin pairs is the same for twins reared together, regardless of zygosity (Knopik et al., 2017a). The EEA is a critical aspect of the twin method; it is assumed that greater similarity between MZ than DZ pairs results only from greater genetic similarity, and no other reason. However, if MZ twins share their environments more closely than DZs, this violates the EEA and would lead to an overestimation of the genetic contribution to variation in a trait. There is some evidence to suggest MZ twins share more similar environments than DZ twins because MZ twins are always the same sex and look identical (Guo, 2001; Hettema et al., 1995), and thus parents may treat MZ twins more similarly than DZs (Felson, 2014). This could affect parent-reported measures of twins behaviours as parents may score twins more similarly if they believe them to be identical or more differently if they believe them to be non-identical.

Violation of the EEA may have led to an overestimation of the heritability estimates described in Chapter Seven and has been suggested as a fundamental flaw of the twin method (Richardson & Norgate, 2005). However, the EEA has been tested using the ‘misclassification of zygosity’ design. Parents of MZ twins often mistakenly believe them to be DZ twins (Van Dongen et al., 2012), due to being misinformed by health professionals during a prenatal scan or at birth. If each twin is observed to have a separate placenta (dichorionic) and amniotic sac (diamniotic) in utero, it is a common misconception that this can be used to accurately classify dizygosity. In reality, separate placentas and amniotic sacs do not denote zygosity, and 25–30% of MZ twins are dichorionic diamniotic due to the MZ zygote splitting early following fertilisation (Ooki et al., 2004; Van Jaarsveld et al., 2012). In Gemini, as many as 27.5% (n=179) of parents of MZ twins mistakenly believed that their twins were DZ (Van Jaarsveld et al., 2012). The ‘misclassification of zygosity’ design compares the correlation of a trait for MZ pairs correctly identified as MZs and MZs who have been misclassified as DZs. If the correlation matches for MZ twins who have been correctly classified and those who are misclassified, then this is seen to provide support for the EEA and would indicate that parental bias in ratings on questionnaires is unlikely. This design was used in Gemini to test for parental bias in reporting of their twins appetites, as measured by the BEBQ and CEBQ (Herle et al., 2016). The findings revealed that parents who misclassified their twins’ zygosity scored them as similarly as parents who correctly classified their twins zygosity (Herle et al., 2016). These findings indicate that parental perception of their twins’ zygosity did not bias ratings of their children’s appetitive traits and thus provides support for the validity of the EEA and the twin method. A number of other studies have also demonstrated that MZ twins correlate to the same extent regardless of believed zygosity status (Conley et al., 2013; Kendler et al., 1993; Scarr & Carter-Saltzman, 1979), providing further support for the validity of the twin method.

8.4.4 Gene-environment correlations

As discussed in Paper Five (Chapter Seven), it is possible that gene-environment correlations may lead to overestimations of measured heritability. The findings described in Chapter Seven, may partly be attributable to passive or evocative gene-environment correlations. A passive gene-environment correlation may occur because parents are responsible for both passing on associated genes and for creating home environments that align with these genetic predispositions, meaning a child is more likely to be raised in a home environment that is correlated with their genotype (Knopik et al., 2017b). For example, a child may inherit genes that predispose them to be more responsive to food cues, while also growing up with a food responsive parent who creates an environment that nurtures the expression of this trait. Evocative gene-environment correlations may occur if a child expresses genetically influenced behaviours that in turn evoke responsive behaviours from their parents (DiLalla et al., 2020). For example, if a child is particularly responsive to food cues their parents may respond by modifying their feeding practices or altering the types of foods and beverages available in the home. Approaches have been developed to account for gene-environment correlations (Purcell, 2002), but larger sample sizes than those available in this thesis are required to conduct these analyses. Future research should aim to utilise such approaches to replicate the findings in larger, more ethnically and socioeconomically diverse samples.

8.5 Conclusion

In summary, this thesis provides evidence for the importance of utilising a comprehensive measure of the home environment when exploring obesogenic risk. The findings highlight that the home environment and, in particular, the home media environment, play an important role in child weight development. The results suggest that the influence of the home environment on weight may not manifest until later childhood, when a child has experienced greater environmental exposure and gained more autonomy over their behaviours. Furthermore, this thesis provides support for BST, supporting the hypothesis that appetite is a key behavioural mediator that helps explain an individual's susceptibility to gain excess weight (or not) in response to the obesogenic home environment. Taken together, these findings provide evidence that the home environment and the home media environment specifically, may be an important target for obesity prevention and treatment strategies. At the same time, this thesis highlights that obesity prevention strategies need to take into account individual susceptibility to the obesogenic home environment.

References

Abbott, R. A., & Davies, P. S. W. (2004). Habitual physical activity and physical activity intensity: Their relation to body composition in 5.0-10.5-y-old children. *European Journal of Clinical Nutrition*. https://doi.org/10.1038/sj.ejcn.1601780

Adachi-Mejia, A., Longacre, M., Gibson, J., Beach, M., Titus-Ernstoff, L., & Dalton, M. (2007). Children with a TV in their bedroom at higher risk for being overweight. *International Journal of Obesity*, *31*(4), 644–651. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc5&AN=2007-05536-004

Aftosmes-Tobio, A., Ganter, C., Gicevic, S., Newlan, S., Simon, C. L., Davison, K. K., & Manganello, J. A. (2016a). A systematic review of media parenting in the context of childhood obesity research. *BMC Public Health*. https://doi.org/10.1186/s12889-016-2981-5

Aftosmes-Tobio, A., Ganter, C., Gicevic, S., Newlan, S., Simon, C. L., Davison, K. K., & Manganello, J. A. (2016b). A systematic review of media parenting in the context of childhood obesity research. *BMC Public Health*, *16*(1), 320. https://doi.org/10.1186/s12889-016-2981-5

Anderson, C. B., Hughes, S. O., Fisher, J. O., & Nicklas, T. A. (2005). Cross-cultural equivalence of feeding beliefs and practices: The psychometric properties of the child feeding questionnaire among Blacks and Hispanics. *Preventive Medicine*, *41*(2), 521–531. https://doi.org/10.1016/J.YPMED.2005.01.003

Anderson, S. E., & Whitaker, R. C. (2010). Household routines and obesity in US preschool-aged children. *Pediatrics*, *125*(3), 420–428. https://doi.org/10.1542/peds.2009-0417

Andrew, T., Hart, D. J., Snieder, H., Lange, M., Spector, T. D., & MacGregor, A. J. (2001). Are Twins and Singletons Comparable? A Study of Disease-related and Lifestyle Characteristics in Adult Women. *Twin Research*, *4*(6), 464–477. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/B402F7B77DD911D2CAB75378219B6C38/S1369052300002300a.pdf/are-twins-and-singletons-comparable-a-study-of-disease-related-and-lifestyle-characteristics-in-adult-women.pdf

Andreyeva, T., Kelly, I. R., & Harris, J. L. (2011). Exposure to food advertising on television: Associations with children's fast food and soft drink consumption and obesity. *Economics and Human Biology*, *9*(3), 221–233. https://doi.org/10.1016/j.ehb.2011.02.004

Angawi, K., & Gaissi, A. (2021). Systematic Review of Setting-Based Interventions for Preventing Childhood Obesity. *BioMed Research International*, *2021*. https://doi.org/10.1155/2021/4477534

Anzman, S. L., Rollins, B. Y., & Birch, L. L. (2010). Parental influence on children's early eating environments and obesity risk: implications for prevention. *International Journal of Obesity*, *34*(7), 1116–1124. https://doi.org/10.1038/ijo.2010.43

Aquilino, W. S., & Sciuto, L. A. L. (1990). Effects of interview mode on self-reported drug use. *Public Opinion Quarterly*, *54*(3). https://doi.org/10.1086/269212

Ash, T., Agaronov, A., Young, T. L., Aftosmes-Tobio, A., & Davison, K. K. (2017). Family-based childhood obesity prevention interventions: A systematic review and quantitative content analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 1–12. https://doi.org/10.1186/S12966-017-0571-2/FIGURES/2

Atherton, K., Fuller, E., Shepherd, P., Strachan, D. P., & Power, C. (2008). Loss and representativeness in a biomedical survey at age 45 years: 1958 British birth cohort. *Journal of Epidemiology and Community Health*, *62*(3), 216–223. https://doi.org/10.1136/jech.2006.058966

Atkin, A J, Corder, K., & van Sluijs, E. M. (2013). Bedroom media, sedentary time and screen-time in children: a longitudinal analysis. *Int J Behav Nutr Phys Act*, *10*, 137. https://doi.org/10.1186/1479-5868-10-137

Atkin, Andrew J, Corder, K., & van Sluijs, E. M. F. (2013). Bedroom media, sedentary time and screen-time in children: a longitudinal analysis. *International Journal of Behavioral Nutrition and Physical Activity 2013 10:1*, *10*(1), 1–10. https://doi.org/10.1186/1479-5868-10-137

Avery, A., Anderson, C., & McCullough, F. (2017). Associations between children's diet quality and watching television during meal or snack consumption: A systematic review. *Maternal & Child Nutrition*, *13*(4). https://doi.org/10.1111/mcn.12428

Bailey-Davis, L., Poulsen, M. N., Hirsch, A. G., Pollak, J., Glass, T. A., & Schwartz, B. S. (2017). Home Food Rules in Relation to Youth Eating Behaviors, Body Mass Index, Waist Circumference, and Percent Body Fat. *Journal of Adolescent Health*, *60*(3), 270–276. https://doi.org/10.1016/j.jadohealth.2016.09.020

Barkeling, B., Ekman, S., & Rossner, S. (1992). Eating behaviour in obese and normal weight 11-year-old children. *International Journal of Obesity*, *16*(5), 355–360.

Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2009). Childhood Motor Skill Proficiency as a Predictor of Adolescent Physical Activity. *Journal of Adolescent Health*, *44*(3), 252–259. https://doi.org/10.1016/j.jadohealth.2008.07.004

Bassul, C., Corish, C. A., & Kearney, J. M. (2021). Associations between Home Environment, Children's and Parents' Characteristics and Children's TV Screen Time Behavior. *International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 1589*, *18*(4), 1589. https://doi.org/10.3390/IJERPH18041589

Bauer, K W, Hearst, M. O., Escoto, K., Berge, J. M., & Neumark-Sztainer, D. (2012). Parental employment and work-family stress: associations with family food environments. *Soc Sci Med*, *75*(3), 496–504. https://doi.org/10.1016/j.socscimed.2012.03.026

Bauer, Katherine W., Haines, J., Miller, A. L., Rosenblum, K., Appugliese, D. P., Lumeng, J. C., & Kaciroti, N. A. (2017). Maternal restrictive feeding and eating in the absence of hunger among toddlers: A cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1),

172. https://doi.org/10.1186/s12966-017-0630-8

Baughcum, A. E., Powers, S. W., Johnson, S. B., Chamberlin, L. A., Deeks, C. M., Jain, A., & Whitaker, R. C. (2001). Maternal feeding practices and beliefs and their relationships to overweight in early childhood. *Journal of Developmental and Behavioral Pediatrics*, *22*(6), 391–408. https://doi.org/10.1097/00004703-200112000-00007

Beaulieu, K., Blundell, J. E., Baak, M. A. van, Battista, F., Busetto, L., Carraça, E. V., Dicker, D., Encantado, J., Ermolao, A., Farpour-Lambert, N., Pramono, A., Woodward, E., Bellicha, A., & Oppert, J.-M. (2021). Effect of exercise training interventions on energy intake and appetite control in adults with overweight or obesity: A systematic review and meta-analysis. *Obesity Reviews*, *22*(S4), e13251. https://doi.org/10.1111/OBR.13251

Beaulieu, K., Hopkins, M., Blundell, J., & Finlayson, G. (2018). Homeostatic and non-homeostatic appetite control along the spectrum of physical activity levels: An updated perspective. *Physiology & Behavior*, *192*, 23–29. https://doi.org/10.1016/J.PHYSBEH.2017.12.032

Bellisle, F. (1999). Food choice, appetite and physical activity. *Public Health Nutrition*, *2*(3a), 357–361. https://www.cambridge.org/core.

Bellissimo, N., Pencharz, P. B., Thomas, S. G., & Anderson, G. H. (2007). Effect of Television Viewing at Mealtime on Food Intake After a Glucose Preload in Boys. *Pediatric Research 2007 61:6*, *61*(6), 745–749. https://doi.org/10.1203/pdr.0b013e3180536591

Bennett, D. A. (2001). How can I deal with missing data in my study? *Australian and New Zealand Journal of Public Health*, *25*(5), 464–469. https://doi.org/10.1111/J.1467-842X.2001.TB00294.X

Bere, E., Sørli Glomnes, E., Te Velde, S. J., & Klepp, K. I. (2008). Determinants of adolescents' soft drink consumption. *Public Health Nutrition*, *11*(1), 49–56. https://doi.org/10.1017/S1368980007000122

Berge, J. M., Meyer, C., Maclehose, R. F., Loth, K., & Neumark-Sztainer, D. (2016). Do Parents Treat Siblings Similarly or Differently with Regard to Feeding Practices, Weight-Related Conversations, and Support for Physical Activity? An Exploratory Analysis. *Childhood Obesity*, *12*(2), 87–93. https://doi.org/10.1089/chi.2015.0049

Berge, J. M., Tate, A. D., Trofholz, A., Conger, K., & Neumark-Sztainer, D. (2016). Sibling eating behaviours and parental feeding practices with siblings: Similar or different? *Public Health Nutrition*, *19*(13), 2415–2423. https://doi.org/10.1017/S1368980016000860

Berge, J. M., Wall, M., Hsueh, T. F., Fulkerson, J. A., Larson, N., & Neumark-Sztainer, D. (2015). The protective role of family meals for youth obesity: 10-year longitudinal associations. *Journal of Pediatrics*, *166*(2), 296–301. https://doi.org/10.1016/j.jpeds.2014.08.030

Bergmeier, H., Skouteris, H., Horwood, S., Hooley, M., & Richardson, B. (2014). Child temperament and maternal predictors of preschool children's eating and body mass index. A prospective study. *Appetite*, *74*, 125–132. https://doi.org/https://dx.doi.org/10.1016/j.appet.2013.12.006

Berkey, C. S., Rockett, H. R., Field, A. E., Gillman, M. W., Frazier, A. L., Camargo, C. A., & Colditz, G. A. (2000). Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. *Pediatrics*, *105*(4). https://doi.org/10.1542/peds.105.4.e56

Biddle, S. J. H., Atkin, A. J., Cavill, N., & Foster, C. (2011). Correlates of physical activity in youth: a review of quantitative systematic reviews. *International Review of Sport and Exercise Psychology*, *4*(1), 25–49. https://doi.org/10.1080/1750984X.2010.548528

Biddle, S. J. H., Gorely, T., Marshall, S. J., Murdey, I., & Cameron, N. (2004). Physical activity and sedentary behaviours in youth: Issues and controversies. In *Journal of The Royal Society for the Promotion of Health* (Vol. 124, Issue 1, pp. 29–33). Sage PublicationsSage CA: Thousand Oaks, CA. https://doi.org/10.1177/146642400312400110

Birch, L. L., Fisher, J. O., Grimm-Thomas, K., Markey, C. N., Sawyer, R., & Johnson, S. L. (2001). Confirmatory factor analysis of the Child Feeding Questionnaire: A measure of parental attitudes, beliefs and practices about child feeding and obesity proneness. *Appetite*, *36*(3), 201–210. https://doi.org/10.1006/appe.2001.0398

Bjelland, M., Brantsæter, A. L., Haugen, M., Meltzer, H. M., Nystad, W., & Andersen, L. F. (2013). Changes and tracking of fruit, vegetables and sugar-sweetened beverages intake from 18 months to 7 years in the Norwegian mother and child cohort study. *BMC Public Health*, *13*(1), 793. https://doi.org/10.1186/1471-2458-13-793

Bjelland, M., Soenens, B., Bere, E., Kovács, É., Lien, N., Maes, L., Manios, Y., Moschonis, G., & Te Velde, S. J. (2015). Associations between parental rules, style of communication and children’s screen time Health behavior, health promotion and society. *BMC Public Health*, *15*(1), 1002. https://doi.org/10.1186/s12889-015-2337-6

Bjørklund, O. Belsky, J., Wichstrøm, Lars. & Steinsbekk, S. (2018). Predictors of eating behavior in middle childhood: A hybrid fixed effects model. *Developmental Psychology*, *54*(6), 1099–1110.

Bjørklund, O., Belsky, J., Wichstrøm, L., & Steinsbekk, S. (2018). Predictors of eating behavior in middle childhood: A hybrid fixed effects model. *Developmental Psychology*, *54*(6), 1099–1110. https://doi.org/10.1037/DEV0000504

Blissett, J. (2018). Effects of Modeling on Children’s Eating Behavior. In J. Lumeng & J. Fisher (Eds.), *Pediatric Food Preferences and Eating Behaviors* (1st ed., pp. 53–69). Academic Press Inc.

Blissett, J., Bennett, C., Fogel, A., Harris, G., & Higgs, S. (2016). Parental modelling and prompting effects on acceptance of a novel fruit in 2-4-year-old children are dependent on children’s food responsiveness. *British Journal of Nutrition*, *115*(3), 554–564. https://doi.org/10.1017/S0007114515004651

Bobko, P., Roth, P. L., & Buster, M. A. (2007). The Usefulness of Unit Weights in Creating Composite Scores. *Organizational Research Methods*, *10*(4). https://doi.org/10.1177/1094428106294734

Boker, S., Neale, M., Maes, H., Wilde, M., Spiegel, M., Brick, T., Spies, J., Estabrook, R., Kenny, S., Bates, T., Mehta, P., & Fox, J. (2011). OpenMx:

An Open Source Extended Structural Equation Modeling Framework. *Psychometrika*, *76*(2), 306. https://doi.org/10.1007/S11336-010-9200-6

Boles, R. E., Johnson, S. L., Burdell, A., Davies, P. L., Gavin, W. J., & Bellows, L. L. (2019). Home food availability and child intake among rural families identified to be at-risk for health disparities. *Appetite*, *134*, 135–141. https://doi.org/10.1016/j.appet.2018.12.002

Boodhna, G. (2014). *Chapter 11: Children's body mass index, overweight and obesity.* (Vol. 1, pp. 1–24). https://files.digital.nhs.uk/publicationimport/pub16xxx/pub16076/hse2013-ch11-child-bmi.pdf

Boonpleng, W., Park, C. G., Gallo, A. M., Corte, C., McCreary, L., & Bergren, M. D. (2013). Ecological Influences of Early Childhood Obesity. *Western Journal of Nursing Research*, *35*(6), 742–759. https://doi.org/10.1177/0193945913480275

Booth, K. M., Pinkston, M. M., & Poston, W. S. C. (2005). Obesity and the Built Environment. *Journal of the American Dietetic Association*, *105*(5), 110–117. https://doi.org/10.1016/J.JADA.2005.02.045

Borghese, M. M., Tremblay, M. S., Katzmarzyk, P. T., Tudor-Locke, C., Schuna Jr., J. M., Leduc, G., Boyer, C., LeBlanc, A. G., & Chaput, J. P. (2015). Mediating role of television time, diet patterns, physical activity and sleep duration in the association between television in the bedroom and adiposity in 10 year-old children. *International Journal of Behavioral Nutrition & Physical Activity*, *12*, 60. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25967920

Bornstein, M. H., Putnick, D. L., Lansford, J. E., Pastorelli, C., Skinner, A. T., Sorbring, E., Tapanya, S., Maria, L., Tirado, U., Zelli, A., Alampay, L. P., Al-Hassan, S. M., Bacchini, D., & Bombi, A. S. (2015). Mother and Father Socially Desirable Responding in Nine Countries: Two Kinds of Agreement and Relations to Parenting Self-Reports HHS Public Access. *Int J Psychol*, *50*(3), 174–185. https://doi.org/10.1002/ijop.12084

Bornstein, M. H., Putnick, D. L., Lansford, J. E., Pastorelli, C., Skinner, A. T., Sorbring, E., Tapanya, S., Uribe Tirado, L. M., Zelli, A., Alampay, L. P., Al-Hassan, S. M., Bacchini, D., Bombi, A. S., Chang, L., Deater-Deckard, K., Di Giunta, L., Dodge, K. A., Malone, P. S., & Oburu, P. (2015). Mother and father socially desirable responding in nine countries: Two kinds of agreement and relations to parenting self-reports. *International Journal of Psychology*, *50*(3), 174–185. https://doi.org/10.1002/ijop.12084

Boswell, N., Byrne, R., & Davies, P. S. W. (2018). Eating behavior traits associated with demographic variables and implications for obesity outcomes in early childhood. *Appetite*, *120*, 482–490. https://doi.org/10.1016/j.appet.2017.10.012

Boutelle, K. N., Kang Sim, D. E., Manzano, M., Rhee, K. E., Crow, S. J., & Strong, D. R. (2019). Role of appetitive phenotype trajectory groups on child body weight during a family-based treatment for children with overweight or obesity. *International Journal of Obesity*, *43*(11), 2302–2308. https://doi.org/10.1038/s41366-019-0463-4

Boutelle, K. N., Knatz, S., Carlson, J., Bergmann, K., & Peterson, C. B. (2017). An Open Trial Targeting Food Cue Reactivity and Satiety Sensitivity in Overweight and Obese Binge Eaters. *Cognitive and Behavioral Practice*, *24*(3), 363–373. https://doi.org/10.1016/j.cbpra.2016.08.003

Bowling, A. (2005). Mode of questionnaire administration can have serious effects on data quality. *Journal of Public Health*, *27*(3), 281–291. https://doi.org/10.1093/pubmed/fdi031

Boyland, E., & Halford, J. C. G. (2013). Television advertising and branding. Effects on eating behaviour and food preferences in children. *Appetite*, *62*, 236–241. https://doi.org/10.1016/J.APPET.2012.01.032

Boyland, E., Nolan, S., Kelly, B., Tudur-Smith, C., Jones, A., Halford, J. C. G., & Robinson, E. (2016). Advertising as a cue to consume: a systematic review and meta-analysis of the effects of acute exposure to unhealthy food and nonalcoholic beverage advertising on intake in children and adults1,2. *The American Journal of Clinical Nutrition*, *103*(2), 519–533. https://doi.org/10.3945/ajcn.115.120022

Boyland, E., & Tatlow-Golden, M. (2017). Exposure, Power and Impact of Food Marketing on Children: Evidence Supports Strong Restrictions. In *European Journal of Risk Regulation* (Vol. 8, Issue 2, pp. 224–236). https://doi.org/10.1017/err.2017.21

Boyland, E., Whalen, R., Christiansen, P., Mcgale, L., Duckworth, J., Halford, J., Clark, M., Rosenberg, G., Vohra, J. 2018, & Vohra, J. (2018). *SEE IT, WANT IT, BUY IT, EAT IT HOW FOOD ADVERTISING IS ASSOCIATED WITH UNHEALTHY EATING BEHAVIOURS IN 7-11 YEAR OLD CHILDREN REFERENCE ACKNOWLEDGEMENTS*. http://www.cancerresearchuk.org/

Braden, A., Rhee, K., Peterson, C. B., Rydell, S. A., Zucker, N., & Boutelle, K. (2014). Associations between child emotional eating and general parenting style, feeding practices, and parent psychopathology. *Appetite*, *80*, 35–40. https://doi.org/https://dx.doi.org/10.1016/j.appet.2014.04.017

Brady, T. M. (2017). Obesity-related hypertension in children. In *Frontiers in Pediatrics* (Vol. 5). https://doi.org/10.3389/fped.2017.00197

Brannon, E. E., Kuhl, E. S., Boles, R. E., Aylward, B. S., Ratcliff, M. B., Valenzuela, J. M., Johnson, S. L., & Powers, S. W. (2013). Strategies for Recruitment and Retention of Families from Low-Income, Ethnic Minority Backgrounds in a Longitudinal Study of Caregiver Feeding and Child Weight. *Children's Health Care : Journal of the Association for the Care of Children's Health*, *42*(3), 198. https://doi.org/10.1080/02739615.2013.816590

Braude, L., & Stevenson, R. J. (2014). Watching television while eating increases energy intake. Examining the mechanisms in female participants. *Appetite*, *76*, 9–16. https://doi.org/10.1016/J.APPET.2014.01.005

Bray, G. A. (1996). Leptin and leptinomania. In *Lancet* (Vol. 348, Issue 9021, pp. 140–141). Elsevier. https://doi.org/10.1016/S0140-6736(05)66103-X

Bringolf-Isler, B., Schindler, C., Kayser, B., Suggs, L. S., & Probst-Hensch, N. (2018). Objectively measured physical activity in population-representative parent-child pairs: parental modelling matters and is context-specific. *BMC*

Public Health 2018 18:1, *18*(1), 1–15. https://doi.org/10.1186/S12889-018-5949-9

Brown, A., & Lee, M. (2012). Breastfeeding during the first year promotes satiety responsiveness in children aged 18-24 months. *Pediatric Obesity*, *7*(5), 382–390. https://doi.org/https://dx.doi.org/10.1111/j.2047-6310.2012.00071.x

Brownbill, R. A., & Ilich, J. Z. (2005). Measuring body composition in overweight individuals by dual energy x-ray absorptiometry. *BMC Medical Imaging*, *5*, 1. https://doi.org/10.1186/1471-2342-5-1

Bryant, M., & Stevens, J. (2006). *Measurement of Food Availability in the Home*. 67–76. https://doi.org/10.1301/nr.2006.feb.67-76

Bryant, M., Ward, D. S., Hales, D., Vaughn, A., Tabak, R. G., & Stevens, J. (2008a). Reliability and validity of the Healthy Home Survey: A tool to measure factors within homes hypothesized to relate to overweight in children. *International Journal of Behavioral Nutrition and Physical Activity*, *5*. https://doi.org/10.1186/1479-5868-5-23

Bryant, M., Ward, D. S., Hales, D., Vaughn, A., Tabak, R. G., & Stevens, J. (2008b). Reliability and validity of the Healthy Home Survey: A tool to measure factors within homes hypothesized to relate to overweight in children. *International Journal of Behavioral Nutrition and Physical Activity*, *5*(1), 23. https://doi.org/10.1186/1479-5868-5-23

Burdette, H. L., & Whitaker, R. C. (2005). A national study of neighborhood safety, outdoor play, television viewing, and obesity in preschool children. *Pediatrics*, *116*(3), 657–662. https://doi.org/10.1542/PEDS.2004-2443

Burkhauser, R. V., & Cawley, J. (2008). Beyond BMI: The value of more accurate measures of fatness and obesity in social science research. *Journal of Health Economics*, *27*(2), 519–529. https://doi.org/10.1016/j.jhealeco.2007.05.005

Cameron, A. J., van Stralen, M. M., Brug, J., Salmon, J., Bere, E., Chinapaw, M. J., De Bourdeaudhuij, I., Jan, N., Manios, Y., Moreno, L. A., & Velde, S. J. (2013). Television in the bedroom and increased body weight: potential explanations for their relationship among European schoolchildren. *Pediatric Obesity*, *8*(2), 130–141. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=23239631

Campbell, K. (2015). Biological, environmental, and social influences on childhood obesity. *Pediatric Research 2016 79:1*, *79*(1), 205–211. https://doi.org/10.1038/pr.2015.208

Campbell, K., & Crawford, D. (2001). Family food environments as determinants of preschool-aged children's eating behaviours: implications for obesity prevention policy. A review. *Australian Journal of Nutrition and Dietetics*, *58*(1), 19–25. https://daa.asn.au/wp-content/uploads/2016/12/58-1-family-food....pdf

Campbell, K., Crawford, D. A., Salmon, J., Carver, A., Garnett, S. P., & Baur, L. A. (2007). Associations Between the Home Food Environment and Obesity-promoting Eating Behaviors in Adolescence*. *Obesity*, *15*(3), 719–730. https://doi.org/10.1038/oby.2007.553

Cao, Y. T., Svensson, V., Marcus, C., Zhang, J., Zhang, J. D., & Sobko, T. (2012). Eating behaviour patterns in Chinese children aged 12-18 months and association with relative weight - factorial validation of the Children's Eating Behaviour Questionnaire. *International Journal of Behavioral Nutrition and Physical Activity*, 5. https://doi.org/http://dx.doi.org/10.1186/1479-5868-9-5

Carnell, S, Haworth, C. M. A., Plomin, R., & Wardle, J. (2008a). Genetic influence on appetite in children. *International Journal of Obesity 2008 32:10*, *32*(10), 1468–1473. https://doi.org/10.1038/ijo.2008.127

Carnell, S, Haworth, C. M. A., Plomin, R., & Wardle, J. (2008b). Genetic influence on appetite in children. *International Journal of Obesity (2005)*, *32*(10), 1468–1473. https://doi.org/10.1038/ijo.2008.127

Carnell, S, & Wardle, J. (2008a). Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *American Journal of Clinical Nutrition*, *88*(1), 22–29. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105791809&site=ehost-live

Carnell, S, & Wardle, J. (2008b). Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *American Journal of Clinical Nutrition*, *88*(1), 22–29. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105791809&site=ehost-live

Carnell, S, & Wardle, J. (2008c). Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *American Journal of Clinical Nutrition*, *88*(1), 22–29. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105791809&site=ehost-live

Carnell, Susan, & Wardle, J. (2007). Measuring behavioural susceptibility to obesity: Validation of the child eating behaviour questionnaire. *Appetite*, *48*(1), 104–113. https://doi.org/10.1016/j.appet.2006.07.075

Carnell, Susan, & Wardle, J. (2008). Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr*, *88*(1), 22–29.

Carter, O. B. J., Patterson, L. J., Donovan, R. J., Ewing, M. T., & Roberts, C. M. (2011). Children's understanding of the selling versus persuasive intent of junk food advertising: Implications for regulation. *Social Science and Medicine*, *72*(6), 962–968. https://doi.org/10.1016/j.socscimed.2011.01.018

Cassimos, D., Sidiropoulos, H., Batzios, S., Balodima, V., & Christoforidis, A. (2011). Sociodemographic and dietary risk factors for excess weight in a greek pediatric population living in Kavala, Northern Greece. *Nutr Clin Pract*, *26*(2), 186–191. https://doi.org/10.1177/0884533611399772

Chahal, H., Fung, C., Kuhle, S., & Veugelers, P. J. (2013). Availability and night-time use of electronic entertainment and communication devices are associated with short sleep duration and obesity among Canadian children. *Pediatric Obesity*, *8*(1), 42–51. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=22962067

Chai, W., & Nepper, M. J. (2015). Associations of the Home Food Environment with Eating Behaviors and Weight Status among Children and Adolescents. *J Nutr Food Sci*, 12. https://doi.org/10.4172/2155-9600.S12-004

Chaput, J. P., Leduc, G., Boyer, C., Belanger, P., LeBlanc, A. G., Borghese, M. M., & Tremblay, M. S. (2014). Electronic screens in children's bedrooms and adiposity, physical activity and sleep: do the number and type of electronic devices matter? *Canadian Journal of Public Health. Revue Canadienne de Sante Publique*, *105*(4), e273-9. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medc&AN=25166130

Chassiakos, Y. R., Radesky, J., Christakis, D., Moreno, M. A., Cross, C., Hill, D., Ameenuddin, N., Hutchinson, J., Boyd, R., Mendelson, R., Smith, J., & Swanson, W. S. (2016). Children and adolescents and digital media. *Pediatrics*, *138*(5). https://doi.org/10.1542/peds.2016-2593

Chen, H., Cohen, P., & Chen, S. (2010). How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies. *Communications in Statistics: Simulation and Computation*, *39*(4), 860–864. https://doi.org/10.1080/03610911003650383

Chen, J. L., Esquivel, J. H., Guo, J., Chesla, C. A., & Tang, S. (2018). Risk factors for obesity in preschool-aged children in China. *International Nursing Review*, *65*(2), 217–224. https://doi.org/10.1111/inr.12371

Chivers, P., Parker, H., Bulsara, M., Beilin, L., & Hands, B. (2012). Parental and early childhood influences on adolescent obesity: A longitudinal study. *Early Child Development and Care*, *182*(8), 1071–1087. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc9&AN=2012-17073-011

Coates, A. E., Hardman, C. A., Halford, J. C. G., Christiansen, P., & Boyland, E. J. (2019). Food and Beverage Cues Featured in YouTube Videos of Social Media Influencers Popular With Children: An Exploratory Study. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02142

Coates, T. J., & Thoresen, C. E. (1981). Behavior and weight changes in three obese adolescents. *Behavior Therapy*, *12*(3), 383–399. https://doi.org/10.1016/S0005-7894(81)80126-8

Cole, T. J. (1989). Using the LMS method to measure skewness in the NCHS and dutch national height standards. *Annals of Human Biology*, *16*(5), 407–419. https://doi.org/10.1080/03014468900000532

Cole, T. J., Faith, M. S., Pietrobelli, A., & Heo, M. (2005). What is the best measure of adiposity change in growing children: BMI, BMI %, BMI z-score or BMI centile? *European Journal of Clinical Nutrition*, *59*(3), 419–425. https://doi.org/10.1038/sj.ejcn.1602090

Cole, T J. (1996). Some Questions about How Growth Standards Are Used. *Hormone Research in Paediatrics*, *45(suppl 2)*(Suppl. 2), 18–23. https://www.karger.com/DOI/10.1159/000184843

Cole, Tim J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: International survey. *British Medical Journal*. https://doi.org/10.1136/bmj.320.7244.1240

Common Sense Media. (2011). *Zero to Eight A Common Sense Media Research Study FALL 2 011*.

Conley, D., Rauscher, E., Dawes, C., Magnusson, P. K. E., & Siegal, M. L. (2013). Heritability and the Equal Environments Assumption: Evidence from Multiple Samples of Misclassified Twins. *Behavior Genetics 2013 43:5*, *43*(5), 415–426. https://doi.org/10.1007/S10519-013-9602-1

Cook, L., O'Reilly, G. A., Derosa, C. J., Rohrbach, L. A., & Spruijt-Metz, D. (2015). Association between home availability and vegetable consumption in youth: A review. In *Public Health Nutrition* (Vol. 18, Issue 4, pp. 640–648). Cambridge University Press. https://doi.org/10.1017/S1368980014000664

Cook, S., & Kavey, R. E. W. (2011). Dyslipidemia and pediatric obesity. In *Pediatric Clinics of North America* (Vol. 58, Issue 6). https://doi.org/10.1016/j.pcl.2011.09.003

Cooke, L. (2008). *Poppets Study HBRC*. https://www.ucl.ac.uk/hbrc/diet/projects.html

Cooke, Lucy. (2007). The importance of exposure for healthy eating in childhood: A review. In *Journal of Human Nutrition and Dietetics* (Vol. 20, Issue 4, pp. 294–301). J Hum Nutr Diet. https://doi.org/10.1111/j.1365-277X.2007.00804.x

Corsini, N., Danthiir, V., Kettler, L., & Wilson, C. (2008). Factor structure and psychometric properties of the Child Feeding Questionnaire in Australian preschool children. *Appetite*, *51*(3), 474–481. https://doi.org/10.1016/j.appet.2008.02.013

Couch, S. C., Glanz, K., Zhou, C., Sallis, J. F., & Saelens, B. E. (2014a). Home food environment in relation to children's diet quality and weight status. *J Acad Nutr Diet*, *114*(10), 1569-1579.e1. https://doi.org/10.1016/j.jand.2014.05.015

Couch, S. C., Glanz, K., Zhou, C., Sallis, J. F., & Saelens, B. E. (2014b). Home food environment in relation to children's dietquality and weight status. *Journal of the Academy of Nutrition and Dietetics*, *114*(10), 1569-1579.e1. https://doi.org/10.1016/j.jand.2014.05.015

Crawford, D. A., Ball, K., Cleland, V. J., Campbell, K. J., Timperio, A. F., Abbott, G., Brug, J., Baur, L. A., & Salmon, J. A. (2012). Home and neighbourhood correlates of BMI among children living in socioeconomically disadvantaged neighbourhoods. *British Journal of Nutrition*, *107*(7), 1028–1036. https://doi.org/10.1017/S0007114511003801

Crawford, D., Cleland, V., Timperio, A., Salmon, J., Andrianopoulos, N., Roberts, R., Giles-Corti, B., Baur, L., & Ball, K. (2010). The longitudinal influence of home and neighbourhood environments on children's body mass index and physical activity over 5 years: the CLAN study. *International Journal of Obesity*, *34*(7), 1177–1187. https://doi.org/10.1038/ijo.2010.57

Croker, H., Cooke, L., & Wardle, J. (2011). Appetitive behaviours of children attending obesity treatment. *Appetite*, *57*(2), 525–529. https://doi.org/https://dx.doi.org/10.1016/j.appet.2011.05.320

Cross, M. B., Hallett, A. M., Ledoux, T. A., O'Connor, D. P., & Hughes, S. O. (2014). Effects of children's self-regulation of eating on parental feeding practices and child weight. *Appetite*, *81*, 76–83. https://doi.org/https://dx.doi.org/10.1016/j.appet.2014.06.014

Cui, Z., Truesdale, K. P., Robinson, T. N., Pemberton, V., French, S. A., Escarfuller, J., Casey, T. L., Hotop, A. M., Matheson, D., Pratt, C. A., Lotas, L. J., Po'E, E., Andrisin, S., & Ward, D. S. (2019). Recruitment strategies for predominantly low-income, multi-racial/ethnic children and parents to 3-year community-based intervention trials: Childhood Obesity Prevention and Treatment Research (COPTR) Consortium. *Trials*, *20*(1). https://doi.org/10.1186/S13063-019-3418-0

Cullen, K. W., Baranowski, T., Owens, E., Marsh, T., Rittenberry, L., & De Moor, C. (2003). Availability, accessibility, and preferences for fruit, 100% fruit juice, and vegetables influence children's dietary behavior. *Health Education and Behavior*, *30*(5), 615–626. https://doi.org/10.1177/1090198103257254

Dallacker, M., Hertwig, R., & Mata, J. (2018). The frequency of family meals and nutritional health in children: a meta-analysis. *Obesity Reviews*, *19*(5), 638–653. https://doi.org/10.1111/obr.12659

Dave, J. M., Evans, A. E., Pfeiffer, K. A., Watkins, K. W., & Saunders, R. P. (2010). Correlates of availability and accessibility of fruits and vegetables in homes of low-income Hispanic families. *Health Education Research*, *25*(1), 97–108. https://doi.org/10.1093/her/cyp044

Davison, K. K., & Birch, L. L. (2001a). Childhood overweight: a contextual model and recommendations for future research. *Obesity Reviews*, *2*(3), 159–171. https://doi.org/10.1046/j.1467-789x.2001.00036.x

Davison, K. K., & Birch, L. L. (2001b). Childhood overweight: A contextual model and recommendations for future research. *Obesity Reviews*, *2*(3), 159–171. https://doi.org/10.1046/j.1467-789x.2001.00036.x

De Craemer, M., De Decker, E., De Bourdeaudhuij, I., Vereecken, C., Deforche, B., Manios, Y., & Cardon, G. (2012). Correlates of energy balance-related behaviours in preschool children: a systematic review. *Obesity Reviews*, *13*(SUPPL. 1), 13–28. https://doi.org/10.1111/j.1467-789X.2011.00941.x

de Groot, C. J., van den Akker, E. L. T., Rings, E., Delemarre-van de Waal, H. A., & van der Grond, J. (2017). Brain structure, executive function and appetitive traits in adolescent obesity. *Pediatric Obesity*, *12*(4), e33–e36. https://doi.org/https://dx.doi.org/10.1111/ijpo.12149

Delfino, L. D., Tebar, W. R., Silva, D. A. S., Gil, F. C. S., Mota, J., & Christofaro, D. G. D. (2020). Food advertisements on television and eating habits in adolescents: a school-based study. *Revista de Saúde Pública*, *54*. https://doi.org/10.11606/S1518-8787.2020054001558

DelParigi, A., Chen, K., Salbe, A. D., Reiman, E. M., & Tataranni, P. A. (2005). Sensory experience of food and obesity: A positron emission tomography study of the brain regions affected by tasting a liquid meal after a prolonged fast. *NeuroImage*, *24*(2), 436–443. https://doi.org/10.1016/j.neuroimage.2004.08.035

DelParigi, A., Pannacciulli, N., Le, D. S. N. T., & Tataranni, P. A. (2005). In pursuit of neural risk factors for weight gain in humans. *Neurobiology of Aging*, *26*(1), 50–55. https://doi.org/10.1016/J.NEUROBIOLAGING.2005.09.008

Demir, D., & Bektas, M. (2017). The effect of childrens' eating behaviors and parental feeding style on childhood obesity. *Eating Behaviors*, *26*, 137–142. https://doi.org/https://dx.doi.org/10.1016/j.eatbeh.2017.03.004

Denney-Wilson, E., Crawford, D., Dobbins, T., Hardy, L., & Okely DEd, A. D. (2009). Influences on consumption of soft drinks and fast foods in adolescents. In *Asia Pac J Clin Nutr* (Vol. 18, Issue 3).

Department of Health, U., Services, H., & for Disease Control, C. (n.d.). *Preventing Chronic Disease, Public Health Research, Practice, and Policy,*. https://doi.org/10.5888/pcd14.170491

Derks, I. P. M., Sijbrands, E. J. G., Wake, M., Qureshi, F., van der Ende, J., Hillegers, M. H. J., Jaddoe, V. W. V., Tiemeier, H., & Jansen, P. W. (2018). Eating behavior and body composition across childhood: a prospective cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *15*(1), 1–9. https://doi.org/10.1186/s12966-018-0725-x

DerSimonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. *Controlled Clinical Trials*, *7*(3), 177–188. https://doi.org/10.1016/0197-2456(86)90046-2

Di Cesare, M., Sorić, M., Bovet, P., Miranda, J. J., Bhutta, Z., Stevens, G. A., Laxmaiah, A., Kengne, A. P., & Bentham, J. (2019). The epidemiological burden of obesity in childhood: A worldwide epidemic requiring urgent action. In *BMC Medicine* (Vol. 17, Issue 1). https://doi.org/10.1186/s12916-019-1449-8

DiLalla, L. F., Mullineaux, P. Y., & Elam, K. K. (2020). Twins. *The Curated Reference Collection in Neuroscience and Biobehavioral Psychology*, 398–407. https://doi.org/10.1016/B978-0-12-809324-5.22704-1

Dolinsky, D. H., Brouwer, R. J. N., Evenson, K. R., Siega-Riz, A. M., & Østbye, T. (2011). Correlates of sedentary time and physical activity among preschool-aged children. *Preventing Chronic Disease*, *8*(6). https://doi.org/10.17615/e5jb-gf29

Domoff, S. E., Miller, A. L., Kaciroti, N., & Lumeng, J. C. (2015). Validation of the Children's Eating Behaviour Questionnaire in a low-income preschool-aged sample in the United States. *Appetite*, *95*, 415–420. https://doi.org/https://dx.doi.org/10.1016/j.appet.2015.08.002

Dooyema, C. A., Belay, B., Foltz, J. L., Williams, N., & Blanck, H. M. (2013). The childhood obesity research demonstration project: A comprehensive community approach to reduce childhood obesity. *Childhood Obesity*, *9*(5), 454–459. https://doi.org/10.1089/chi.2013.0060

dos Passos, D. R., Gigante, D. P., Maciel, F. V, & Matijasevich, A. (2015). [Children's eating behaviour: comparison between normal and overweight children from a school in Pelotas, Rio Grande do Sul, Brazil]. *Revista Paulista de Pediatria*, *33*(1), 42–49. https://doi.org/https://dx.doi.org/10.1016/j.rpped.2014.11.007

Downs, S. M., Arnold, A., Marshall, D., McCargar, L. J., Raine, K. D., & Willows,

N. D. (2009). Associations among the food environment, diet quality and weight status in Cree children in Québec. *Public Health Nutrition*, *12*(9), 1504–1511. https://doi.org/10.1017/S1368980008004515

Dube, N., Khan, K., Loehr, S., Chu, Y., & Veugelers, P. (2017). The use of entertainment and communication technologies before sleep could affect sleep and weight status: a population-based study among children. *Int J Behav Nutr Phys Act*, *14*(1), 97. https://doi.org/10.1186/s12966-017-0547-2

Dunton, G. F., Kawabata, K., Intille, S., Wolch, J., & Pentz, M. A. (2012). Assessing the social and physical contexts of children's leisure-time physical activity: An Ecological Momentary Assessment study. *American Journal of Health Promotion*, *26*(3), 135–142. https://doi.org/10.4278/ajhp.100211-QUAN-43

Egger, G., & Swinburn, B. (1997). An "ecological" approach to the obesity pandemic. *BMJ*, *315*, 477–480. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2127317/pdf/9284671.pdf

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple , graphical test measures of funnel plot asymmetry. *Bmj*, *315*(7109), 629–634. https://doi.org/10.1136/bmj.315.7109.629

Eichinger, M., Schneider, S., & De Bock, F. (2017). Subjectively and objectively assessed social and physical environmental correlates of preschoolers' accelerometer-based physical activity. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1). https://doi.org/10.1186/s12966-017-0577-9

Eichler, J., Schmidt, R., Poulain, T., Hiemisch, A., Kiess, W., & Hilbert, A. (2019). Stability, continuity, and bi-directional associations of parental feeding practices and standardized child body mass index in children from 2 to 12 years of age. *Nutrients*, *11*(8). https://doi.org/10.3390/nu11081751

El-Sayed, A. M., Scarborough, P., & Galea, S. (2012). Socioeconomic inequalities in childhood obesity in the United Kingdom: A systematic review of the literature. *Obesity Facts*, *5*(5). https://doi.org/10.1159/000343611

Elks, C. E., den Hoed, M., Zhao, J. H., Sharp, S. J., Wareham, N. J., Loos, R. J. F., & Ong, K. K. (2012). Variability in the Heritability of Body Mass Index: A Systematic Review and Meta-Regression. *Frontiers in Endocrinology*, *3*(FEB), 29. https://doi.org/10.3389/fendo.2012.00029

Emond, J. A., Tovar, A., Li, Z., Lansigan, R. K., & Gilbert-Diamond, D. (2017). FTO genotype and weight status among preadolescents: Assessing the mediating effects of obesogenic appetitive traits. *Appetite*, *117*, 321–329. https://doi.org/http://dx.doi.org/10.1016/j.appet.2017.07.009

Engelen, L., Bundy, A. C., Lau, J., Naughton, G., Wyver, S., Bauman, A., & Baur, L. (2015). Understanding patterns of young children's physical activity after school - It's all about context: A cross-sectional study. *Journal of Physical Activity and Health*, *12*(3), 335–339. https://doi.org/10.1123/jpah.2013-0153

Epstein, L. H., Paluch, R., & Coleman, K. J. (1996). Differences in salivation to repeated food cues in obese and nonobese women. *Psychosomatic*

Medicine, *58*(2), 160–164. https://doi.org/10.1097/00006842-199603000-00011

Epstein, L. H., Roemmich, J. N., Robinson, J. L., Paluch, R. A., Winiewicz, D. D., Fuerch, J. H., & Robinson, T. N. (2008). A Randomized Trial of the Effects of Reducing Television Viewing and Computer Use on Body Mass Index in Young Children. *Archives of Pediatrics & Adolescent Medicine*, *162*(3), 239–245. https://doi.org/10.1001/ARCHPEDIATRICS.2007.45

Escobar, R. S., O'Donnell, K. A., Colalillo, S., Pawlby, S., Steiner, M., Meaney, M. J., Levitan, R. D., Silveira, P. P., & Team, M. S. (2014). Better quality of mother-child interaction at 4 years of age decreases emotional overeating in IUGR girls. *Appetite*, *81*, 337–342. https://doi.org/https://dx.doi.org/10.1016/j.appet.2014.06.107

Fairclough, S. J., Boddy, L. M., Hackett, A. F., & Stratton, G. (2009). Associations between children's socioeconomic status, weight status, and sex, with screen-based sedentary behaviours and sport participation. *International Journal of Pediatric Obesity*, *4*(4), 299–305. https://doi.org/10.3109/17477160902811215

Faith, M. S., Carnell, S., & Kral, T. V. E. (2013). Genetics of food intake self-regulation in childhood: Literature review and research opportunities. In *Human Heredity* (Vol. 75, Issues 2–4, pp. 80–89). https://doi.org/10.1159/000353879

Falciglia, G. A., & Gussow, J. D. (1980). Television commercials and eating behavior of obese and normal-weight women. *Journal of Nutrition Education*, *12*(4), 196–199. https://doi.org/10.1016/S0022-3182(80)80161-0

Farajian, P., Panagiotakos, D. B., Risvas, G., Malisova, O., & Zampelas, A. (2014). Hierarchical analysis of dietary, lifestyle and family environment risk factors for childhood obesity: the GRECO study. *European Journal of Clinical Nutrition*, *68*(10), 1107–1112. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24824010

Farrow, C. V., & Blissett, J. (2008). Controlling feeding practices: Cause or consequence of early child weight? *Pediatrics*, *121*(1). https://doi.org/10.1542/peds.2006-3437

Felson, J. (2014). What can we learn from twin studies? A comprehensive evaluation of the equal environments assumption. *Social Science Research*, *43*, 184–199. https://doi.org/10.1016/j.ssresearch.2013.10.004

Ferrari, G. L., Araujo, T. L., Oliveira, L. C., Matsudo, V., & Fisberg, M. (2015). Association between electronic equipment in the bedroom and sedentary lifestyle, physical activity, and body mass index of children. *Jornal de Pediatria*, *91*(6), 574–582. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=26126700

Ferrari, G. L. M., Matsudo, V., Katzmarzyk, P. T., & Fisberg, M. (2017). Prevalence and factors associated with body mass index in children aged 9-11 years. *Jornal de Pediatria*, *93*(6), 601–609. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fullte

xt&D=medl&AN=28506666

Ferreira, I., Van Der Horst, K., Wendel-Vos, W., Kremers, S., Van Lenthe, F. J., & Brug, J. (2007). Environmental correlates of physical activity in youth - A review and update. In *Obesity Reviews* (Vol. 8, Issue 2, pp. 129–154). John Wiley & Sons, Ltd. https://doi.org/10.1111/j.1467-789X.2006.00264.x

Fildes, A., Mallan, K. M., Cooke, L., van Jaarsveld, C. H., Llewellyn, C. H., Fisher, A., & Daniels, L. (2015). The relationship between appetite and food preferences in British and Australian children. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 116. https://doi.org/10.1186/s12966-015-0275-4

Fisher, J. O., & Birch, L. L. (1999). Restricting access to foods and children's eating. *Appetite*, *32*(3), 405–419. https://doi.org/10.1006/appe.1999.0231

Fleiss, J. . (1986). Reliability of measurement. In: The design and analysis of clinical experiments. *Wiley, New York*.

Fletcher, A., Wolfenden, L., Wyse, R., Bowman, J., McElduff, P., & Duncan, S. (2013). A randomised controlled trial and mediation analysis of the "Healthy Habits", telephone-based dietary intervention for preschool children. *The International Journal of Behavioral Nutrition and Physical Activity*, *10*(1), 43. https://doi.org/10.1186/1479-5868-10-43

Folkvord, F., & Hermans, R. C. J. (2020). Food Marketing in an Obesogenic Environment: a Narrative Overview of the Potential of Healthy Food Promotion to Children and Adults. *Current Addiction Reports 2020 7:4*, *7*(4), 431–436. https://doi.org/10.1007/S40429-020-00338-4

Frankel, L. A., O'Connor, T. M., Chen, T. A., Nicklas, T., Power, T. G., & Hughes, S. O. (2014). Parents' perceptions of preschool children's ability to regulate eating. Feeding style differences. *Appetite*, *76*, 166–174. https://doi.org/https://dx.doi.org/10.1016/j.appet.2014.01.077

Freeman, J. V, Cole, T. J., Chinn, S., Jones, P. R., White, E. M., & Preece, M. A. (1995). Cross sectional stature and weight reference curves for the UK, 1990. *Archives of Disease in Childhood*, *73*(1), 17. http://adc.bmj.com/content/73/1/17.abstract

Frieden, T. R., Dietz, W., & Collins, J. (2010). Reducing childhood obesity through policy change: Acting now to prevent obesity. In *Health Affairs* (Vol. 29, Issue 3, pp. 357–363). Health Affairs . https://doi.org/10.1377/hlthaff.2010.0039

Fuemmeler, B. F., Lovelady, C. A., Zucker, N. L., & Ostbye, T. (2013). Parental Obesity Moderates the Relationship Between Childhood Appetitive Traits and Weight. *Obesity*, *21*(4), 815–823. https://doi.org/10.1002/oby.20144

Fulkerson, J. A., Nelson, M. C., Lytle, L., Moe, S., Heitzler, C., & Pasch, K. E. (2008a). The validation of a home food inventory. *International Journal of Behavioral Nutrition and Physical Activity*, *5*. https://doi.org/10.1186/1479-5868-5-55

Fulkerson, J. A., Nelson, M. C., Lytle, L., Moe, S., Heitzler, C., & Pasch, K. E. (2008b). The validation of a home food inventory. *International Journal of Behavioral Nutrition and Physical Activity*, *5*, 55. https://doi.org/10.1186/1479-5868-5-55

Gable, S., & Lutz, S. (2000). Household, parent, and child contributions to childhood obesity. *Family Relations: An Interdisciplinary Journal of Applied Family Studies*, *49*(3), 293–300. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc3&AN=2000-00053-008

Galloway, A. T., Lee, Y., & Birch, L. L. (2003). Predictors and consequences of food neophobia and pickiness in young girls. *Journal of the American Dietetic Association*, *103*(6), 692–698. https://doi.org/10.1053/jada.2003.50134

Gardner, F. (2000). Methodological Issues in the Direct Observation of Parent–Child Interaction: Do Observational Findings Reflect the Natural Behavior of Participants? *Clinical Child and Family Psychology Review 2000 3:3*, *3*(3), 185–198. https://doi.org/10.1023/A:1009503409699

Gardner, K. R., Sapienza, C., & Fisher, J. O. (2015). Genetic and epigenetic associations to obesity-related appetite phenotypes among African-American children. *Pediatric Obesity*, *10*(6), 476–482. https://doi.org/https://dx.doi.org/10.1111/ijpo.12010

Gattshall, M. L., Shoup, J., Marshall, J. A., Crane, L. A., & Estabrooks, P. A. (2008). Validation of a survey instrument to assess home environments for physical activity and healthy eating in overweight children. *International Journal of Behavioral Nutrition and Physical Activity*, *5*(1), 3. https://doi.org/10.1186/1479-5868-5-3

Gibson, E. L., & Cooke, L. (2017). Understanding Food Fussiness and Its Implications for Food Choice, Health, Weight and Interventions in Young Children: The Impact of Professor Jane Wardle. *Current Obesity Reports*, *6*(1), 46–56. https://doi.org/10.1007/s13679-017-0248-9

Gingold, J. A., Simon, A. E., & Schoendorf, K. C. (2013). Excess Screen Time in US Children: Association With Family Rules and Alternative Activities. *Http://Dx.Doi.Org/10.1177/0009922813498152*, *53*(1), 41–50. https://doi.org/10.1177/0009922813498152

Golan, M. (2006). Parents as agents of change in childhood obesity - From research to practice. *International Journal of Pediatric Obesity*, *1*(2), 66–76. https://doi.org/10.1080/17477160600644272

Golan, M., & Weizman, A. (1998). Reliability and validity of the Family Eating and Activity Habits Questionnaire. *European Journal of Clinical Nutrition*, *52*(10), 771–777. https://doi.org/10.1038/sj.ejcn.1600647

Gomes, T. N., Katzmarzyk, P. T., dos Santos, F. K., de Chaves, R. N., Santos, D., Pereira, S., Champagne, C. M., Hedeker, D., & Maia, J. (2015). Are BMI and Sedentariness Correlated? A Multilevel Study in Children. *Nutrients*, *7*(7), 5889–5904. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=26193311

Granich, J., Rosenberg, M., Knuiman, M. W., & Timperio, A. (2011). Individual, social, and physical environment factors associated with electronic media use among children: Sedentary behavior at home. *Journal of Physical Activity and Health*, *8*(5), 613–625. https://doi.org/10.1123/jpah.8.5.613

Gregory, J. E., Paxton, S. J., & Brozovic, A. M. (2010). Maternal feeding practices, child eating behaviour and body mass index in preschool-aged children: A prospective analysis. *The International Journal of Behavioral Nutrition and Physical Activity Vol 7 2010, ArtID 55*, *7*. https://doi.org/http://dx.doi.org/10.1186/1479-5868-7-55

Grumbach, K., Coleman, B. G., Arger, P. H., Mintz, M. C., Gabbe, S. V., & Mennuti, M. T. (1986). Twin and singleton growth patterns compared using US. *Radiology*, *158*(1), 237–241. https://doi.org/10.1148/radiology.158.1.3510021

Grunseit, A. C., Taylor, A. J., Hardy, L. L., & King, L. (2011). Composite measures quantify households'obesogenic potential and adolescents' risk behaviors. *Pediatrics*, *128*(2). https://doi.org/10.1542/peds.2010-3331

Gubbels, J. S., Kremers, S. P., Goldbohm, R. A., Stafleu, A., & Thijs, C. (2012). Energy balance-related behavioural patterns in 5-year-old children and the longitudinal association with weight status development in early childhood. *Public Health Nutrition*, *15*(8), 1402–1410. https://doi.org/10.1017/S1368980011003089

Gubbels, J. S., Kremers, S. P., Stafleu, A., de Vries, S. I., Goldbohm, R., Dagnelie, P. C., de Vries, N. K., van Buuren, S., & Thijs, C. (2011). Association between parenting practices and children's dietary intake, activity behavior and development of body mass index: The KOALA Birth Cohort Study. *The International Journal of Behavioral Nutrition and Physical Activity Vol 8 2011, ArtID 18*, *8*. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc8&AN=2012-31145-001

Guo, G., Liu, H., Wang, L., Shen, H., & Hu, W. (2015). The Genome-Wide Influence on Human BMI Depends on Physical Activity, Life Course, and Historical Period. *Demography*, *52*(5), 1651–1670. https://doi.org/10.1007/S13524-015-0421-2

Guo, S.-W. (2001). Does Higher Concordance in Monozygotic Twins Than in Dizygotic Twins Suggest a Genetic Component? *Human Heredity*, *51*(3), 121–132. https://doi.org/10.1159/000053333

Hahs-Vaughn, D. L. (2005). Primer for Using and Understanding Weights With National Datasets. *The Journal of Experimental Education*, *73*(3), 221–248. https://doi.org/10.3200/JEXE.73.3.221-248

Hahs-Vaughn, D. L. (2006). Analysis of data from complex samples. *Http://Dx.Doi.Org/10.1080/17437270600891572*, *29*(2), 165–183. https://doi.org/10.1080/17437270600891572

Hales, D., Vaughn, A. E., Mazzucca, S., Bryant, M. J., Tabak, R. G., McWilliams, C., Stevens, J., & Ward, D. S. (2013). Development of HomeSTEAD's physical activity and screen time physical environment inventory. *International Journal of Behavioral Nutrition & Physical Activity*, *10*, 132. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=24313962

Hamaker, E. L., Kuiper, R. M., & Grasman, R. P. P. P. (2015). A critique of the cross-lagged panel model. *Psychological Methods*, *20*(1), 102–116. https://doi.org/10.1037/a0038889

Hankey, M., Williams, N. A., & Dev, D. (2016). Uninvolved maternal feeding style moderates the association of emotional overeating to preschoolers' body mass index z-scores. *Journal of Nutrition Education and Behavior*, *48*(8), 530–537. https://doi.org/http://dx.doi.org/10.1016/j.jneb.2016.06.006

Hanson, N. I., Neumark-Sztainer, D., Eisenberg, M. E., Story, M., & Wall, M. (2005). Associations between parental report of the home food environment and adolescent intakes of fruits, vegetables and dairy foods. *Public Health Nutrition*, *8*(1), 77–85. https://doi.org/10.1079/phn2005661

Hardman, C. A., Christiansen, P., & Wilkinson, L. L. (2016). Using food to soothe: Maternal attachment anxiety is associated with child emotional eating. *Appetite*, *99*, 91–96. https://doi.org/https://dx.doi.org/10.1016/j.appet.2016.01.017

Hardy, L. L., King, L., Hector, D., & Lloyd, B. (2012). Weight status and weight-related behaviors of children commencing school. *Preventive Medicine*, *55*(5), 433–437. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=22995371

Harris, H. A., Fildes, A., Mallan:, K. M., & Llewellyn, C. H. (2016). Maternal feeding practices and fussy eating in toddlerhood: a discordant twin analysis. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/s12966-016-0408-4

Harris, J. L., Bargh, J. A., & Brownell, K. D. (2009). Priming Effects of Television Food Advertising on Eating Behavior. *Health Psychology*, *28*(4), 404–413. https://doi.org/10.1037/A0014399

Harris, P. A., Taylor, R., Minor, B., Elliott, V., Fernandez, M., O'Neal, L., McLeod, L., Delacqua, G., Delacqua, F., Kirby, J., & Duda, S. (2019). The REDCap consortium: Building an international community of software platform partners. *Journal of Biomedical Informatics*, *95*. https://doi.org/10.1016/J.JBI.2019.103208

Harris, P., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. (2009). Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of Biomedical Informatics*, *42*(2), 377–381. https://doi.org/10.1016/J.JBI.2008.08.010

Harrison, M. E., Norris, M. L., Obeid, N., Fu, M., Weinstangel, H., & Sampson, M. (2015). Systematic review of the effects of family meal frequency on psychosocial outcomes in youth. *Canadian Family Physician Medecin de Famille Canadien*, *61*(2).

Hawkes, D., & Plewis, I. (2006). Modelling non-response in the National Child Development Study. *Journal of the Royal Statistical Society. Series A: Statistics in Society*, *169*(3). https://doi.org/10.1111/j.1467-985X.2006.00401.x

Haycraft, E., Farrow, C., Meyer, C., Powell, F., & Blissett, J. (2011). Relationships between temperament and eating behaviours in young children. *Appetite*, *56*(3), 689–692. https://doi.org/https://dx.doi.org/10.1016/j.appet.2011.02.005

Hayes, J. F., Altman, M., Kolko, R. P., Balantekin, K. N., Holland, J. C., Stein,

R. I., Saelens, B. E., Welch, R. R., Perri, M. G., Schechtman, K. B., Epstein, L. H., & Wilfley, D. E. (2016a). Decreasing food fussiness in children with obesity leads to greater weight loss in family-based treatment. *Obesity*, *24*(10), 2158–2163. https://doi.org/https://dx.doi.org/10.1002/oby.21622

Hayes, J. F., Altman, M., Kolko, R. P., Balantekin, K. N., Holland, J. C., Stein, R. I., Saelens, B. E., Welch, R. R., Perri, M. G., Schechtman, K. B., Epstein, L. H., & Wilfley, D. E. (2016b). Decreasing food fussiness in children with obesity leads to greater weight loss in family-based treatment. *Obesity*, *24*(10), 2158–2163. https://doi.org/https://dx.doi.org/10.1002/oby.21622

He, M., Tucker, P., Gilliland, J., Irwin, J. D., Larsen, K., & Hess, P. (2012). The Influence of Local Food Environments on Adolescents' Food Purchasing Behaviors. *International Journal of Environmental Research and Public Health 2012, Vol. 9, Pages 1458-1471*, *9*(4), 1458–1471. https://doi.org/10.3390/IJERPH9041458

Hearn, M., Baranowski, T., Baranowski, J., Doyle, C., Smith, M., Lin, L. S., & Resnicow, K. (1998). Environmental influences on dietary behavior among children: Availability and accessibility of fruits and vegetables enable consumption. *Journal of Health Education*, *29*(1), 26–32. https://doi.org/10.1080/10556699.1998.10603294

Hebden, L., Hector, D., Hardy, L. L., & King, L. (2013). A fizzy environment: Availability and consumption of sugar-sweetened beverages among school students. *Preventive Medicine*, *56*(6), 416–418. https://doi.org/10.1016/j.ypmed.2013.02.017

Hebert, J., Clemow, L., Pbert, L., Ockene, I., & Ockene, J. (1995). *Social Desirability Bias in Dietary Self-Report May Compromise the Validity of Dietary Intake Measures* (Vol. 24). https://doi.org/10.1093/ije/24.2.389

Heilmann, A., Rouxel, P., Fitzsimons, E., Kelly, Y., & Watt, R. (2017). Longitudinal associations between television in the bedroom and body fatness in a UK cohort study. *International Journal of Obesity*, *41*(10), 1503–1509. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-02265-005

Helle, C., Hillesund, E. R., Wills, A. K., & Øverby, N. C. (2019). Evaluation of an eHealth intervention aiming to promote healthy food habits from infancy - the Norwegian randomized controlled trial Early Food for Future Health. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 1. https://doi.org/10.1186/s12966-018-0763-4

Hendy, H. M., & Raudenbush, B. (2000). Effectiveness of teacher modeling to encourage food acceptance in preschool children. *Appetite*, *34*(1), 61–76. https://doi.org/10.1006/appe.1999.0286

Herle, M., Fildes, A., van Jaarsveld, C., Rijsdijk, F., & Llewellyn, C. H. (2016). Parental Reports of Infant and Child Eating Behaviors are not Affected by Their Beliefs About Their Twins' Zygosity. *Behavior Genetics*, *46*(6), 763–771. https://doi.org/10.1007/s10519-016-9798-y

Hettema, J. M., Neale, M. C., & Kendler, K. S. (1995). Physical similarity and the equal-environment assumption in twin studies of psychiatric disorders. *Behavior Genetics 1995 25:4*, *25*(4), 327–335. https://doi.org/10.1007/BF02197281

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *BMJ (Clinical Research Ed.)*, *327*(7414), 557–560. https://doi.org/10.1136/bmj.327.7414.557

Hill, D., Ameenuddin, N., Chassiakos, Y. R., Cross, C., Radesky, J., Hutchinson, J., Boyd, R., Mendelson, R., Moreno, M. A., Smith, J., & Swanson, W. S. (2016). Media use in school-aged children and adolescents. *Pediatrics*, *138*(5). https://doi.org/10.1542/peds.2016-2592

Ho-Urriola, J., Guzman-Guzman, I. P., Smalley, S. V, Gonzalez, A., Weisstaub, G., Dominguez-Vasquez, P., Valladares, M., Amador, P., Hodgson, M. I., Obregon, A. M., & Santos, J. L. (2014). Melanocortin-4 receptor polymorphism rs17782313: association with obesity and eating in the absence of hunger in Chilean children. *Nutrition*, *30*(2), 145–149. https://doi.org/https://dx.doi.org/10.1016/j.nut.2013.05.030

Hochstim, J. R. (1967). A Critical Comparison of Three Strategies of Collecting Data from Households. *Journal of the American Statistical Association*, *62*(319). https://doi.org/10.1080/01621459.1967.10500909

Hooper, D., Coughlan, J., & Mullen, M. R. (2008). Structural equation modelling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods*, *6*(1). https://doi.org/10.21427/D79B73

Horan, M., Gibney, E., Molloy, E., & McAuliffe, F. (2015). Methodologies to assess paediatric adiposity. In *Irish Journal of Medical Science* (Vol. 184, Issue 1, pp. 53–68). Springer-Verlag London Ltd. https://doi.org/10.1007/s11845-014-1124-1

Horn, E. E., Turkheimer, E., Strachan, E., & Duncan, G. E. (2015). Behavioral and Environmental Modification of the Genetic Influence on Body Mass Index: A Twin Study. *Behavior Genetics*, *45*(4). https://doi.org/10.1007/s10519-015-9718-6

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hughes, S. O., Power, T. G., Papaioannou, M. A., Cross, M. B., Nicklas, T. A., Hall, S. K., & Shewchuk, R. M. (2011). Emotional climate, feeding practices, and feeding styles: An observational analysis of the dinner meal in Head Start families. *International Journal of Behavioral Nutrition and Physical Activity*, *8*. https://doi.org/10.1186/1479-5868-8-60

Humenikova, L., & Gates, G. E. (2008). Social and physical environmental factors and child overweight in a sample of American and Czech school-aged children: A pilot study. *Journal of Nutrition Education and Behavior*, *40*(4), 251–257. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2008-08654-005

Hunot, C., Fildes, A., Croker, H., Johnson, F., & Beeken, R. J. (2016). Development of a brief Appetitive Trait Tailored Intervention (ATTI) in a sample of overweight and obese adults. *34th Annual Scientific Meeting of The Obesity Society*. https://www.researchgate.net/publication/309720102_Development_of_a_brief_Appetitive_Trait_Tailored_Intervention_ATTI_in_a_sample_of_overweight_and_obese_adults

Hunot, Claudia, Fildes, A., Croker, H., Llewellyn, C. H., Wardle, J., & Beeken, R. J. (2016). Appetitive traits and relationships with BMI in adults: Development of the Adult Eating Behaviour Questionnaire. *Appetite*, *105*, 356–363. https://doi.org/10.1016/j.appet.2016.05.024

Huybrechts, I., Himes, J. H., Ottevaere, C., De Vriendt, T., De Keyzer, W., Cox, B., Van Trimpont, I., De Bacquer, D., & De Henauw, S. (2011). Validity of parent-reported weight and height of preschool children measured at home or estimated without home measurement: A validation study. *BMC Pediatrics*, *11*. https://doi.org/10.1186/1471-2431-11-63

Huynh, D. T., Dibley, M. J., Sibbritt, D., Tran, H. T., & Le, Q. T. (2011). Influence of contextual and individual level risk factors on adiposity in a preschool child cohort in Ho Chi Minh City, Vietnam. *International Journal of Pediatric Obesity*, *6*(2–2), e487–e500. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc8&AN=2011-14759-060

IBM Corp. (2019). *IBM SPSS Statistics for Windows, Version 26.0.* (No. 26). IBM Corp.

Ihmels, M. A., Welk, G. J., Eisenmann, J. C., & Nusser, S. M. (2009). Development and preliminary validation of a Family Nutrition and Physical Activity (FNPA) screening tool. *The International Journal of Behavioral Nutrition and Physical Activity Vol 6 2009, ArtID 14*, *6*. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2012-30463-001

Ihmels, M. A., Welk, G. J., Eisenmann, J. C., Nusser, S. M., & Myers, E. F. (2009). Prediction of BMI change in young children with the family nutrition and physical activity (FNPA) screening tool. *Annals of Behavioral Medicine*, *38*(1), 60–68. https://doi.org/10.1007/s12160-009-9126-3

Inhulsen, M. B. M. R., Mérelle, S. Y. M., & Renders, C. M. (2017). Parental feeding styles, young children's fruit, vegetable, water and sugar-sweetened beverage consumption, and the moderating role of maternal education and ethnic background. *Public Health Nutrition*, *20*(12), 2124–2133. https://doi.org/10.1017/S1368980017001409

J, U., R, S., & D, S. (2006). Associations between television viewing and consumption of commonly advertised foods among New Zealand children and young adolescents. *Public Health Nutrition*, *9*(5), 606–612. https://doi.org/10.1079/PHN2005899

Jaarsveld, C., Johnson, L., Llewellyn, C., & Wardle, J. (2010). *Gemini: A UK Twin Birth Cohort With a Focus on Early Childhood Weight Trajectories, Appetite and the Family Environment* (Vol. 13). https://doi.org/10.1375/twin.13.1.72

Jacob, R., Drapeau, V., Tremblay, A., Provencher, V., Bouchard, C., & Pérusse, L. (2018a). The role of eating behavior traits in mediating genetic susceptibility to obesity. *Am J Clin Nutr*, *108*, 445–452. https://doi.org/10.1093/ajcn/nqy130

Jacob, R., Drapeau, V., Tremblay, A., Provencher, V., Bouchard, C., & Pérusse, L. (2018b). The role of eating behavior traits in mediating genetic susceptibility to obesity. *The American Journal of Clinical Nutrition*, *108*(3), 445–452. https://doi.org/10.1093/AJCN/NQY130

Jago, R., Edwards, M. J., Urbanski, C. R., & Sebire, S. J. (2013). General and specific approaches to media parenting: A systematic review of current measures, associations with screen-viewing, and measurement implications. In *Childhood Obesity* (Vol. 9, Issue SUPPL.1). Mary Ann Liebert, Inc. 140 Huguenot Street, 3rd Floor New Rochelle, NY 10801 USA. https://doi.org/10.1089/chi.2013.0031

Jago, R., Page, A., Froberg, K., Sardinha, L. B., Klasson-Heggebø, L., & Andersen, L. B. (2008). Screen-viewing and the home TV environment: The European Youth Heart Study. *Preventive Medicine*, *47*(5), 525–529. https://doi.org/10.1016/j.ypmed.2008.07.016

Jago, R., Sebire, S. J., Gorely, T., Cillero, I. H., & Biddle, S. J. (2011). "I'm on it 24/7 at the moment": A qualitative examination of multi-screen viewing behaviours among UK 10-11 year olds. *International Journal of Behavioral Nutrition and Physical Activity 2011 8:1*, *8*(1), 1–8. https://doi.org/10.1186/1479-5868-8-85

Jago, R., Sebire, S. J., Lucas, P. J., Turner, K. M., Bentley, G. F., Goodred, J. K., Stewart-Brown, S., & Fox, K. R. (2013). Parental modelling, media equipment and screen-viewing among young children: cross-sectional study. *BMJ Open*, *3*(4), e002593. https://doi.org/10.1136/BMJOPEN-2013-002593

Jago, R., Stamatakis, E., Gama, A., Carvalhal, I. M., Nogueira, H., Rosado, V., & Padez, C. (2012). Parent and Child Screen-Viewing Time and Home Media Environment. *Am J Prev Med*, *43*(2), 150–158. https://doi.org/10.1016/j.amepre.2012.04.012

Jago, R., Thompson, J. L., Sebire, S. J., Wood, L., Pool, L., Zahra, J., & Lawlor, D. A. (2014a). Cross-sectional associations between the screen-time of parents and young children: Differences by parent and child gender and day of the week. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 1–8. https://doi.org/10.1186/1479-5868-11-54

Jago, R., Thompson, J. L., Sebire, S. J., Wood, L., Pool, L., Zahra, J., & Lawlor, D. A. (2014b). Cross-sectional associations between the screen-time of parents and young children: Differences by parent and child gender and day of the week. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 54. https://doi.org/10.1186/1479-5868-11-54

Jahnke, D. L., & Warschburger, P. A. (2008). Familial transmission of eating behaviors in preschool-aged children. *Obesity*, *16*(8), 1821–1825. https://doi.org/https://dx.doi.org/10.1038/oby.2008.255

Jansen, P. W., de Barse, L. M., Jaddoe, V. W. V., Verhulst, F. C., Franco, O. H., & Tiemeier, H. (2017). Bi-directional associations between child fussy eating and parents' pressure to eat: Who influences whom? *Physiology & Behavior*, *176*, 101–106. https://doi.org/10.1016/J.PHYSBEH.2017.02.015

Jansen, P. W., Roza, S. J., Jaddoe, V. W., Mackenbach, J. D., Raat, H., Hofman, A., Verhulst, F. C., & Tiemeier, H. (2012). Children's eating behavior, feeding practices of parents and weight problems in early childhood: Results from the population-based Generation R Study. *The International Journal of Behavioral Nutrition and Physical Activity Vol 9 2012, ArtID 130*, *9*. https://doi.org/http://dx.doi.org/10.1186/1479-5868-9-130

Jansen, P. W., Tharner, A., Van Der Ende, J., Wake, M., Raat, H., Hofman, A., Verhulst, F. C., Van Ijzendoorn, M. H., Jaddoe, V. W. V., & Tiemeier, H. (2014). Feeding practices and child weight: Is the association bidirectional in preschool children? *American Journal of Clinical Nutrition*, *100*(5), 1329–1336. https://doi.org/10.3945/ajcn.114.088922

Jarrett, R. L., Bahar, O. S., & Kersh, R. T. (2016). "When We Do Sit Down Together." *Journal of Family Issues*, *37*(11), 1483–1513. https://doi.org/10.1177/0192513X14547417

Johnson, W., Krueger, R. F., Bouchard, T. J., & McGue, M. (2002). The Personalities of Twins: Just Ordinary Folks. *Twin Research and Human Genetics*, *5*(2), 125–131. https://doi.org/10.1375/TWIN.5.2.125

Jones, B. L., & Fiese, B. H. (2014). Parent routines, child routines, and family demographics associated with obesity in parents and preschool-aged children. *Frontiers in Psychology Vol 5 2014, ArtID 374*, *5*. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc11&AN=2014-41178-001

Jones, R. A., Okely, A. D., Gregory, P., & Cliff, D. P. (2009). Relationships between weight status and child, parent and community characteristics in preschool children. *International Journal of Pediatric Obesity*, *4*(1), 54–60. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2009-02079-005

Kaushal ∗, N., & Rhodes, R. E. (2014). The home physical environment and its relationship with physical activity and sedentary behavior: A systematic review. *Preventive Medicine*, *67*, 221–237. https://doi.org/10.1016/j.ypmed.2014.07.026

Keihner, A. J., Mitchell, P. R., Kitzmann, C., Sugerman, S., & Foerster, S. B. (2009). Psychosocial, socioeconomic, behavioral, and environmental risk factors for BMI and overweight among 9- to 11-year-old children. *Californian Journal of Health Promotion*, *7*(S1), 1–20. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105071284&site=ehost-live

Kelder, S. H., Perry, C. L., Klepp, K. I., & Lytle, L. L. (1994). Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. *American Journal of Public Health*, *84*(7), 1121–1126. https://doi.org/10.2105/AJPH.84.7.1121

Kelley, G. A., Kelley, K. S., & Pate, R. R. (n.d.). *Exercise and adiposity in overweight and obese children and adolescents: a systematic review with network meta-analysis of randomised trials*. https://doi.org/10.1136/bmjopen-2019-031220

Kelly, B., Bochynska, K., Kornman, K., & Chapman, K. (2008). Internet food marketing on popular children's websites and food product websites in Australia. *Public Health Nutrition*, *11*(11), 1180–1187. https://doi.org/10.1017/S1368980008001778

Kelly, B., Vandevijvere, S., Ng, S., Adams, J., Allemandi, L., Bahena-Espina, L., Barquera, S., Boyland, E., Calleja, P., Carmona-Garcés, I. C., Castronuovo, L., Cauchi, D., Correa, T., Corvalán, C., Cosenza-Quintana, E. L., Fernández-Escobar, C., González-Zapata, L. I., Halford, J., Jaichuen, N., … Swinburn, B. (2019). Global benchmarking of children's exposure to television advertising of unhealthy foods and beverages across 22 countries. *Obesity Reviews*, *20*(S2), 116–128. https://doi.org/10.1111/obr.12840

Kendler, K. S., Neale, M. C., Kessler, R. C., Heath, A. C., & Eaves, L. J. (1993). A test of the equal-environment assumption in twin studies of psychiatric illness. *Behavior Genetics*, *23*(1), 21–27. https://doi.org/10.1007/BF01067551

Kesten, J. M., Sebire, S. J., Turner, K. M., Stewart-Brown, S., Bentley, G., & Jago, R. (2015). Associations between rule-based parenting practices and child screen viewing: A cross-sectional study. *Preventive Medicine Reports*, *2*. https://doi.org/10.1016/j.pmedr.2015.01.005

Kim, H. S., Park, Y. H., Park, H. B., & Kim, S. H. (2014). Estimation of effects of factors related to preschooler body mass index using quantile regression model. *Asian Nurs Res (Korean Soc Nurs Sci)*, *8*(4), 293–299. https://doi.org/10.1016/j.anr.2014.07.005

King, B. M., Ivester, A. N., Burgess, P. D., Shappell, K. M., Coleman, K. L., Cespedes, V. M., Pruitt, H. S., Burden, G. K., & Bour, E. S. (2016). Adults with Obesity Underreport High-calorie Foods in the Home. *Health Behavior and Policy Review*, *3*(5), 439–443. https://doi.org/10.14485/hbpr.3.5.4

King, N. A., Snell, L., Smith, R. D., & Blundell, J. E. (1996). Effects of short-term exercise on appetite responses in unrestrained females. *European Journal of Clinical Nutrition*, *50*(10), 663–667. https://www.cochranelibrary.com/es/central/doi/10.1002/central/CN-00352085/full

King, N., & Blundell, J. (1995). High-fat foods overcome the energy expenditure induced by high-intensity cycling or running. *European Journal of Clinical Nutrition*.

King, Neil A, Caudwell, P. P., Hopkins, M., Stubbs, J. R., Naslund, E., & Blundell, J. E. (2009). Dual-process action of exercise on appetite control: increase in orexigenic drive but improvement in meal-induced satiety. *The American Journal of Clinical Nutrition*, *90*(4), 921–927. https://doi.org/10.3945/AJCN.2009.27706

Kininmonth, A., Smith, A., Carnell, S., Steinsbekk, S., Fildes, A., & Llewellyn, C. (2021). The association between childhood adiposity and appetite assessed using the Child Eating Behavior Questionnaire and Baby Eating Behavior Questionnaire: A systematic review and meta-analysis. In *Obesity Reviews* (Vol. 22, Issue 5). Obes Rev. https://doi.org/10.1111/obr.13169

Kininmonth, A., Smith, A. D., Llewellyn, C. H., Dye, L., Lawton, C. L., & Fildes, A. (2021). The relationship between the home environment and child adiposity: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *18*(1), 4. https://doi.org/10.1186/s12966-020-01073-9

Kininmonth, A.R., Schrempft, S., Smith, A., Dye, L., Lawton, C., Fisher, A., Llewellyn, C. H., & Fildes, A. (n.d.). Associations between the obesogenic home environment and childhood weight: a cross-lagged panel analysis. *International Journal of Obesity*.

Kininmonth, A.R., Schrempft, S., Smith, A., Dye, L., Lawton, C., Fisher, A., Llewellyn, C. H., & Fildes, A. (2022). The Home Environment Interview and associations with energy balance behaviours and body weight in school-aged children – A feasibility, reliability, and validity study. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/s12966-021-01235-3

Kininmonth, Alice R., Smith, A. D., Llewellyn, C. H., & Fildes, A. (2020). Socioeconomic status and changes in appetite from toddlerhood to early childhood. *Appetite*, *146*, 104517. https://doi.org/10.1016/j.appet.2019.104517

Klesges, R. C., Coates, T. J., Brown, G., Sturgeon-Tillisch, J., Moldenhauer-Klesges, L. M., Holzer, B., Woolfrey, J., & Vollmer, J. (1983). Parental influences on children's eating behavior and relative weight. *Journal of Applied Behavior Analysis*, *16*(4), 371–378. https://doi.org/10.1901/jaba.1983.16-371

Klump, K. L., McGue, M., & Iacono, W. G. (2000). Age differences in genetic and environmental influences on eating attitudes and behaviors in preadolescent and adolescent female twins. *Journal of Abnormal Psychology*, *109*(2), 239. https://doi.org/10.1037/0021-843X.109.2.239

Klump, K. L., McGue, M., & Iacono, W. G. (2003). Differential heritability of eating attitudes and behaviors in prepubertal versus pubertal twins. *International Journal of Eating Disorders*, *33*(3), 287–292. https://doi.org/10.1002/EAT.10151

Knopik, V., Neiderhiser, J., DeFries, J. C., & Plomin, R. (2017a). *Behavioural Genetics* (Seventh Ed). Worth Publishers Macmillan Learning.

Knopik, V., Neiderhiser, J., DeFries, J. C., & Plomin, R. (2017b). Chapter 8: The Interplay between genes and environment. In C. Linsmeier, S. Berger, & M. Rostek (Eds.), *Behavioral Genetics* (7th ed., pp. 111–130). Worth Publishers Macmillan Learning.

Knopik, V., Neiderhiser, J., DeFries, J. C., & Plomin, R. (2017c). Estimating Genetic and Environmental Influences. In *Behavioral Genetics* (pp. 93–109).

Knopik, V., Neiderhiser, J., DeFries, J. C., & Plomin, R. (2017d). Nature, Nurture, and Human Behavior. In *Behavior Genetics* (12th ed., pp. 79–92). Worth Publishers Macmillan Learning.

Knowlden, A. P., & Sharma, M. (2012). Systematic review of family and home-based interventions targeting paediatric overweight and obesity. *Obesity Reviews*, *13*(6), 499–508. https://doi.org/10.1111/J.1467-789X.2011.00976.X/FORMAT/PDF

Koch, A., & Pollatos, O. (2014a). Interoceptive sensitivty, body weight and eating behavior in children: a prospective study. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.01003

Koch, A., & Pollatos, O. (2014b). Interoceptive sensitivty, body weight and eating behavior in children: a prospective study. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.01003

Korn, E. L., & Graubard, B. I. (1995). Examples of Differing Weighted and Unweighted Estimates from a Sample Survey. *The American Statistician*, *49*(3), 291. https://doi.org/10.2307/2684203

Kral, T. V. E., & Faith, M. S. (2009). Influences on Child Eating and Weight Development from a Behavioral Genetics Perspective. *Journal of Pediatric Psychology*, *34*(6), 596–605. https://doi.org/10.1093/jpepsy/jsn037

Kral, Tanja V E, & Faith, M. S. (2007). Child eating patterns and weight regulation: a developmental behaviour genetics framework. *Acta Paediatrica*, *96*(SUPPL. 454), 29–34. https://doi.org/10.1111/j.1651-2227.2007.00167.x

Kremers, S. P., de Bruijn, G.-J., Visscher, T. L., van Mechelen, W., de Vries, N. K., & Brug, J. (2006). Environmental influences on energy balance-related behaviors: A dual-process view. *International Journal of Behavioral Nutrition and Physical Activity 2006 3:1*, *3*(1), 1–10. https://doi.org/10.1186/1479-5868-3-9

Kröller, K., & Warschburger, P. (2008). Associations between maternal feeding style and food intake of children with a higher risk for overweight. *Appetite*, *51*(1), 166–172. https://doi.org/10.1016/J.APPET.2008.01.012

Lane, A., Harrison, M., & Murphy, N. (2014). Screen time increases risk of overweight and obesity in active and inactive 9-year-old Irish children: a cross sectional analysis. *Journal of Physical Activity & Health*, *11*(5), 985–991. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=23799255

Larsen, J. K., Sleddens, E. F. C., Vink, J. M., van den Broek, N., & Kremers, S. P. J. (2017). The sex-specific interaction between food responsiveness and sleep duration explaining body mass index among children. *Sleep Medicine*, *40*, 106–109. https://doi.org/10.1016/j.sleep.2017.09.025

Larson, N., Miller, J. M., Eisenberg, M. E., Watts, A. W., Story, M., & Neumark-Sztainer, D. (2017). Multicontextual correlates of energy-dense, nutrient-poor snack food consumption by adolescents. *Appetite*, *112*, 23–34. https://doi.org/10.1016/j.appet.2017.01.008

Laskey, M. A. (1996). Dual-energy X-ray absorptiometry and body composition. *Nutrition*, *12*(1), 45–51. https://doi.org/10.1016/0899-9007(95)00017-8

LeBlanc, A. G., Broyles, S. T., Chaput, J. P., Leduc, G., Boyer, C., Borghese, M. M., & Tremblay, M. S. (2015). Correlates of objectively measured sedentary time and self-reported screen time in Canadian children. *International Journal of Behavioral Nutrition & Physical Activity*, *12*, 38. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25889903

LeBlanc, A. G., Katzmarzyk, P. T., Barreira, T. V, Broyles, S. T., Chaput, J. P., Church, T. S., Fogelholm, M., Harrington, D. M., Hu, G., Kuriyan, R., Kurpad, A., Lambert, E. V, Maher, C., Maia, J., Matsudo, V., Olds, T., Onywera, V., Sarmiento, O. L., Standage, M., … Group, I. R. (2015). Correlates of Total Sedentary Time and Screen Time in 9-11 Year-Old Children around the World: The International Study of Childhood Obesity, Lifestyle and the Environment. *PLoS ONE [Electronic Resource]*, *10*(6), e0129622. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medc&AN=26068231

Lehto, R., Ray, C., Lahti-Koski, M., Roos, E., Lehto, R., Ray, C., Lahti-Koski, M., & Roos, E. (2011). Health behaviors, waist circumference and waist-to-height ratio in children. *European Journal of Clinical Nutrition*, *65*(7), 841–848. https://doi.org/10.1038/ejcn.2011.49

Li, B., Adab, P., & Cheng, K. K. (2014). Family and neighborhood correlates of overweight and obesogenic behaviors among Chinese children. *International Journal of Behavioral Medicine*, *21*(4), 700–709. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24057407

Lin, Y. C., Fung, X. C. C., Tsai, M. C., Strong, C., Hsieh, Y. P., & Lin, C. Y. (2019). Insufficient Physical Activity and Overweight: Does Caregiver Screen-Viewing Matter? *Journal of Child and Family Studies*, *28*(1), 286–297. https://doi.org/10.1007/s10826-018-1247-5

Linabery, A. M., Nahhas, R. W., Johnson, W., Choh, A. C., Towne, B., Odegaard, A. O., Czerwinski, S. A., & Demerath, E. W. (2013). Stronger influence of maternal than paternal obesity on infant and early childhood body mass index: the Fels Longitudinal Study. *Pediatric Obesity*, *8*(3), 159–169. https://doi.org/10.1111/J.2047-6310.2012.00100.X

Lipowska, M., Lipowski, M., Jurek, P., Jankowska, A. M., & Pawlicka, P. (2018). Gender and body-fat status as predictors of parental feeding styles and children's nutritional knowledge, eating habits and behaviours. *International Journal of Environmental Research and Public Health*, *15*(5). https://doi.org/10.3390/ijerph15050852

Liszewska, N., Scholz, U., Radtke, T., Horodyska, K., Liszewski, M., & Luszczynska, A. (2018). Association between children's physical activity and parental practices enhancing children's physical activity: The moderating effects of children's BMI z-score. *Frontiers in Psychology Vol 8 2018, ArtID 2359*, *8*. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-04598-001

Little, R. J. A., & Rubin, D. B. (2002). Statistical analysis with missing data. In *Statistical Analysis with Missing Data*. wiley. https://doi.org/10.1002/9781119013563

Llewellyn, A., Simmonds, M., Owen, C. G., & Woolacott, N. (2016). Childhood obesity as a predictor of morbidity in adulthood: A systematic review and meta-analysis. *Obesity Reviews*, *17*(1), 56–67. https://doi.org/10.1111/obr.12316

Llewellyn, C., & Fildes, A. (2017). Behavioural Susceptibility Theory: Professor

Jane Wardle and the Role of Appetite in Genetic Risk of Obesity. *Current Obesity Reports*, *6*(1), 38–45. https://doi.org/10.1007/s13679-017-0247-x

Llewellyn, C., Trzaskowski, M., van Jaarsveld, C. H., Plomin, R., & Wardle, J. (2014). Satiety mechanisms in genetic risk of obesity. *JAMA Pediatr*, *168*(4), 338–344. https://doi.org/https://dx.doi.org/10.1001/jamapediatrics.2013.4944

Llewellyn, C., van Jaarsveld, C. H., Johnson, L., Carnell, S., & Wardle, J. (2011). Development and factor structure of the Baby Eating Behaviour Questionnaire in the Gemini birth cohort. *Appetite*, *57*(2), 388–396. https://doi.org/https://dx.doi.org/10.1016/j.appet.2011.05.324

Llewellyn, C., van Jaarsveld, C. H. M., Plomin, R., Fisher, A., & Wardle, J. (2012). Inherited behavioral susceptibility to adiposity in infancy: a multivariate genetic analysis of appetite and weight in the Gemini birth cohort. *American Journal of Clinical Nutrition*, *95*(3), 633–639. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108164473&site=ehost-live

Llewellyn, C., & Wardle, J. (2015). Behavioral susceptibility to obesity: Gene–environment interplay in the development of weight. *Physiology & Behavior*, *152*, 494–501. https://doi.org/https://doi.org/10.1016/j.physbeh.2015.07.006

Llewellyn, C H, van Jaarsveld, C. H. M., Johnson, L., Carnell, S., & Wardle, J. (2010). Nature and nurture in infant appetite: analysis of the Gemini twin birth cohort. *The American Journal of Clinical Nutrition*, *91*(5), 1172–1179. https://doi.org/10.3945/ajcn.2009.28868

Llewellyn, Clare H. (2018). Genetic susceptibility to the “obesogenic” environment: the role of eating behavior in obesity and an appetite for change. *Am J Clin Nutr*, *108*, 429–430. https://doi.org/10.1093/ajcn/nqy210

Llewellyn, Clare H, van Jaarsveld, C. H., Boniface, D., Carnell, S., & Wardle, J. (2008). Eating rate is a heritable phenotype related to weight in children. *The American Journal of Clinical Nutrition*, *88*(6), 1560–1566. https://doi.org/10.3945/AJCN.2008.26175

Llewellyn, Clare H, van Jaarsveld, C. H. M., Plomin, R., Fisher, A., & Wardle, J. (2012). Inherited behavioral susceptibility to adiposity in infancy: a multivariate genetic analysis of appetite and weight in the Gemini birth cohort. *American Journal of Clinical Nutrition*, *95*(3), 633–639. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108164473&site=ehost-live

Lluch, A., King, N., & Blundell, J. (1998). Exercise in dietary restrained women: no effect on energy intake but change in hedonic ratings. *European Journal of Clinical Nutrition 1998 52:4*, *52*(4), 300–307. https://doi.org/10.1038/sj.ejcn.1600555

Lo, C. B., Waring, M. E., Pagoto, S. L., & Lemon, S. C. (2015). A television in the bedroom is associated with higher weekday screen time among youth with attention deficit hyperactivity disorder (ADD/ADHD). *Preventive Medicine Reports*, *2*, 1–3. https://doi.org/10.1016/J.PMEDR.2014.11.001

Loh, D. A., Moy, F. M., Zaharan, N. L., & Mohamed, Z. (2013). Eating behaviour among multi-ethnic adolescents in a middle-income country as measured by the self-reported Children’s Eating Behaviour Questionnaire. *PLoS ONE*

[Electronic Resource], *8*(12), e82885. https://doi.org/https://dx.doi.org/10.1371/journal.pone.0082885

Lopez-Barron, R. G., Jimenez-Cruz, A., & Bacardi-Gascon, M. (2015). Modifiable environmental obesity risk factors among elementary school children in a Mexico-us border city. *Nutricion Hospitalaria*, *31*(5), 2047–2053. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25929373

Lora, K. R., Hubbs-Tait, L., Ferris, A. M., & Wakefield, D. (2016). African-American and Hispanic children's beverage intake: Differences in associations with desire to drink, fathers' feeding practices, and weight concerns. *Appetite*, *107*, 558–567. https://doi.org/http://dx.doi.org/10.1016/j.appet.2016.09.012

Lytle, L. A., Hearst, M. O., Fulkerson, J., Murray, D. M., Martinson, B., Klein, E., Pasch, K., & Samuelson, A. (2011). Examining the relationships between family meal practices, family stressors, and the weight of youth in the family. *Annals of Behavioral Medicine*, *41*(3), 353–362. https://doi.org/10.1007/s12160-010-9243-z

MacFarlane, A., Cleland, V., Crawford, D., Campbell, K., & Timperio, A. (2009). Longitudinal examination of the family food environment and weight status among children. *International Journal of Pediatric Obesity*, *4*(4), 343–352. https://doi.org/10.3109/17477160902846211

Maes, H. H. M., Neale, M. C., & Eaves, L. J. (1997). Genetic and Environmental Factors in Relative Body Weight and Human Adiposity. *Behavior Genetics 1997 27:4*, *27*(4), 325–351. https://doi.org/10.1023/A:1025635913927

Maitland, C., Stratton, G., Foster, S., Braham, R., & Rosenberg, M. (2013). A place for play? The influence of the home physical environment on children's physical activity and sedentary behaviour. In *International Journal of Behavioral Nutrition and Physical Activity* (Vol. 10, Issue 1, pp. 1–21). BioMed Central. https://doi.org/10.1186/1479-5868-10-99

Mallan, K., Fildes, A., Magarey, A., & Daniels, L. (2016). The Relationship between Number of Fruits, Vegetables, and Noncore Foods Tried at Age 14 Months and Food Preferences, Dietary Intake Patterns, Fussy Eating Behavior, and Weight Status at Age 3.7 Years. In *Journal of the academy of nutrition and dietetics* (Vol. 116, Issue 4, pp. 630–637). https://doi.org/10.1016/j.jand.2015.06.006

Mallan, K., Nambiar, S., Magarey, A., & Daniels, L. (2014). Satiety responsiveness in toddlerhood predicts energy intake and weight status at four years of age. In *Appetite* (Vol. 74, pp. 79–85). https://doi.org/10.1016/j.appet.2013.12.001

Mallan, K M, Fildes, A., Magarey, A. M., & Daniels, L. A. (2016). The Relationship between Number of Fruits, Vegetables, and Noncore Foods Tried at Age 14 Months and Food Preferences, Dietary Intake Patterns, Fussy Eating Behavior, and Weight Status at Age 3.7 Years. *J Acad Nutr Diet*, *116*(4), 630–637. https://doi.org/10.1016/j.jand.2015.06.006

Mallan, K M, Liu, W. H., Mehta, R. J., Daniels, L. A., Magarey, A., & Battistutta, D. (2013). Maternal report of young children's eating styles. Validation of the Children's Eating Behaviour Questionnaire in three ethnically diverse Australian samples. *Appetite*, *64*, 48–55. https://doi.org/https://dx.doi.org/10.1016/j.appet.2013.01.003

Mallan, Kimberley M, Nambiar, S., Magarey, A. M., & Daniels, L. A. (2014). Satiety responsiveness in toddlerhood predicts energy intake and weight status at four years of age. *Appetite*, *74*, 79–85. https://doi.org/https://doi.org/10.1016/j.appet.2013.12.001

Mascola, A. J., Bryson, S. W., & Agras, W. S. (2010). Picky eating during childhood: a longitudinal study to age 11 years. *Eating Behaviors*, *11*(4), 253–257. https://doi.org/10.1016/j.eatbeh.2010.05.006

Mathialagan, A., Nallasamy, N., & Razali, S. N. (2018). Physical activity and media environment as antecedents of childhood obesity in malaysia. *Asian Journal of Pharmaceutical and Clinical Research*, *11*(9), 287–292. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emexb&AN=624270344

McCaffery, J. M., Papandonatos, G. D., Bond, D. S., Lyons, M. J., & Wing, R. R. (2009). Gene × environment interaction of vigorous exercise and body mass index among male Vietnam-era twins. *The American Journal of Clinical Nutrition*, *89*(4), 1011–1018. https://doi.org/10.3945/AJCN.2008.27170

McCarthy, E. K., Chaoimh, C., Murray, D. M., Hourihane, J. O., Kenny, L. C., & Kiely, M. (2015). Eating behaviour and weight status at 2 years of age: data from the Cork BASELINE Birth Cohort Study. *European Journal of Clinical Nutrition*, *69*(12), 1356–1359. https://doi.org/https://dx.doi.org/10.1038/ejcn.2015.130

McKenzie, T. L., Sallis, J. F., Nader, P. R., Patterson, T. L., Elder, J. P., Berry, C. C., Rupp, J. W., Atkins, C. J., Buono, M. J., & Nelson, J. A. (1991). BEACHES: AN OBSERVATIONAL SYSTEM FOR ASSESSING CHILDREN'S EATING AND PHYSICAL ACTIVITY BEHAVIORS AND ASSOCIATED EVENTS. *Journal of Applied Behavior Analysis*, *24*(1), 141–151. https://doi.org/10.1901/jaba.1991.24-141

McPhie, S, Skouteris, H., McCabe, M., Ricciardelli, L. A., Milgrom, J., Baur, L. A., Aksan, N., & Dell'aquila, D. (2011). Maternal correlates of preschool child eating behaviours and body mass index: a cross-sectional study. *International Journal of Pediatric Obesity*, *6*(5–6), 476–480. https://doi.org/https://dx.doi.org/10.3109/17477166.2011.598937

McPhie, Skye, Skouteris, H., Fuller-Tyszkiewicz, M., McCabe, M., Ricciardelli, L. A., Milgrom, J., Baur, L. A., & Dell'Aquila, D. (2012). Maternal predictors of preschool child-eating behaviours, food intake and body mass index: A prospective study. *Early Child Development and Care*, *182*(8), 999–1014. https://doi.org/http://dx.doi.org/10.1080/03004430.2012.678595

Mei, Z., Grummer-Strawn, L. M., Pietrobelli, A., Goulding, A., Goran, M. I., & Dietz, W. H. (2002). Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents. *American Journal of Clinical Nutrition*, *75*(6), 978–985. https://doi.org/10.1093/ajcn/75.6.978

Mihrshahi, S., Drayton, B. A., Bauman, A. E., & Hardy, L. L. (2017).

Associations between childhood overweight, obesity, abdominal obesity and obesogenic behaviors and practices in Australian homes. *BMC Public Health*, *18*, 1–10. https://doi.org/10.1186/s12889-017-4595-y

Min, J., Chiu, D. T., & Wang, Y. (2013a). Variation in the heritability of body mass index based on diverse twin studies: a systematic review. *Obesity Reviews*, *14*(11), 871–882. https://doi.org/doi:10.1111/obr.12065

Min, J., Chiu, D. T., & Wang, Y. (2013b). Variation in the heritability of body mass index based on diverse twin studies: a systematic review. *Obesity Reviews : An Official Journal of the International Association for the Study of Obesity*, *14*(11), 871–882. https://doi.org/10.1111/obr.12065

Modesti, P. A., Reboldi, G., Cappuccio, F. P., Agyemang, C., Remuzzi, G., Rapi, S., Perruolo, E., Parati, G., & Settings, E. W. G. on C. R. in L. R. (2016). Panethnic Differences in Blood Pressure in Europe: A Systematic Review and Meta-Analysis. *PLOS ONE*, *11*(1), e0147601. https://doi.org/10.1371/journal.pone.0147601

Monasta, L., Batty, G. D., Cattaneo, A., Lutje, V., Ronfani, L., Van Lenthe, F. J., & Brug, J. (2010). Early-life determinants of overweight and obesity: A review of systematic reviews. In *Obesity Reviews* (Vol. 11, Issue 10, pp. 695–708). Obes Rev. https://doi.org/10.1111/j.1467-789X.2010.00735.x

Moore, L. L., Lombardi, D. A., White, M. J., Campbell, J. L., Oliveria, S. A., & Ellison, R. C. (1991). Influence of parents' physical activity levels on activity levels of young children. *The Journal of Pediatrics*, *118*(2), 215–219. https://doi.org/10.1016/S0022-3476(05)80485-8

Moreno, J. P., Kelley, M. Lou, Landry, D. N., Paasch, V., Terlecki, M. A., Johnston, C. A., & Foreyt, J. P. (2011). Development and validation of the Family Health Behavior Scale. *International Journal of Pediatric Obesity*, *6*(2–2), e480–e486. https://doi.org/10.3109/17477166.2011.575148

Mosli, R. H., Lumeng, J. C., Kaciroti, N., Peterson, K. E., Rosenblum, K., Baylin, A., & Miller, A. L. (2015). Higher weight status of only and last-born children. Maternal feeding and child eating behaviors as underlying processes among 4-8 year olds. *Appetite*, *92*, 167–172. https://doi.org/https://dx.doi.org/10.1016/j.appet.2015.05.021

Musher-Eizenman, D., & Holub, S. (2007). Comprehensive feeding practices questionnaire: Validation of a new measure of parental feeding practices. *Journal of Pediatric Psychology*, *32*(8), 960–972. https://doi.org/10.1093/jpepsy/jsm037

Must, A., & Tybor, D. J. (2005). Physical activity and sedentary behavior: A review of longitudinal studies of weight and adiposity in youth. *International Journal of Obesity*. https://doi.org/10.1038/sj.ijo.0803064

Mustelin, L., Silventoinen, K., Pietiläinen, K., Rissanen, A., & Kaprio, J. (2008). Physical activity reduces the influence of genetic effects on BMI and waist circumference: a study in young adult twins. *International Journal of Obesity 2009 33:1*, *33*(1), 29–36. https://doi.org/10.1038/ijo.2008.258

Nepper, M. J., & Chai, W. (2016). Assessment of Home Food Environment among Healthy Weight and Overweight School-age Children. *Health Behavior and Policy Review*, *3*(6), 568–580. https://doi.org/10.14485/hbpr.3.6.6

Neumark-Sztainer, D., Hannan, P. J., Story, M., Croll, J., & Perry, C. (2003). Family meal patterns: Associations with sociodemographic characteristics and improved dietary intake among adolescents. *Journal of the American Dietetic Association*, *103*(3), 317–322. https://doi.org/10.1053/JADA.2003.50048

Neumark-Sztainer, D., Wall, M., Perry, C., & Story, M. (2003). Correlates of fruit and vegetable intake among adolescents: Findings from Project EAT. *Preventive Medicine*, *37*(3), 198–208. https://doi.org/10.1016/S0091-7435(03)00114-2

Newsom, J. (2015). Cross-Lagged Panel Models. In *Longitudinal Structural Equation Modeling: A comprehensive introduction* (pp. 122–138). Taylor and Francis Inc.

NHS. (2018). *National Child Measurement Programme, England - 2017/18 School Year [PAS]*. 2018 Health and Social Care Information Centre. https://digital.nhs.uk/data-and-information/publications/statistical/national-child-measurement-programme/2017-18-school-year

NHS Digital. (2020a). *National Child Measurement Programme, England 2019/20 School Year - NHS Digital*. National Child Measurement Programme. https://digital.nhs.uk/data-and-information/publications/statistical/national-child-measurement-programme/2019-20-school-year

NHS Digital. (2020b, October 29). *National Child Measurement Programme, England 2019/20 School Year*. National Child Measurement Programme. https://digital.nhs.uk/data-and-information/publications/statistical/national-child-measurement-programme/2019-20-school-year/age

Nisbett, R. E. (1968). Taste, deprivation, and weight determinants of eating behavior. *Journal of Personality and Social Psychology*, *10*(2), 107–116. https://doi.org/10.1037/h0026283

Notara, V., Magriplis, E., Prapas, C., Antonogeorgos, G., Rojas-Gil, A. P., Kornilaki, E. N., Lagiou, A., & Panagiotakos, D. B. (2019). Parental weight status and early adolescence body weight in association with socioeconomic factors. *Journal of Education and Health Promotion*, *8*(1). https://doi.org/10.4103/JEHP.JEHP_14_19

Oberski, D. (2014). Lavaan.survey: An R package for complex survey analysis of structural equation models. *Journal of Statistical Software*, *57*(1), 1–27. https://doi.org/10.18637/jss.v057.i01

Obregon, A. M., Valladares, M., & Goldfield, G. (2017). Association of the dopamine D2 receptor rs1800497 polymorphism and eating behavior in Chilean children. *Nutrition*, *35*, 139–145. https://doi.org/https://dx.doi.org/10.1016/j.nut.2016.11.005

Ofcom. (2019). *Children and parents media use and attitudes: annex 1*. https://www.ofcom.org.uk/__data/assets/pdf_file/0027/134892/Children-and-Parents-Media-Use-and-Attitudes-Annex-1.pdf

Ofcom. (2020a). *Children and parents: media use and attitudes report 2019*. https://www.ofcom.org.uk/making-sense-of-media.

Ofcom. (2020b). *Children and parents: media use and attitudes report 2019*.

https://www.ofcom.org.uk/making-sense-of-media.

Office for National Statistics. (2000). *SOC 2000: Previous version of the Standard Occupational Classification*. Office for National Statistics. https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/socarchive

Office for National Statistics. (2006). *Birth statistics Series FM1 no.35. Review of the Registrar General on births and patterns of family building in England and Wales, 2006.* Crown copyright 2007.

Office for National Statistics. (2019). *The National Statistics Socio-economic classification (NS-SEC)*. Office for National Statistics. https://www.ons.gov.uk/methodology/classificationsandstandards/otherclassifications/thenationalstatisticssocioeconomicclassificationnssecrebasedonsoc2010

Ogden, J., Reynolds, R., & Smith, A. (2006). Expanding the concept of parental control: A role for overt and covert control in children's snacking behaviour? *Appetite*, *47*(1), 100–106. https://doi.org/10.1016/j.appet.2006.03.330

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information and Management*, *42*(1), 15–29. https://doi.org/10.1016/j.im.2003.11.002

Ooki, S., Yokoyama, Y., & Asaka, A. (2004). Zygosity misclassification of twins at birth in Japan. In *Twin Research* (Vol. 7, Issue 3). https://doi.org/10.1375/136905204774200497

Oude Groeniger, J., de Koster, W., & van der Waal, J. (2020). Time-varying Effects of Screen Media Exposure in the Relationship Between Socioeconomic Background and Childhood Obesity. *Epidemiology*, *31*(4), 578–586. https://doi.org/10.1097/EDE.0000000000001210

Overcash, F. M., Vickers, Z., Ritter, A. E., Mann, T., Mykerezi, E., Redden, J., Rendahl, A. K., Davey, C., & Reicks, M. (2019). An in-home intervention of parent-implemented strategies to increase child vegetable intake: results from a non-randomized cluster-allocated community trial. *BMC Public Health 2019 19:1*, *19*(1), 1–13. https://doi.org/10.1186/S12889-019-7079-4

Paduano, S., Borsari, L., Salvia, C., Arletti, S., Tripodi, A., Pinca, J., & Borella, P. (2020). Risk Factors for Overweight and Obesity in Children Attending the First Year of Primary Schools in Modena, Italy. *Journal of Community Health*, *45*(2), 301–309. https://doi.org/10.1007/s10900-019-00741-7

Palfreyman, Z., Haycraft, E., & Meyer, C. (2013). *Unintentional Role Models: Links Between Maternal Eating Psychopathology and the Modelling of Eating Behaviours*. https://doi.org/10.1002/erv.2219

Palfreyman, Z., Haycraft, E., & Meyer, C. (2014). Development of the Parental Modelling of Eating Behaviours Scale (PARM): links with food intake among children and their mothers. *Maternal & Child Nutrition*, *10*(4), 617–629. https://doi.org/10.1111/j.1740-8709.2012.00438.x

Pamungkas, R. A., & Chamroonsawasdi, K. (2019). Home-Based Interventions to Treat and Prevent Childhood Obesity: A Systematic Review and Meta-Analysis. *Behavioral Sciences*, *9*(4). https://doi.org/10.3390/BS9040038

Park, S. H., Park, C. G., Bahorski, J. S., & Cormier, E. (2019). Factors influencing obesity among preschoolers: multilevel approach. *International Nursing Review*, *66*(3), 346–355. https://doi.org/10.1111/inr.12513

Parkinson, K N, Drewett, R. F., Le Couteur, A. S., & Adamson, A. J. (2010). Do maternal ratings of appetite in infants predict later Child Eating Behaviour Questionnaire scores and body mass index? *Appetite*, *54*(1), 186–190. https://doi.org/http://dx.doi.org/10.1016/j.appet.2009.10.007

Parkinson, Kathryn N., Drewett, R. F., Le Couteur, A. S., & Adamson, A. J. (2010). Do maternal ratings of appetite in infants predict later Child Eating Behaviour Questionnaire scores and body mass index? *Appetite*, *54*(1), 186–190. https://doi.org/10.1016/j.appet.2009.10.007

Pearson, N., Ball, K., & Crawford, D. (2011). Predictors of changes in adolescents' consumption of fruits, vegetables and energy-dense snacks. *British Journal of Nutrition*, *105*(5), 795–803. https://doi.org/10.1017/S0007114510004290

Pearson, N., Biddle, S. J. H., Griffiths, P., Johnston, J. P., & Haycraft, E. (2018). Clustering and correlates of screen-time and eating behaviours among young children. *BMC Public Health*, *18*(1), 753. https://doi.org/10.1186/s12889-018-5698-9

Pearson, N., Griffiths, P., Biddle, S. J. H., Johnston, J. P., & Haycraft, E. (2017). Individual, behavioural and home environmental factors associated with eating behaviours in young adolescents. *Appetite*, *112*, 35–43. https://doi.org/10.1016/j.appet.2017.01.001

Pearson, N., Timperio, A., Salmon, J., Crawford, D., & Biddle, S. J. H. (2009). Family influences on children's physical activity and fruit and vegetable consumption. *International Journal of Behavioral Nutrition and Physical Activity*, *6*, 34. https://doi.org/10.1186/1479-5868-6-34

Pesch, M. H., Appugliese, D. P., Miller, A. L., Rosenblum, K. L., Lumeng, J. C., & Bauer, K. W. (2018). Approaches to restrictive feeding: Associations with child weight and eating behavior. *Eating Behaviors*, *31*, 74–79. https://doi.org/10.1016/J.EATBEH.2018.08.006

Pinard, C A, Yaroch, A. L., Hart, M. H., Serrano, E. L., McFerren, M. M., & Estabrooks, P. A. (2014). The Validity and reliability of the Comprehensive Home Environment Survey (CHES). *Health Promotion Practice*, *15*(1), 109–117. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=23471699

Pinard, Courtney A., Yaroch, A. L., Hart, M. H., Serrano, E. L., McFerren, M. M., & Estabrooks, P. A. (2014). The Validity and Reliability of the Comprehensive Home Environment Survey (CHES). *Health Promotion Practice*, *15*(1), 109–117. https://doi.org/10.1177/1524839913477863

Pinard, Courtney A, Yaroch, A. L., Hart, M. H., Serrano, E. L., McFerren, M. M., & Estabrooks, P. A. (2012). Measures of the home environment related to childhood obesity: a systematic review. *Public Health Nutrition*, *15*(1), 97–109. https://doi.org/10.1017/S1368980011002059

Power, C., Lake, J. K., & Cole, T. J. (1997). Measurement and long-term health risks of child and adolescent fatness. In *International Journal of Obesity* (Vol. 21, Issue 7, pp. 507–526). https://doi.org/10.1038/sj.ijo.0800454

Powers, S. W., Chamberlin, L. A., van Schaick, K. B., Sherman, S. N., & Whitaker, R. C. (2006). Maternal feeding strategies, child eating behaviors, and child BMI in low-income African-American preschoolers. *Obesity*, *14*(11), 2026–2033. https://doi.org/https://dx.doi.org/10.1038/oby.2006.237

Price, T. S., Freeman, B., Craig, I., Petrill, S. A., Ebersole, L., & Plomin, R. (2000). Infant zygosity can be assigned by parental report questionnaire data. *Twin Research and Human Genetics*, *3*(3), 129–133. https://doi.org/10.1375/TWIN.3.3.129

Puder, J. J., & Munsch, S. (2010). Psychological correlates of childhood obesity. *International Journal of Obesity 2010 34:2*, *34*(2), S37–S43. https://doi.org/10.1038/ijo.2010.238

Pulgarón, E. R. (2013). Childhood Obesity: A Review of Increased Risk for Physical and Psychological Comorbidities. *Clinical Therapeutics*, *35*(1), A18–A32. https://doi.org/10.1016/J.CLINTHERA.2012.12.014

Purcell, S. (2002). Variance Components Models for Gene–Environment Interaction in Twin Analysis. *Twin Research and Human Genetics*, *5*(6), 554–571. https://doi.org/10.1375/TWIN.5.6.554

Purslow, L. R., van Jaarsveld, C. H. M., Semmler, C., & Wardle, J. (2009). Validity and prognostic value of parental ratings of children's activity. *Preventive Medicine*, *49*(1). https://doi.org/10.1016/j.ypmed.2009.04.010

Quah, P L, Chan, Y. H., Aris, I. M., Pang, W. W., Toh, J. Y., Tint, M. T., Broekman, B. F., Saw, S. M., Kwek, K., Godfrey, K. M., Gluckman, P. D., Chong, Y. S., Meaney, M. J., Yap, F. K., van Dam, R. M., Lee, Y. S., Chong, M. F., & Group, G. S. (2015). Prospective associations of appetitive traits at 3 and 12 months of age with body mass index and weight gain in the first 2 years of life. *BMC Pediatrics*, *15*, 153. https://doi.org/https://dx.doi.org/10.1186/s12887-015-0467-8

Quah, P L, Cheung, Y. B., Pang, W. W., Toh, J. Y., Saw, S. M., Godfrey, K. M., Yap, F., Chong, Y. S., & Mary, C. F. F. (2017). Validation of the Children's Eating Behavior Questionnaire in 3 year old children of a multi-ethnic Asian population: The GUSTO cohort study. *Appetite*, *113*, 100–105. https://doi.org/http://dx.doi.org/10.1016/j.appet.2017.02.024

Quah, Phaik Ling, Cheung, Y. B., Pang, W. W., Toh, J. Y., Saw, S.-M., Godfrey, K. M., Yap, F., Chong, Y. S., & Mary, C. F.-F. (2017). Validation of the Children's Eating Behavior Questionnaire in 3 year old children of a multi-ethnic Asian population: The GUSTO cohort study. *Appetite*, *113*, 100–105. https://doi.org/https://doi.org/10.1016/j.appet.2017.02.024

Quah, Phaik Ling, Syuhada, G., Fries, L. R., Chan, M. J., Lim, H. X., Toh, J. Y., Sugianto, R., Aris, I. M., Lee, Y. S., Yap, F., Godfrey, K. M., Gluckman, P. D., Chong, Y. S., Shek, L. P., Tan, K. H., Forde, C. G., & Chong, M. F. F. (2018). Maternal feeding practices in relation to dietary intakes and BMI in 5 year-olds in a multi-ethnic Asian population. *PLoS ONE*, *13*(9). https://doi.org/10.1371/journal.pone.0203045

Quick, V., Martin-Biggers, J., Povis, G. A., Hongu, N., Worobey, J., & Byrd-Bredbenner, C. (2017). A socio-ecological examination of weight-related characteristics of the home environment and lifestyles of households with young children. *Nutrients*, *9*(6). https://doi.org/10.3390/nu9060604

R Core Team. (2018). *RStudio: Integrated development Environment for R* (3.5.0). http://www.rstudio.org/

Rahman, T., Cushing, R. A., & Jackson, R. J. (2011). Contributions of Built Environment to Childhood Obesity. *Mount Sinai Journal of Medicine: A Journal of Translational and Personalized Medicine*, *78*(1), 49–57. https://doi.org/10.1002/MSJ.20235

Rainham, D. G., Bates, C. J., Blanchard, C. M., Dummer, T. J., Kirk, S. F., & Shearer, C. L. (2012). Spatial classification of youth physical activity patterns. *American Journal of Preventive Medicine*, *42*(5), e87–e96. https://doi.org/10.1016/j.amepre.2012.02.011

Ramirez, E. R., Norman, G. J., Rosenberg, D. E., Kerr, J., Saelens, B. E., Durant, N., & Sallis, J. F. (2011). Adolescent screen time and rules to limit screen time in the home. *Journal of Adolescent Health*, *48*(4), 379–385. https://doi.org/10.1016/j.jadohealth.2010.07.013

Rankin, J., Matthews, L., Cobley, S., Han, A., Sanders, R., Wiltshire, H. D., & Baker, J. S. (2016). Psychological consequences of childhood obesity: psychiatric comorbidity and prevention. *Adolescent Health, Medicine and Therapeutics*, *7*, 125. https://doi.org/10.2147/AHMT.S101631

Reddon, H., Guéant, J.-L., & Meyre, D. (2016). The importance of gene–environment interactions in human obesity. *Clinical Science*, *130*(18), 1571–1597. https://doi.org/10.1042/CS20160221

Reilly, J. J., & Kelly, J. (2010). Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. *International Journal of Obesity 2011 35:7*, *35*(7), 891–898. https://doi.org/10.1038/ijo.2010.222

Reilly, J. J., Methven, E., McDowell, Z. C., Hacking, B., Alexander, D., Stewart, L., & Kelnar, C. J. H. (2003). Health consequences of obesity. In *Archives of Disease in Childhood* (Vol. 88, Issue 9, pp. 748–752). https://doi.org/10.1136/adc.88.9.748

Richardson, K., & Norgate, S. (2005). The equal environments assumption of classical twin studies may not hold. *British Journal of Educational Psychology*, *75*(3), 339–350. https://doi.org/10.1348/000709904X24690

Ridgers, N. D., & Fairclough, S. (2011). Assessing free-living physical activity using accelerometry: Practical issues for researchers and practitioners. In *European Journal of Sport Science* (Vol. 11, Issue 3, pp. 205–213). https://doi.org/10.1080/17461391.2010.501116

Rijsdijk, F. V., & Sham, P. C. (2002). Analytic approaches to twin data using structural equation models. *Briefings in Bioinformatics*, *3*(2), 119–133. https://doi.org/10.1093/BIB/3.2.119

Roach, E., Viechnicki, G. B., Retzloff, L. B., Davis-Kean, P., Lumeng, J. C., & Miller, A. L. (2017). Family food talk, child eating behavior, and maternal feeding practices. *Appetite*, *117*, 40–50. https://doi.org/http://dx.doi.org/10.1016/j.appet.2017.06.001

Rodenburg, G, Oenema, A., Kremers, S. P., & van de Mheen, D. (2013). Clustering of diet- and activity-related parenting practices: cross-sectional findings of the INPACT study. *International Journal of Behavioral Nutrition*

& Physical Activity, *10*, 36. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=23531232

Rodenburg, Gerda, Kremers, S. P. J., Oenema, A., & Van De Mheen, D. (2014). Associations of parental feeding styles with child snacking behaviour and weight in the context of general parenting. *Public Health Nutrition*, *17*(5), 960–969. https://doi.org/10.1017/S1368980013000712

Rodgers, R. F., Paxton, S. J., Massey, R., Campbell, K. J., Wertheim, E. H., Skouteris, H., & Gibbons, K. (2013). Maternal feeding practices predict weight gain and obesogenic eating behaviors in young children: a prospective study. *International Journal of Behavioral Nutrition & Physical Activity*, *10*, 24. https://doi.org/https://dx.doi.org/10.1186/1479-5868-10-24

Roe, L., Strong, C., Whiteside, C., Neil, A., & Mant, D. (1994). Dietary intervention in primary care: Validity of the dine method for diet assessment. *Family Practice*, *11*(4). https://doi.org/10.1093/fampra/11.4.375

Rokholm, B., Silventoinen, K., Ängquist, L., Skytthe, A., Kyvik, K. O., & Sørensen, T. I. A. (2011). Increased genetic variance of BMI with a higher prevalence of obesity. *PLoS ONE*, *6*(6). https://doi.org/10.1371/journal.pone.0020816

Rokholm, B., Silventoinen, K., Tynelius, P., Gamborg, M., Sørensen, T. I. A., & Rasmussen, F. (2011). Increasing genetic variance of body mass index during the swedish obesity epidemic. *PLoS ONE*, *6*(11), e27135. https://doi.org/10.1371/journal.pone.0027135

Rosenberg, D. E., Sallis, J. F., Kerr, J., Maher, J., Norman, G. J., Durant, N., Harris, S. K., & Saelens, B. E. (2010). Brief scales to assess physical activity and sedentary equipment in the home. *The International Journal of Behavioral Nutrition and Physical Activity Vol 7 2010, ArtID 10*, *7*. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc7&AN=2012-31433-001

Rosenkranz, R. R., & Dzewaltowski, D. A. (2008a). *Model of the home food environment pertaining to childhood obesity*. https://doi.org/10.1111/j.1753-4887.2008.00017.x

Rosenkranz, R. R., & Dzewaltowski, D. A. (2008b). Model of the home food environment pertaining to childhood obesity. *Nutrition Reviews*, *66*(3), 123–140. https://doi.org/10.1111/j.1753-4887.2008.00017.x

Rosenkranz, R. R., & Dzewaltowski, D. A. (2008c). Model of the home food environment pertaining to childhood obesity. *Nutrition Reviews*, *66*(3), 123–140. https://doi.org/10.1111/j.1753-4887.2008.00017.x

Rosseel, Y. (2012). *lavaan: an R package for structural equation modeling and more Version 0.5-12 (BETA)*. http://cran.r-project.org/.

Rudy, E., Bauer, K. W., Hughes, S. O., O'Connor, T. M., Vollrath, K., Davey, A., Correa, N. E. M., Chen, T. A., & Fisher, J. O. (2016). Interrelationships of child appetite, weight and snacking among Hispanic preschoolers. *Pediatric Obesity.* https://doi.org/http://dx.doi.org/10.1111/ijpo.12186

Russell, S. J., Croker, H., & Viner, R. M. (2019). The effect of screen advertising on children's dietary intake: A systematic review and meta-analysis. In *Obesity Reviews* (Vol. 20, Issue 4, pp. 554–568). Blackwell Publishing Ltd. https://doi.org/10.1111/obr.12812

Rutherford, L., Brown, J. E., Skouteris, H., Fuller-Tyszkiewicz, M., & Bittman, M. (2015). Screen media, parenting practices, and the family environment in Australia: A longitudinal study of young children's media use, lifestyles, and outcomes for healthy weight. *Journal of Children and Media*, *9*(1), 22–39. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc12&AN=2015-03175-003

Ryan, K., Dockray, S., & Linehan, C. (2019). A systematic review of tailored eHealth interventions for weight loss. *DIGITAL HEALTH*, *5*, 205520761982668. https://doi.org/10.1177/2055207619826685

S, N. H. (2018). National Child Measurement Programme, England - 2017/18 School Year [PAS]. *2018 Health and Social Care Information Centre*. https://digital.nhs.uk/data-and-information/publications/statistical/national-child-measurement-programme/2017-18-school-year

Saelens, B. E., & Epstein, L. H. (1996). Reinforcing Value of Food in Obese and Non-obese Women. In *Appetite* (Vol. 27).

Saelens, B. E., Sallis, J. F., Nader, P. R., Broyles, S. L., Berry, C. C., & Taras, H. L. (2002). Home environmental influences on children's television watching from early to middle childhood. *Journal of Developmental and Behavioral Pediatrics*, *23*(3), 127–132. https://doi.org/10.1097/00004703-200206000-00001

Sagar, R., & Gupta, T. (2017). Psychological Aspects of Obesity in Children and Adolescents. *The Indian Journal of Pediatrics 2017 85:7*, *85*(7), 554–559. https://doi.org/10.1007/S12098-017-2539-2

Sallis, J. F., Prochaska, J. J., & Taylor, W. C. (2000). A review of correlates of physical activity of children and adolescents. *Medicine and Science in Sports and Exercise*, *32*(5), 963–975. https://doi.org/10.1097/00005768-200005000-00014

Sanchez, U., Weisstaub, G., Santos, J. L., Corvalan, C., & Uauy, R. (2016). GOCS cohort: Children's eating behavior scores and BMI. *European Journal of Clinical Nutrition*, *70*(8), 925–928. https://doi.org/http://dx.doi.org/10.1038/ejcn.2016.18

Sandvik, P., Ek, A., Somaraki, M., Hammar, U., Eli, K., & Nowicka, P. (2018). Picky eating in Swedish preschoolers of different weight status: Application of two new screening cut-offs. *International Journal of Behavioral Nutrition and Physical Activity*, *15*(1). https://doi.org/10.1186/s12966-018-0706-0

Sanlier, N., Arslan, S., Buyukgenc, N., & Toka, O. (2018). Are eating behaviors related with by body mass index, gender and age? *Ecology of Food and Nutrition*, *57*(4), 372–387. https://doi.org/10.1080/03670244.2018.1493470

Santiago-Torres, M., Adams, A. K., Carrel, A. L., Larowe, T. L., & Schoeller, D. A. (2014). Home food availability, parental dietary intake, and familial eating habits influence the diet quality of urban hispanic children. *Childhood Obesity*, *10*(5), 408–415. https://doi.org/10.1089/chi.2014.0051

Savage, J. S., Fisher, J. O., & Birch, L. L. (2007). Parental Influence on Eating

Behavior: Conception to Adolescence. *The Journal of Law, Medicine & Ethics*, *35*(1), 22–34. https://doi.org/10.1111/j.1748-720X.2007.00111.x

Scarr, S. (1992). Developmental theories for the 1990s: development and individual differences. In *Child development* (Vol. 63, Issue 1). https://doi.org/10.1111/j.1467-8624.1992.tb03591.x

Scarr, Sandra, & Carter-Saltzman, L. (1979a). Twin method: Defense of a critical assumption. *Behavior Genetics*, *9*(6), 527–542. https://doi.org/10.1007/BF01067349

Scarr, Sandra, & Carter-Saltzman, L. (1979b). Twin method: Defense of a critical assumption. *Behavior Genetics*, *9*(6), 527–542. https://doi.org/10.1007/BF01067349

Schachter, S. (1968). Obesity and eating. *Science*, *161*(3843), 751–756. https://doi.org/10.1126/science.161.3843.751

Schalkwijk, A. A., van der Zwaard, B. C., Nijpels, G., Elders, P. J., & Platt, L. (2018). The impact of greenspace and condition of the neighbourhood on child overweight. *European Journal of Public Health*, *28*(1), 88–94. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc14&AN=2018-05454-017

Schoeppe, S., Vandelanotte, C., Bere, E., Lien, N., Verloigne, M., Kovács, É., Manios, Y., Bjelland, M., Vik, F. N., & Van Lippevelde, W. (2017). The influence of parental modelling on children’s physical activity and screen time: Does it differ by gender? *European Journal of Public Health*, *27*(1), 152–157. https://doi.org/10.1093/EURPUB/CKW182

Schrempft, S., van Jaarsveld, C. H., & Fisher, A. (2017a). Exploring the potential of a wearable camera to examine the early obesogenic home environment: Comparison of sensecam images to the home environment interview. *Journal of Medical Internet Research*, *19*(10), e332. https://doi.org/10.2196/JMIR.7748

Schrempft, S., van Jaarsveld, C. H., & Fisher, A. (2017b). Exploring the potential of a wearable camera to examine the early obesogenic home environment: Comparison of sensecam images to the home environment interview. *Journal of Medical Internet Research*, *19*(10), e332. https://doi.org/10.2196/JMIR.7748

Schrempft, S., van Jaarsveld, C. H. M., Fisher, A., Fildes, A., & Wardle, J. (2016). Maternal characteristics associated with the obesogenic quality of the home environment in early childhood. *Appetite*, *107*, 392–397. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medc&AN=27554185

Schrempft, S., Van Jaarsveld, C. H. M., Fisher, A., & Wardle, J. (2015). The obesogenic quality of the home environment: Associations with diet, physical activity, TV viewing, and BMI in preschool children. *PLoS ONE*, *10*(8), e0134490. https://doi.org/10.1371/journal.pone.0134490

Schrempft, S., van Jaarsveld, C. M., Fisher, A., & et al. (2018). Variation in the heritability of child body mass index by obesogenic home environment. *JAMA Pediatr*, *172*(12), 1153–1160. https://doi.org/10.1001/jamapediatrics.2018.1508

Seghers, J., & Rutten, C. (2010). Clustering of multiple lifestyle behaviours and its relationship with weight status and cardiorespiratory fitness in a sample of Flemish 11- to 12-year-olds. *Public Health Nutrition*, *13*(11), 1838–1846. https://doi.org/10.1017/S1368980010000418

Selzam, S., McAdams, T. A., Coleman, J. R. I., Carnell, S., O'Reilly, P. F., Plomin, R., & Llewellyn, C. H. (2018). Evidence for gene-environment correlation in child feeding: Links between common genetic variation for BMI in children and parental feeding practices. *PLoS Genetics*, *14*(11). https://doi.org/10.1371/JOURNAL.PGEN.1007757

Serene, T. E., Shamarina, S., & Mohd, N. M. (2011). Familial and socio-environmental predictors of overweight and obesity among primary school children in Selangor and Kuala Lumpur. *Malays J Nutr*, *17*(2), 151–162.

Serrano, M., Torres, R., Perez, C. M., & Palacios, C. (2014). Social environment factors, diet quality, and body weight in 12-year-old children from four public schools in Puerto Rico. *Puerto Rico Health Sciences Journal*, *33*(2), 80–87. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24964643

Shepard, D. N., & Chandler-Laney, P. C. (2015). Prospective associations of eating behaviors with weight gain in infants. *Obesity*, *23*(9), 1881–1885. https://doi.org/https://dx.doi.org/10.1002/oby.21168

Shift. (2018). *Families and Food: How the environment influences what families eat*. https://www.gsttcharity.org.uk/sites/default/files/Bite_Size_Report.pdf

Showell, N. N., Fawole, O., Segal, J., Wilson, R. F., Cheskin, L. J., Bleich, S. N., Wu, Y., Lau, B., & Wang, Y. (2013). A systematic review of home-based childhood obesity prevention studies. In *Pediatrics*. https://doi.org/10.1542/peds.2013-0786

Shrewsbury, V., & Wardle, J. (2008). Socioeconomic Status and Adiposity in Childhood: A Systematic Review of Cross-sectional Studies 1990–2005. *Obesity*, *16*(2), 275–284. https://doi.org/10.1038/oby.2007.35

Sijtsma, A., Koller, M., Sauer, P. J., & Corpeleijn, E. (2015). Television, sleep, outdoor play and BMI in young children: the GECKO Drenthe cohort. *European Journal of Pediatrics*, *174*(5), 631–639. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=25367053

Sijtsma, A., Sauer, P. J., & Corpeleijn, E. (2015). Parental correlations of physical activity and body mass index in young children-The GECKO Drenthe cohort. *The International Journal of Behavioral Nutrition and Physical Activity Vol 12 2015, ArtID 132*, *12*. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc12&AN=2015-47173-001

Silva Garcia, K., Power, T. G., Fisher, J. O., O'Connor, T. M., & Hughes, S. O. (2016). Latina mothers' influences on child appetite regulation. *Appetite*, *103*, 200–207. https://doi.org/http://dx.doi.org/10.1016/j.appet.2016.04.013

Silventoinen, K., Huppertz, C., Beijsterveldt, C. E. M. van, Bartels, M., Willemsen, G., & Boomsma, D. I. (2016). The genetic architecture of body mass index from infancy to adulthood modified by parental education.

Obesity, *24*(9), 2004–2011. https://doi.org/10.1002/OBY.21588

Silventoinen, K., Jelenkovic, A., Sund, R., Hur, Y. M., Yokoyama, Y., Honda, C., Hjelmborg, J. B., Moller, S., Ooki, S., Aaltonen, S., Ji, F., Ning, F., Pang, Z., Rebato, E., Busjahn, A., Kandler, C., Saudino, K. J., Jang, K. L., Cozen, W., … Kaprio, J. (2016). Genetic and environmental effects on body mass index from infancy to the onset of adulthood: An individual-based pooled analysis of 45 twin cohorts participating in the COllaborative project of Development of Anthropometrical measures in Twins (CODATwins). *American Journal of Clinical Nutrition*, *104*(2), 371–379. https://doi.org/10.3945/ajcn.116.130252

Silventoinen, K., Rokholm, B., Kaprio, J., & Sørensen, T. I. A. (2009). The genetic and environmental influences on childhood obesity: a systematic review of twin and adoption studies. *International Journal of Obesity 2010 34:1*, *34*(1), 29–40. https://doi.org/10.1038/ijo.2009.177

Simmonds, M., Burch, J., Llewellyn, A., Griffiths, C., Yang, H., Owen, C., Duffy, S., & Woolacott, N. (2015). The use of measures of obesity in childhood for predicting obesity and the development of obesity-related diseases in adulthood: A systematic review and meta-analysis. *Health Technology Assessment*, *19*(43). https://doi.org/10.3310/hta19430

Simmonds, M., Llewellyn, A., Owen, C. G., & Woolacott, N. (2016). Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. *Obes Rev*, *17*(2), 95–107. https://doi.org/10.1111/obr.12334

Sirard, J. R., Nelson, M. C., Pereira, M. A., & Lytle, L. A. (2008). Validity and reliability of a home environment inventory for physical activity and media equipment. *International Journal of Behavioral Nutrition and Physical Activity 2008 5:1*, *5*(1), 1–10. https://doi.org/10.1186/1479-5868-5-24

Sirikulchayanonta, C., Ratanopas, W., Temcharoen, P., & Srisorrachatr, S. (2011). Self discipline and obesity in Bangkok school children. *BMC Public Health*, *11*(1), 158. https://doi.org/10.1186/1471-2458-11-158

Sleddens, E. F.C., Kremers, S. P. J., Hughes, S. O., Cross, M. B., Thijs, C., De Vries, N. K., & O’Connor, T. M. (2012). Physical activity parenting: A systematic review of questionnaires and their associations with child activity levels. *Obesity Reviews*, *13*(11), 1015–1033. https://doi.org/10.1111/J.1467-789X.2012.01018.X

Sleddens, E F C, Gubbels, J. S., Kremers, S. P. J., van der Plas, E., & Thijs, C. (2017). Bidirectional associations between activity-related parenting practices, and child physical activity, sedentary screen-based behavior and body mass index: a longitudinal analysis. *International Journal of Behavioral Nutrition & Physical Activity*, *14*(1), 89. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medl&AN=28683749

Sleddens, Ester F.C., Kremers, S. P. J., De Vries, N. K., & Thijs, C. (2010). Relationship between parental feeding styles and eating behaviours of Dutch children aged 6–7. *Appetite*, *54*(1), 30–36. https://doi.org/10.1016/J.APPET.2009.09.002

Sleddens, Ester F C, Kremers, S. P. J., & Thijs, C. (2008). The Children’s Eating Behaviour Questionnaire: Factorial validity and association with body mass index in Dutch children aged 6-7. *The International Journal of Behavioral Nutrition and Physical Activity Vol 5 2008, ArtID 49*, *5*. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2014-47912-001

Smith, J. M., & Ditschun, T. L. (2009). Controlling satiety: how environmental factors influence food intake. In *Trends in Food Science and Technology* (Vol. 20, Issues 6–7, pp. 271–277). https://doi.org/10.1016/j.tifs.2009.03.009

Smith, S. M., Sumar, B., & Dixon, K. A. (2014). Musculoskeletal pain in overweight and obese children. In *International Journal of Obesity* (Vol. 38, Issue 1). https://doi.org/10.1038/ijo.2013.187

Somaraki, M., Eli, K., Sorjonen, K., Flodmark, C. E., Marcus, C., Faith, M. S., Osowski, C. P., Ek, A., & Nowicka, P. (2018). Perceived child eating behaviours and maternal migrant background. *Appetite*, *125*, 302–313. https://doi.org/10.1016/j.appet.2018.02.010

Sorensen, T. I. A., Price, R. A., Stunkard, A. J., & Schulsinger, F. (1989). Genetics of obesity in adult adoptees and their biological siblings. *British Medical Journal*, *298*(6666), 87–90. https://doi.org/10.1136/bmj.298.6666.87

Soussignan, R., Schaal, B., Boulanger, V., Gaillet, M., & Jiang, T. (2012). Orofacial reactivity to the sight and smell of food stimuli. Evidence for anticipatory liking related to food reward cues in overweight children. *Appetite*, *58*(2), 508–516. https://doi.org/https://dx.doi.org/10.1016/j.appet.2011.12.018

Spence, J. C., Carson, V., Casey, L., & Boule, N. (2011). Examining behavioural susceptibility to obesity among Canadian pre-school children: the role of eating behaviours. *International Journal of Pediatric Obesity*, *6*(2–2), e501-7. https://doi.org/https://dx.doi.org/10.3109/17477166.2010.512087

Spurrier, N. J., Magarey, A. A., Golley, R., Curnow, F., & Sawyer, M. G. (2008). Relationships between the home environment and physical activity and dietary patterns of preschool children: a cross-sectional study. *International Journal of Behavioral Nutrition and Physical Activity 2008 5:1*, *5*(1), 1–12. https://doi.org/10.1186/1479-5868-5-31

Steinsbekk, Llewellyn, C. H., Fildes, A., & Wichstrøm, L. (2017). *Body composition impacts appetite regulation in middle childhood. A prospective study of Norwegian community children*. *14*(1), 70.

Steinsbekk, S, & Wichstrom, L. (2015). Predictors of Change in BMI From the Age of 4 to 8. *Journal of Pediatric Psychology*, *40*(10), 1056–1064. https://doi.org/https://dx.doi.org/10.1093/jpepsy/jsv052

Steinsbekk, Silje, Belsky, J., & Wichstrom, L. (2016). Parental feeding and child eating: An investigation of reciprocal effects. *Child Development*, *87*(5), 1538–1549. https://doi.org/http://dx.doi.org/10.1111/cdev.12546

Steinsbekk, Silje, Llewellyn, C. H., Fildes, A., & Wichstrom, L. (2017). Body composition impacts appetite regulation in middle childhood. A prospective study of Norwegian community children. *The International Journal of Behavioral Nutrition and Physical Activity Vol 14 2017, ArtID 70*, *14*.

https://doi.org/http://dx.doi.org/10.1186/s12966-017-0528-5

Steinsbekk, Wichstrøm, L., & Wichstrom, L. (2015). Predictors of Change in BMI From the Age of 4 to 8. *Journal of Pediatric Psychology*, *40*(10), 1056–1064.

Stenhammar, C., Sarkadi, A., & Edlund, B. (2007). The role of parents' educational background in healthy lifestyle practices and attitudes of their 6-year-old children. *Public Health Nutrition*, *10*(11), 1305–1313. https://doi.org/10.1017/S1368980007696396

Story, M., & French, S. (2004). Food advertising and marketing directed at children and adolescents in the US. In *International Journal of Behavioral Nutrition and Physical Activity* (Vol. 1). https://doi.org/10.1186/1479-5868-1-3

Strasburger, V. C. (2001). Children and TV advertising: Nowhere to run, nowhere to hide. In *Journal of Developmental and Behavioral Pediatrics* (Vol. 22, Issue 3). https://doi.org/10.1097/00004703-200106000-00006

Stunkard, A. J., Foch, T. T., & Hrubec, Z. (1986). A Twin Study of Human Obesity. *JAMA: The Journal of the American Medical Association*, *256*(1), 51–54. https://doi.org/10.1001/jama.1986.03380010055024

Stunkard, A. J., & Messick, S. (1985). The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *Journal of Psychosomatic Research*, *29*(1), 71–83. https://doi.org/10.1016/0022-3999(85)90010-8

Stunkard, A. J., Sørensen, T. I. A., Hanis, C., Teasdale, T. W., Chakraborty, R., Schull, W. J., & Schulsinger, F. (1986). An Adoption Study of Human Obesity. *New England Journal of Medicine*, *314*(4), 193–198. https://doi.org/10.1056/nejm198601233140401

Svensson, V., Lundborg, L., Cao, Y., Nowicka, P., Marcus, C., & Sobko, T. (2011). Obesity related eating behaviour patterns in Swedish preschool children and association with age, gender, relative weight and parental weight - factorial validation of the Children's Eating Behaviour Questionnaire. *International Journal of Behavioral Nutrition and Physical Activity*, 134. https://doi.org/http://dx.doi.org/10.1186/1479-5868-8-134

Sweetman, C., McGowan, L., Croker, H., & Cooke, L. (2011). Characteristics of Family Mealtimes Affecting Children's Vegetable Consumption and Liking. *Journal of the American Dietetic Association*, *111*(2). https://doi.org/10.1016/j.jada.2010.10.050

Swinburn, B., Egger, G., & Raza, F. (1999). Dissecting Obesogenic Environments: The Development and Application of a Framework for Identifying and Prioritizing Environmental Interventions for Obesity. *Preventive Medicine*, *29*(6), 563–570. https://doi.org/10.1006/PMED.1999.0585

Swinburn, B., Kraak, V. I., Allender, S., Atkins, V. J., Baker, P. I., Bogard, J. R., Brinsden, H., Calvillo, A., De Schutter, O., Devarajan, R., Ezzati, M., Friel, S., Goenka, S., Hammond, R. A., Hastings, G., Hawkes, C., Herrero, M., Hovmand, P. S., Howden, M., … Dietz, W. H. (2019). The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. In *The Lancet* (Vol. 393, Issue 10173, pp. 791–846). Elsevier.

https://doi.org/10.1016/S0140-6736(18)32822-8

Syrad, H., Johnson, L., Wardle, J., & Llewellyn, C. H. (2016). Appetitive traits and food intake patterns in early life. *American Journal of Clinical Nutrition*, *103*(1), 231–235. https://doi.org/10.3945/ajcn.115.117382

Tandon, P., Grow, H. M., Couch, S., Glanz, K., Sallis, J. F., Frank, L. D., & Saelens, B. E. (2014). Physical and social home environment in relation to children's overall and home-based physical activity and sedentary time. *Preventive Medicine*, *66*, 39–44. https://doi.org/10.1016/j.ypmed.2014.05.019

Tandon, P., Zhou, C., Sallis, J. F., Cain, K. L., Frank, L. D., & Saelens, B. E. (2012a). Home environment relationships with children's physical activity, sedentary time, and screen time by socioeconomic status. *International Journal of Behavioral Nutrition and Physical Activity*, *9*, 88. https://doi.org/10.1186/1479-5868-9-88

Tandon, P., Zhou, C., Sallis, J. F., Cain, K. L., Frank, L. D., & Saelens, B. E. (2012b). Home environment relationships with children's physical activity, sedentary time, and screen time by socioeconomic status. *International Journal of Behavioral Nutrition and Physical Activity*, *9*(1), 88. https://doi.org/10.1186/1479-5868-9-88

Tandon, P., Zhou, C., Sallis, J. F., Cain, K. L., Frank, L. D., & Saelens, B. E. (2012c). Home environment relationships with children's physical activity, sedentary time, and screen time by socioeconomic status. *International Journal of Behavioral Nutrition and Physical Activity*, *9*. https://doi.org/10.1186/1479-5868-9-88

Tatlow-Golden, M., Tracey, L., & Dolphin, L. (2016). Who's feeding the kids online? Digital Food Marketing and Children in Ireland. *Irish Heart Foundation*. www.irishheart.ie

Tay, C. W., Chin, Y. S., Lee, S. T., Khouw, I., Poh, B. K., & Group, S. M. S. (2016). Association of Eating Behavior With Nutritional Status and Body Composition in Primary School-Aged Children. *Asia-Pacific Journal of Public Health*, *28*(5 Suppl), 47S-58S. https://doi.org/https://dx.doi.org/10.1177/1010539516651475

Taylor, A., Wilson, C., Slater, A., & Mohr, P. (2011). Parent- and child-reported parenting. Associations with child weight-related outcomes. *Appetite*, *57*(3), 700–706. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc8&AN=2011-26397-022

Temple, J. L., Giacomelli, A. M., Kent, K. M., Roemmich, J. N., & Epstein, L. H. (2007). Television watching increases motivated responding for food and energy intake in children 1-3. In *Original Research Communications*. https://academic.oup.com/ajcn/article-abstract/85/2/355/4649500

Terry, K., & Beck, S. (1985). Eating style and food storage habits in the home: Assessment of obese and nonobese families. *Behavior Modification*, *9*(2), 242–261. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc2&AN=1986-01647-001

Tester, J. M., Rosas, L. G., & Leung, C. W. (2020). Food Insecurity and

Pediatric Obesity: a Double Whammy in the Era of COVID-19. In *Current Obesity Reports* (Vol. 9, Issue 4). https://doi.org/10.1007/s13679-020-00413-x

The Health and Social Care Information Centre. (2008). Health Survey for England - 2007: Healthy lifestyles: knowledge, attitudes and behaviour. In R. Craig & N. Shelton (Eds.), *Health Survey for England 2007*. The NHS Information centre for health and social care. https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/health-survey-for-england-2007-healthy-lifestyles-knowledge-attitudes-and-behaviour

Thivel, D., Aucouturier, J., Doucet, éric, Saunders, T. J., & Chaput, J. P. (2013). Daily energy balance in children and adolescents. Does energy expenditure predict subsequent energy intake? *Appetite*, *60*(1), 58–64. https://doi.org/10.1016/J.APPET.2012.09.022

Tiberio, S. S., Kerr, D. C., Capaldi, D. M., Pears, K. C., Kim, H. K., & Nowicka, P. (2014). Parental monitoring of children's media consumption: the long-term influences on body mass index in children. *JAMA Pediatr*, *168*(5), 414–421. https://doi.org/10.1001/jamapediatrics.2013.5483

Timperio, A., Salmon, J., Ball, K., Baur, L. A., Telford, A., Jackson, M., Salmon, L., & Crawford, D. (2008). Family physical activity and sedentary environments and weight change in children. *International Journal of Pediatric Obesity*, *3*(3), 160–167. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105530583&site=ehost-live

Torres, R., Serrano, M., Perez, C. M., & Palacios, C. (2014). Physical environment, diet quality, and body weight in a group of 12-year-old children from four public schools in Puerto Rico. *Puerto Rico Health Sciences Journal*, *33*(1), 14–21. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med8&AN=24665604

Totland, T. H., Bjelland, M., Lien, N., Bergh, I. H., Gebremariam, M. K., Grydeland, M., Ommundsen, Y., & Andersen, L. F. (2013). Adolescents' prospective screen time by gender and parental education, the mediation of parental influences. *International Journal of Behavioral Nutrition and Physical Activity 2013 10:1*, *10*(1), 1–10. https://doi.org/10.1186/1479-5868-10-89

Trouton, A., Spinath, F. M., & Plomin, R. (2002). Twins Early Development Study (TEDS): A multivariate, longitudinal genetic investigation of language, cognition and behavior problems in childhood. *Twin Research*, *5*(5), 444–448. https://doi.org/10.1375/136905202320906255

Tucker, L. A. (2017). Objectively measured physical activity predicts subsequent energy intake in 300 women. *Public Health Nutrition*, *20*(1), 112–120. https://doi.org/10.1017/S1368980016001841

Turkheimer, E., & Gottesman, I. I. (1991). Individual Differences and the Canalization of Human Behavior. *Developmental Psychology*, *27*(1). https://doi.org/10.1037/0012-1649.27.1.18

Umstattd Meyer, M. R., Sharkey, J. R., Patterson, M. S., & Dean, W. R. (2013).

Understanding contextual barriers, supports, and opportunities for physical activity among Mexican-origin children in Texas border colonias: a descriptive study. *BMC Public Health*, *13*, 14. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=23297793

Valentine, J. C., Pigott, T. D., & Rothstein, H. R. (2010). How Many Studies Do You Need? *Journal of Educational and Behavioral Statistics*, *35*(2), 215–247. https://doi.org/10.3102/1076998609346961

Van De Gaar, V. M., Jansen, W., Van Der Kleij, M. J. J., & Raat, H. (2016). Do children report differently from their parents and from observed data? Cross-sectional data on fruit, water, sugar-sweetened beverages and break-time foods. *BMC Public Health*, *16*(1). https://doi.org/10.1186/s12889-016-2963-7

van Deutekom, A. W., Chinapaw, M. J., Vrijkotte, T. G., & Gemke, R. J. (2016). The association of birth weight and postnatal growth with energy intake and eating behavior at 5 years of age-A birth cohort study. *The International Journal of Behavioral Nutrition and Physical Activity Vol 13 2016, ArtID 15*, *13*. https://doi.org/http://dx.doi.org/10.1186/s12966-016-0335-4

Van Dommelen, P., De Gunst, M., Van Vaart, A. Der, Van Buuren, S., & Boomsma, D. (2008). Growth references for height, weight and body mass index of twins aged 0-2.5 years. *Acta Paediatrica, International Journal of Paediatrics*, *97*(8), 1099–1104. https://doi.org/10.1111/j.1651-2227.2008.00853.x

Van Dongen, J., Slagboom, P. E., Draisma, H. H. M., Martin, N. G., & Boomsma, D. I. (2012). The continuing value of twin studies in the omics era. In *Nature Reviews Genetics* (Vol. 13, Issue 9). https://doi.org/10.1038/nrg3243

Van Jaarsveld, C. H. M., Llewellyn, C. H., Fildes, A., Fisher, A., & Wardle, J. (2012). Are my twins identical: parents may be misinformed by prenatal scan observations. *BJOG: An International Journal of Obstetrics & Gynaecology*, *119*(5), 517–518. https://doi.org/10.1111/J.1471-0528.2012.03281.X

van Jaarsveld, C H, Johnson, L., Llewellyn, C., & Wardle, J. (2010). Gemini: a UK twin birth cohort with a focus on early childhood weight trajectories, appetite and the family environment. *Twin Res Hum Genet*, *13*(1), 72–78. https://doi.org/10.1375/twin.13.1.72

van Jaarsveld, Cornelia Hm, Llewellyn, C. H., Johnson, L., & Wardle, J. (2011a). Prospective associations between appetitive traits and weight gain in infancy. *American Journal of Clinical Nutrition*, *94*(6), 1562–1567. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108207259&site=ehost-live

van Jaarsveld, Cornelia Hm, Llewellyn, C. H., Johnson, L., & Wardle, J. (2011b). Prospective associations between appetitive traits and weight gain in infancy. *American Journal of Clinical Nutrition*, *94*(6), 1562–1567. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108207259&site=ehost-live

Van Lippevelde, W, Te Velde, S. J., Verloigne, M., Van Stralen, M. M., De

Bourdeaudhuij, I., Manios, Y., Bere, E., Vik, F. N., Jan, N., Fernandez Alvira, J. M., Chinapaw, M. J., Bringolf-Isler, B., Kovacs, E., Brug, J., & Maes, L. (2013). Associations between family-related factors, breakfast consumption and BMI among 10- to 12-year-old European children: the cross-sectional ENERGY-study. *PLoS ONE [Electronic Resource]*, *8*(11), e79550. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med7&AN=24282508

Van Lippevelde, Wendy, te Velde, S. J., Verloigne, M., De Bourdeaudhuij, I., Manios, Y., Bere, E., Jan, N., Fernández-Alvira, J. M., Chinapaw, M. J. M., Bringolf-Isler, B., Kovacs, E., Brug, J., & Maes, L. (2013). Associations between home- and family-related factors and fruit juice and soft drink intake among 10- to 12-year old children. The ENERGY project. *Appetite*, *61*. https://doi.org/10.1016/j.appet.2012.10.019

van Strien, T., Frijters, J. E. R., Bergers, G. P. A., & Defares, P. B. (1986). The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders*, *5*(2), 295–315. https://doi.org/10.1002/1098-108X(198602)5:2<295::AID-EAT2260050209>3.0.CO;2-T

Vandewater, E. A., Rideout, V. J., Wartella, E. A., Huang, X., Lee, J. H., & Shim, M. S. (2007). Digital childhood: Electronic media and technology use among infants, toddlers, and preschoolers. *Pediatrics*, *119*(5). https://doi.org/10.1542/peds.2006-1804

Vaughn, A. E., Dearth-Wesley, T., Tabak, R. G., Bryant, M., & Ward, D. S. (2017). Development of a Comprehensive Assessment of Food Parenting Practices: The Home Self-Administered Tool for Environmental Assessment of Activity and Diet Family Food Practices Survey. *Journal of the Academy of Nutrition and Dietetics*, *117*(2), 214–227. https://doi.org/10.1016/j.jand.2016.07.021

Vaughn, A. E., Hales, D. P., Neshteruk, C. D., & Ward, D. S. (2019). HomeSTEAD's physical activity and screen media practices and beliefs survey: Instrument development and integrated conceptual model. *PLoS ONE*, *14*(12). https://doi.org/10.1371/journal.pone.0226984

Vaughn, A. E., Tabak, R. G., Bryant, M. J., & Ward, D. S. (2013). Measuring parent food practices: a systematic review of existing measures and examination of instruments. In *International Journal of Behavioral Nutrition and Physical Activity* (Vol. 10). https://doi.org/10.1186/1479-5868-10-61

Vaughn, A. E., Ward, D. S., Fisher, J. O., Faith, M. S., Hughes, S. O., Kremers, S. P. J., Musher-Eizenman, D. R., O'Connor, T. M., Patrick, H., & Power, T. G. (2016). Fundamental constructs in food parenting practices: A content map to guide future research. *Nutrition Reviews*, *74*(2), 98–117. https://doi.org/10.1093/nutrit/nuv061

Ventura, A. K., & Birch, L. L. (2008). Does parenting affect children's eating and weight status? *The International Journal of Behavioral Nutrition and Physical Activity*, *5*, 15. https://doi.org/10.1186/1479-5868-5-15

Vereecken, C. A., Keukelier, E., & Maes, L. (2004). Influence of mother's educational level on food parenting practices and food habits of young children. *Appetite*, *43*(1), 93–103. https://doi.org/10.1016/j.appet.2004.04.002

Verloigne, M., Lippevelde, W. Van, Maes, L., Brug, J., & Bourdeaudhuij, I. De. (2012). Family- and school-based correlates of energy balance-related behaviours in 10–12-year-old children: a systematic review within the ENERGY (EuropeaN Energy balance Research to prevent excessive weight Gain among Youth) project. *Public Health Nutrition*, *15*(8), 1380–1395. https://doi.org/10.1017/S1368980011003168

Verloigne, M., Van Lippevelde, W., Maes, L., Brug, J., & De Bourdeaudhuij, I. (2012). Family- and school-based correlates of energy balance-related behaviours in 10-12-year-old children: A systematic review within the ENERGY (EuropeaN Energy balance Research to prevent excessive weight Gain among Youth) project. In *Public Health Nutrition* (Vol. 15, Issue 8, pp. 1380–1395). Cambridge University Press. https://doi.org/10.1017/S1368980011003168

Vesely, S., & Klöckner, C. A. (2020). Social Desirability in Environmental Psychology Research: Three Meta-Analyses. In *Frontiers in Psychology* (Vol. 11, p. 1395). Frontiers Media S.A. https://doi.org/10.3389/fpsyg.2020.01395

Viana, V., Sinde, S., & Saxton, J. C. (2008). Children's Eating Behaviour Questionnaire: associations with BMI in Portuguese children. *British Journal of Nutrition*, *100*(2), 445–450. http://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=105669370&site=ehost-live

Vollmer, R L, Adamsons, K., Foster, J. S., & Mobley, A. R. (2015). Association of fathers' feeding practices and feeding style on preschool age children's diet quality, eating behavior and body mass index. *Appetite*, *89*, 274–281. https://doi.org/https://dx.doi.org/10.1016/j.appet.2015.02.021

Vollmer, Rachel L, & Baietto, J. (2017). Practices and preferences: Exploring the relationships between food-related parenting practices and child food preferences for high fat and/or sugar foods, fruits, and vegetables. *Appetite*, *113*, 134–140. https://doi.org/https://doi.org/10.1016/j.appet.2017.02.019

Wainschtein, P., Jain, D. P., Yengo, L., Zheng, Z., TOPMed Anthropometry Working Group, T.-O. for P. M. C., Cupples, L. A., Shadyab, A. H., McKnight, B., Shoemaker, B. M., Mitchell, B. D., Psaty, B. M., Kooperberg, C., Roden, D., Darbar, D., Arnett, D. K., Regan, E. A., Boerwinkle, E., Rotter, J. I., Allison, M. A., … Visscher, P. M. (2019). Recovery of trait heritability from whole genome sequence data. *BioRxiv*, 588020. https://doi.org/10.1101/588020

Wang, Y., & Beydoun, M. A. (2007). The obesity epidemic in the United States - Gender, age, socioeconomic, racial/ethnic, and geographic characteristics: A systematic review and meta-regression analysis. In *Epidemiologic Reviews* (Vol. 29, Issue 1). https://doi.org/10.1093/epirev/mxm007

Wardle, J., & Carnell, S. (2009). Appetite is a Heritable Phenotype Associated with Adiposity. *Annals of Behavioral Medicine*, *38*(suppl_1), s25–s30. https://doi.org/10.1007/s12160-009-9116-5

Wardle, J., Carnell, S., Haworth, C. M., & Plomin, R. (2008). Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment. *Am J Clin Nutr*, *87*(2), 398–404. https://doi.org/10.1093/ajcn/87.2.398

Wardle, J., Guthrie, C. A., Sanderson, S., & Rapoport, L. (2001). Development of the Children's Eating Behaviour Questionnaire. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *42*(7), 963–970. https://doi.org/10.1017/S0021963001007727

Wardle, J., Sanderson, S., Guthrie, C. A., Rapoport, L., & Plomin, R. (2002). Parental feeding style and the intergenerational transmission of obesity risk. *Obesity Research*, *10*(6), 453–462. https://doi.org/10.1038/oby.2002.63

Warwick Institute for Employment Research. (2020). *Cascot: Computer Assisted Structured Coding Tool*. Warwick Institute for Employment Research. https://warwick.ac.uk/fac/soc/ier/software/cascot/choose_classificatio/

Watts, A. W., Barr, S. I., Hanning, R. M., Lovato, C. Y., & Mâsse, L. C. (2018). The home food environment and associations with dietary intake among adolescents presenting for a lifestyle modification intervention. *BMC Nutrition*, *4*(1), 3. https://doi.org/10.1186/s40795-018-0210-6

Webber, L, Hill, C., Saxton, J., Van Jaarsveld, C. H., & Wardle, J. (2009). Eating behaviour and weight in children. *International Journal of Obesity*, *33*(1), 21–28. https://doi.org/https://dx.doi.org/10.1038/ijo.2008.219

Webber, Laura, Cooke, L., Hill, C., & Wardle, J. (2010). Child adiposity and maternal feeding practices: a longitudinal analysis. *The American Journal of Clinical Nutrition*, *92*(6), 1423–1428. https://doi.org/10.3945/ajcn.2010.30112

Webber, Laura, Hill, C., Saxton, J., Jaarsveld, C., & Wardle, J. (2008). *Eating Behaviour and Weight in Children* (Vol. 33). https://doi.org/10.1038/ijo.2008.219

Weir, L. A., Etelson, D., & Brand, D. A. (2006). Parents' perceptions of neighborhood safety and children's physical activity. *Preventive Medicine*, *43*(3), 212–217. https://doi.org/10.1016/J.YPMED.2006.03.024

Welk, G. J., Blair, S. N., Wood, K., Jones, S., & Thompson, R. W. (2000). A comparative evaluation of three accelerometry-based physical activity monitors. *Medicine and Science in Sports and Exercise*, *32*(9 SUPPL.). https://doi.org/10.1097/00005768-200009001-00008

Wells, G., Shea, B., Robertson, J., Peterson, J., Welch, V., Losos, M., & Tugwell, P. (n.d.). *The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomized Studies in Meta-Analysis*.

Weston, R., & Gore, P. A. (2006). A Brief Guide to Structural Equation Modeling. *The Counseling Psychologist*, *34*(5), 719–751. https://doi.org/10.1177/0011000006286345

Wethington, H., Pan, L., & Sherry, B. (2013). The association of screen time, television in the bedroom, and obesity among school-aged youth: 2007 national survey of children's health. *Journal of School Health*, *83*(8), 573–

581. https://doi.org/10.1111/josh.12067

Wiecha, J. L., Peterson, K. E., Ludwig, D. S., Kim, J., Sobol, A., & Gortmaker, S. L. (2006). When children eat what they watch: Impact of television viewing on dietary intake in youth. *Archives of Pediatrics and Adolescent Medicine*, *160*(4), 436–442. https://doi.org/10.1001/ARCHPEDI.160.4.436

Wilk, P., Clark, A. F., Maltby, A., Smith, C., Tucker, P., & Gilliland, J. A. (2018). Examining individual, interpersonal, and environmental influences on children's physical activity levels. *SSM - Population Health*, *4*, 76–85. https://doi.org/10.1016/j.ssmph.2017.11.004

Wilson, A., & Norden, N. (2015). *The R Project for Statistical Computing The R Project for Statistical Computing*. URL: Http://Www. r-Project. Org/254. https://www.r-project.org/

Wood, A. C., Blissett, J. M., Brunstrom, J. M., Carnell, S., Faith, M. S., Fisher, J. O., Hayman, L. L., Khalsa, A. S., Hughes, S. O., Miller, A. L., Momin, S. R., Welsh, J. A., Woo, J. G., & Haycraft, E. (2020). Caregiver Influences on Eating Behaviors in Young Children. *Journal of the American Heart Association*. https://doi.org/10.1161/jaha.119.014520

World Health Organisation. (2013). WHO Definition of key terms. In *HIV Publication Guidelines*. https://www.who.int/hiv/pub/guidelines/arv2013/intro/keyterms/en/

Wright, C., & Birks, E. (2000). Risk factors for failure to thrive: a population-based survey. *Child: Care, Health and Development*, *26*(1), 5–16. https://doi.org/10.1046/j.1365-2214.2000.00135.x

Xue, Z., Lee, E., Monika, D., & Wutoh, A. (1998). NESUG 17 Analysis Building Logistic Regression Models to Analyze Survey Data with Complex Sampling Design NESUG 17 Analysis. *Test*.

Yee, A. Z. H., Lwin, M. O., & Ho, S. S. (2017). The influence of parental practices on child promotive and preventive food consumption behaviors: A systematic review and meta-analysis. In *International Journal of Behavioral Nutrition and Physical Activity* (Vol. 14, Issue 1, p. 47). BioMed Central Ltd. https://doi.org/10.1186/s12966-017-0501-3

Yengo, L., Sidorenko, J., Kemper, K. E., Zheng, Z., Wood, A. R., Weedon, M. N., Frayling, T. M., Hirschhorn, J., Yang, J., & Visscher, P. M. (2018). Meta-analysis of genome-wide association studies for height and body mass index in ∼700000 individuals of European ancestry. *Human Molecular Genetics*, *27*(20), 3641–3649. https://doi.org/10.1093/HMG/DDY271

Young, E. M., Fors, S. W., & Hayes, D. M. (2004). Associations between Perceived Parent Behaviors and Middle School Student Fruit and Vegetable Consumption. *Journal of Nutrition Education and Behavior*, *36*(1), 2–12. https://doi.org/https://doi.org/10.1016/S1499-4046(06)60122-X

Appendix A

Gemini study materials

A.1 Ethical approval for Gemini data collection

UCL RESEARCH ETHICS COMMITTEE
OFFICE FOR THE VICE PROVOST RESEARCH

17th October 2018

Dr Clare Llewellyn
Department of Behavioural Science and Health
UCL

Dear Dr Llewellyn

Notification of Ethics Approval with Provisos
Project ID/Title: 1624/004: Gemini – Health and Development Phase 2

In my capacity as Joint Chair of the UCL Research Ethics Committee (REC) I am pleased to confirm that your study has been ethically approved by the UCL REC until **30th September 2023**.

Ethical approval is also subject to the following conditions:

Notification of Amendments to the Research
You must seek Chair's approval for proposed amendments (to include extensions to the duration of the project) to the research for which this approval has been given. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing an 'Amendment Approval Request Form'
http://ethics.grad.ucl.ac.uk/responsibilities.php

Adverse Event Reporting – Serious and Non-Serious
It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator (ethics@ucl.ac.uk) immediately the incident occurs. Where the adverse incident is unexpected and serious, the Joint Chairs will decide whether the study should be terminated pending the opinion of an independent expert. For non-serious adverse events the Joint Chairs of the Ethics Committee should again be notified via the Ethics Committee Administrator within ten days of the incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Joint Chairs will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

Final Report
At the end of the data collection element of your research we ask that you submit a very brief report (1-2 paragraphs will suffice) which includes in particular issues relating to the ethical implications of the research i.e. issues obtaining consent, participants withdrawing from the research, confidentiality, protection of participants from physical and mental harm etc.
In addition, please:

- ensure that you follow all relevant guidance as laid out in UCL's Code of Conduct for Research: http://www.ucl.ac.uk/srs/governance-and-committees/resgov/code-of-conduct-research
- note that you are required to adhere to all research data/records management and storage procedures agreed as part of your application. This will be expected even after completion of the study.

With best wishes for the research.

Yours sincerely

Professor Michael Heinrich
Joint Chair, UCL Research Ethics Committee

A.2 Gemini baseline questionnaire (T0)

Family ID Number

WELCOME TO

gemini

health and development in twins

Booklet 1 - You and Your Family

Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
2-16 Torrington Place
London, WC1E 6BT
Gemini@public-health.ucl.ac.uk

HOW TO FILL IN THIS BOOKLET

Thank you for agreeing to fill out this booklet. Before you start, here is a bit of guidance:

- We realise that parents of twins are very busy! We are especially grateful.
- We know the questionnaire is quite long, but please try to answer *all* the questions you are asked. This will help us to get a full picture of you and your twins' circumstances.
- Please be as honest as you can when answering our questions. We want to know what you really think. Everything you tell us will be kept strictly confidential.
- This may sound obvious, but please write as clearly as possible. This will help us use all the valuable information you have provided.

Here is an example of how a question *could* be answered.

Most of the questions in this booklet will ask you to tick a box next to the answer that is most suitable. Some will also ask you to describe this answer in more detail, for example:

A1. Do you think your twins are identical or non-identical?	Identical ☑ Non-identical ☐
Why do you think this?	…The twins shared the same sac and placenta…
A2. As your twins grow older, do you have more time for yourself?	Yes ☑ No ☐

THIS QUESTIONNAIRE IS TO BE COMPLETED BY THE <u>MOTHER</u> OF THE TWINS.
IF YOU ARE NOT THE MOTHER, PLEASE CONTACT US AND WE WILL SEND YOU THE APPROPRIATE QUESTIONNAIRE

THANK YOU FOR YOUR TIME AND ASSISTANCE IN FILLING OUT THIS BOOKLET

YOUR TWINS

A1.	**Are you the primary caregiver of the twins?**	Yes	☐	No	☐
A2.	**What is your first born twin's name?**	______________________			
	Is your first born twin a boy or a girl?	Boy	☐	Girl	☐
	What is his/her date of birth?	____ / ____ / ______ DD MM YYYY			
A3.	**What is your second born twin's name?**	______________________			
	Is your second born twin a boy or a girl?	Boy	☐	Girl	☐

The next few questions are all about whether your twins are identical or non-identical. This section needs to be completed only if you have same sex twins (please note: non-identical twins are often called fraternal twins)

If your twins are opposite sex, please go straight to B1 on page 6

A4. Have you ever been told by a health professional (e.g. doctor, nurse, consultant) that your twins are identical or non-identical?

Yes, identical	☐	Yes, non-identical	☐	No	☐

If YES, why did they think this?____

____

A5. Do you think your twins are identical or non- identical?

Identical	☐	Non-identical	☐

Why do you think this is? ____

____

A6. As your twins have grown older, has the likeness between them:

Become less	☐	Remained the same	☐	Become more	☐

A7. When looking at the twins:

	None	Only slight difference	Clear difference
Are there differences in the shade of your twins' hair?	☐	☐	☐
Are there differences in the texture of your twins' hair (fine or coarse, straight or curly etc)?	☐	☐	☐
Are there differences in the colour of your twins' eyes?	☐	☐	☐
Are there differences in the shape of your twins' ear lobes?	☐	☐	☐

A8. Have either of your twins' teeth begun to come through? Yes ☐ No ☐

If yes, was it at about the same time?

Yes, the twins had matching teeth on the same side come through within a few days of each other	☐
Yes, the twins had matching teeth on opposite sides come through within a few days of each other	☐
Yes, the twins had different teeth come through within a few days of each other	☐
No, the twins' first teeth did not come through within a few days of each other	☐

A9. Do you know your twins' ABO blood group and Rhesus (Rh) factors?

Yes ☐ No ☐

If YES, what are they? (please tick a blood group and rhesus factor for each twin)

	Blood group:				Rhesus factor:	
	A	B	AB	O	Rh+	Rh-
1st born	☐	☐	☐	☐	☐	☐
2nd born	☐	☐	☐	☐	☐	☐

A10. When looking at a new photograph of your twins, can you tell them apart (without looking at their clothes or using any other clues)?

Yes, easily	Yes, but it is hard sometimes	No, I often confuse them in photographs
☐	☐	☐

A11. Do any of the following people ever mistake your twins for each other?

	Yes, often	Yes, sometimes	Rarely or never	Not applicable
Your partner / husband	☐	☐	☐	☐
Older brothers or sisters	☐	☐	☐	☐
Other relatives	☐	☐	☐	☐
Babysitter or day carer	☐	☐	☐	☐
Close friends	☐	☐	☐	☐
Casual friends	☐	☐	☐	☐
People meeting the twins for the first time	☐	☐	☐	☐

A12. If the twins are ever mistaken for one another, does this ever happen when they are together?

Yes, often	Yes, sometimes	No, almost never	They are not mistaken for one another
☐	☐	☐	☐

A13. Would you say that your twins:

Are as physically alike as "two peas in a pod" (virtually the same)	☐
Are as physically alike as brothers and sisters are	☐
Do not look very much alike at all	☐

ABOUT YOU

B1. What is your date of birth? _____ / _____ / _______
DD MM YYYY

B2. In general, would you say your own health is:

Excellent	Very good	Good	Fair	Poor
☐	☐	☐	☐	☐

B3. About how tall are you?

______ centimetres (cms) OR ______ feet (ft) and ______ inches

B4. About how much do you weigh? If possible, use weighing scales for current weights, otherwise please give estimates

______ kilograms (kgs) OR ______ stones (st) and ______ pounds (lbs)

B5. Given your age and height, would you say that you are:

Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight
☐	☐	☐	☐	☐

B6. Do you have any educational qualifications? (please tick all that apply or equivalents)

No qualifications	CSE, GCSE or 'O' Level	Vocational qualification (GNVQ, BTEC)	'A' or 'AS' level	Higher National Certificate (HNC) or Diploma (HND)	Undergraduate degree	Postgraduate qualification (Masters, PhD)
☐	☐	☐	☐	☐	☐	☐

Other, please describe: ______________________________

B7. Do you currently have a job?

On maternity leave	Yes, full-time	Yes, part-time	No	Stay at home to look after the children
☐	☐	☐	☐	☐

If NO, or stay at home to look after children please go straight to B9 on page 7

B8. What is your FULL job title? (please describe) ______________________________

Do you need any special qualifications for your job?

Yes ☐ No ☐ Unsure ☐

If YES, please describe: ______________________________

____

B9. What is your ethnic group? Tick the appropriate box to indicate your cultural background

White		Black		Asian		Mixed		Chinese or any other	
White British	☐	Caribbean	☐	Indian	☐	White and Black Caribbean	☐	Chinese	☐
White Irish	☐	African	☐	Pakistani	☐	White and Black African	☐		
				Bangladeshi	☐	White and Asian	☐		
Other White background (please specify)	☐	Other Black background (please specify)	☐	Other Asian background (please specify)	☐	Other Mixed background (please specify)	☐	Any other (please specify)	☐
____________		____________		____________		____________		____________	

B10. Do you smoke cigarettes at all nowadays? Yes ☐ No ☐

If Yes, how many cigarettes a day do you usually smoke? ____ cigarettes per day

B11. Do you usually participate in the following activities? If so, how many times per week and for how long? (Write 0 if you do not participate in any activity)

Strenuous exercise (heart beats rapidly) i.e. running, jogging, hockey, football, squash, vigorous swimming, vigorous cycling	____ times per week	____ minutes per session
Moderate exercise (not exhausting) i.e. fast walking, tennis, easy cycling, badminton, easy swimming, dancing	____ times per week	____ minutes per session
Mild exercise (minimal effort) i.e. yoga, fishing from river bank, bowling, golf, easy walking	____ times per week	____ minutes per session

B12. In the last week about how many servings of .... did you eat?

	Less than 1 per week	1 per week	2-4 per week	5-6 per week	1 per day	2 per day	3 per day	4 or more per day
VEGETABLES (excluding potatoes)	☐	☐	☐	☐	☐	☐	☐	☐
FRUIT (fresh, frozen or canned)	☐	☐	☐	☐	☐	☐	☐	☐

B13. What is your marital status?

Married or cohabiting	Divorced	Widowed	Separated	Single
☐	☐	☐	☐	☐

If you are not married or cohabiting, please go to straight to D1 on page 10

ABOUT THE PERSON YOU LIVE WITH
(i.e. your husband or partner)

C1. What is your partner's relationship to the twins?

Natural father of the twins	Legal guardian of the twins	Other
☐	☐	☐

If other, please describe: ____

C2. What is your partner's date of birth? _____ / _____ / _______
DD MM YYYY

C3. About how tall is your partner?

______ centimetres (cms) OR ______ feet (ft) and ______ inches

C4. About how much does your partner weigh? If possible, use weighing scales for current weights, otherwise please give estimates

______ kilograms (kgs) OR ______ stones (st) and ______ pounds (lbs)

C5. Does your partner have any educational qualifications? (please tick all that apply or equivalents)

No qualifications	CSE, GCSE or 'O' Level	Vocational qualification (GNVQ, BTEC)	'A' or 'AS' level	Higher National Certificate (HNC) or Diploma (HND)	Undergraduate degree	Postgraduate qualification (Masters, PhD)
☐	☐	☐	☐	☐	☐	☐

Other, please describe: ____

C6. Does your partner currently have a job?

Yes, full-time	Yes, part-time	No	Stay at home to look after the children
☐	☐	☐	☐

If NO, or stay at home to look after children, please go straight to C8 on page 9

C7. What is your partner's FULL job title? (please describe) ______________________________

Are there any special qualifications needed for their job?

Yes ☐ No ☐ Unsure ☐

If YES, please describe: ____

C8. What is your partner's ethnic group? Tick the appropriate box to indicate your partner's cultural background

White		Black		Asian		Mixed		Chinese or any other	
White British	☐	Caribbean	☐	Indian	☐	White and Black Caribbean	☐	Chinese	☐
White Irish	☐	African	☐	Pakistani	☐	White and Black African	☐		
				Bangladeshi	☐	White and Asian	☐		
Other White background (please specify)	☐	Other Black background (please specify)	☐	Other Asian background (please specify)	☐	Other Mixed background (please specify)	☐	Any other (please specify)	☐
___________		___________		___________		___________		___________	

C9. Does your partner smoke cigarettes at all nowadays?	Yes ☐	No ☐
If Yes, how many cigarettes a day does your partner usually smoke?	____ cigarettes per day	

C10. Does your partner usually participate in the following activities? If so, how many times per week and for how long? (Write 0 if your partner does not participate in any activity)

Strenuous exercise (heart beats rapidly) i.e. running, jogging, hockey, football, squash, vigorous swimming, vigorous cycling	____ times per week	____ minutes per session
Moderate exercise (not exhausting) i.e. fast walking, tennis, easy cycling, badminton, easy swimming, dancing	____ times per week	____ minutes per session
Mild exercise (minimal effort) i.e. yoga, fishing from river band, bowling, golf, easy walking	____ times per week	____ minutes per session

C11. In the last week about how many servings of .... did your partner eat?

	Less than 1 per week	1 per week	2-4 per week	5-6 per week	1 per day	2 per day	3 per day	4 or more per day
VEGETABLES (excluding potatoes)	☐	☐	☐	☐	☐	☐	☐	☐
FRUIT (fresh, frozen or canned)	☐	☐	☐	☐	☐	☐	☐	☐

ABOUT OTHER CHILDREN IN THE HOME

D1. How many other children live in the home with your twins? (please write number)

__________ children

If there are no other children living in the home, please go straight to E1 on page 11

D2. Please tell us about all the children who live in the home with the twins:

Child's name	Date of birth	Sex		Does the child have the same mother as the twins?		Does the child have the same natural father as the twins?	
		Boy	Girl	Yes	No	Yes	No
__________	___/___/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	___/___/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	___/___/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	___/___/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	___/___/____ DD MM YYYY	☐	☐	☐	☐	☐	☐
__________	___/___/____ DD MM YYYY	☐	☐	☐	☐	☐	☐

If there are more than six other children or if there is anything else you would like to tell us about your family, please tell us in the open space below

	YOUR PREGNANCY WITH THE TWINS	

E1.	**About how much weight did you gain during your pregnancy with the twins?**						
	______ kilograms (kgs)	OR	____ stones (st) and ____ pounds (lbs)				
E2.	**When you became pregnant with the twins, were you having any fertility treatment?**			Yes	☐	No	☐
	If YES, please describe: ______________________________						
E3.	**Were you regularly taking any medicine whilst pregnant?**			Yes	☐	No	☐
	If YES, was this: (please tick all that apply)	For first 3 months ☐		For middle 3 months	☐	For last 3 months	☐
	Please describe the type of medication: ______________________________						
E4.	**Did you smoke any cigarettes whilst pregnant?**			Yes	☐	No	☐
	If YES, was this: (please tick all that apply)	For first 3 months ☐		For middle 3 months	☐	For last 3 months	☐
	How many cigarettes a day did you smoke, on average? (write 0 if you smoked no cigarettes whilst pregnant)				_______ cigarettes per day		
E5.	**Did you drink any alcohol whilst pregnant?**			Yes	☐	No	☐
	If YES, was this: (please tick all that apply)	For first 3 months ☐		For middle 3 months	☐	For last 3 months	☐
	How many units of alcohol did you drink per week, on average? (1 unit = 1 glass of wine, or 1 measure of spirits, or ½ a pint of beer) (write 0 if you drank no alcohol whilst pregnant)				_______ units per week		
E6.	**Did you experience any severe stress during your pregnancy (e.g. bereavement, serious illness in the family or major money problems)?**			Yes	☐	No	☐
	If YES, please describe: ______________________________						
	______________________________						

E7. During your pregnancy did you experience any of the following:

	Yes	No	Unsure
Morning sickness	☐	☐	☐
High blood pressure (pregnancy induced / gestational)	☐	☐	☐
Diabetes (pregnancy induced / gestational)	☐	☐	☐
Toxaemia / pre-eclampsia	☐	☐	☐
Vaginal bleeding	☐	☐	☐
Anaemia / iron deficiency	☐	☐	☐
Rubella / German Measles	☐	☐	☐
Slow growth of baby / babies	☐	☐	☐
Other serious pregnancy related problem (please describe)	☐	☐	☐

____

____

E8. Did you experience any physical or mental health problem in the first 6 months after birth; and were any of those problems diagnosed by a doctor?

Yes, diagnosed by a doctor ☐   Yes, but not diagnosed by a doctor ☐   No ☐

If YES, please describe: ______________________________

____

E9. Have you ever been diagnosed with heart disease or diabetes, before or after your pregnancy?

	Yes	No	Unsure
Heart disease	☐	☐	☐
Diabetes (unrelated to pregnancy)	☐	☐	☐

E10. In their lives, have any family members ever been diagnosed with heart disease or diabetes?

	Father of twins	Brother or sister of twins	Your mother	Your father	Mother of the twins' father	Father of the twins' father	None
Heart disease	☐	☐	☐	☐	☐	☐	☐
Diabetes	☐	☐	☐	☐	☐	☐	☐

E11. In general, how would you describe the weights of your family members throughout their lives?

	Very underweight	Slightly underweight	About the right weight	Slightly overweight	Very overweight	Unsure
Father of the twins	☐	☐	☐	☐	☐	☐
Your mother	☐	☐	☐	☐	☐	☐
Your father	☐	☐	☐	☐	☐	☐
Mother of the twins' father	☐	☐	☐	☐	☐	☐
Father of the twins' father	☐	☐	☐	☐	☐	☐

THE TWINS' BIRTH

F1. **How many weeks pregnant were you at the time of delivery?** __________ weeks

F2. **Was the birth by Caesarean section?**

	Yes	No	Unsure
	☐	☐	☐

If YES, why? ______________________________

____

F3. **Approximately how long was the gap between the births?**

_______ hours OR _______ minutes

F4. **Did transfusion between twins occur (twin to twin transfusion syndrome)?**

	Yes	No	Unsure
	☐	☐	☐

F5. **Did your babies get a blood transfusion soon after birth?**

	Yes	No	Unsure
	☐	☐	☐

F6. **Were there any other complications or concerns about either twin <u>at birth</u>?**

	Yes	No	Unsure
1st born	☐	☐	☐
2nd born	☐	☐	☐

If Yes in 1st born, please describe: ______________________________

____

____

____

If Yes in 2nd born, please describe: ______________________________

____

____

____

F7.	**Did either of the twins have any special care after birth (e.g. incubators)?**			
		Yes	No	
	1st born	☐	☐	
	2nd born	☐	☐	
	If Yes in 1st born, please describe:	______________________		
	______________________			
	If Yes in 2nd born, please describe:	______________________		
	______________________			
F8.	**If yes, how long did they stay in special care?**			
	1st born	_____ days	or	_____ weeks
	2nd born	_____ days	or	_____ weeks
F9.	**How long did the twins stay in hospital after birth?**			
	1st born	_____ days	or	_____ weeks
	2nd born	_____ days	or	_____ weeks
F10.	**Do either of your twins have:**			
		Yes, 1st born	Yes, 2nd born	Neither
	Physical problems (e.g. cleft lip, hole in the heart)	☐	☐	☐
	If Yes in 1st born, please describe:	______________________		
	If Yes in 2nd born, please describe:	______________________		
		Yes, 1st born	Yes, 2nd born	Neither
	Genetic or chromosomal problems (e.g. Down's Syndrome, PKU)	☐	☐	☐
	If Yes in 1st born, please describe:	______________________		
	If Yes in 2nd born, please describe:	______________________		
		Yes, 1st born	Yes, 2nd born	Neither
	Any other medical problem after birth	☐	☐	☐
	If Yes in 1st born, please describe:	______________________		
	______________________			
	If Yes in 2nd born, please describe:	______________________		
	______________________			

F11. Sometimes it is difficult to start feeding due to birth-related complications or other medical problems. Straight after birth, did either of your twins experience any complications which made it difficult to start feeding?

Yes, in 1st born ☐	Yes, in 2nd born ☐	No ☐

If Yes in 1st born, please describe: ______________________________

____

If Yes in 2nd born, please describe: ______________________________

____

F12. Were there any other times when feeding your twins was difficult, e.g. due to illness of the twins, health problems of parent, changes in jobs or moving house.

Yes, in 1st born ☐	Yes, in 2nd born ☐	No ☐

If Yes, please describe for each twin: (Use the back of the questionnaire if you need extra space)

Problem 1 in 1st born	______________________________
	At which ages did this influence your twins eating? __to__ weeks or __to__ months
Problem 2 in 1st born	______________________________
	At which ages did this influence your twins eating? __to__ weeks or __to__ months
Problem 1 in 2nd born	______________________________
	At which ages did this influence your twins eating? __to__ weeks or __to__ months
Problem 2 in 2nd born	______________________________
	At which ages did this influence your twins eating? __to__ weeks or __to__ months

THE TWINS' ILLNESSES AND ACCIDENTS

F13. About how many times have your babies seen the doctor due to illness or accidents since birth?

	Number of visits	
1st born	________	
2nd born	________	

F14. Since birth, have your babies been admitted to hospital?

	No	Yes, once	Yes, more than once (write number)
1st born	☐	☐	________
2nd born	☐	☐	________

F15. Please briefly describe each hospital admission (Use the back of the questionnaire if you need more space)

	Age of twin (months)	Number of hospital nights	Reason for admission:
1st born	________	________	________________________________
	________	________	________________________________
	________	________	________________________________
	________	________	________________________________
	________	________	________________________________
	________	________	________________________________
2nd born	________	________	________________________________
	________	________	________________________________
	________	________	________________________________
	________	________	________________________________
	________	________	________________________________
	________	________	________________________________

SOME FINAL QUESTIONS ABOUT YOU AND YOUR FAMILY

G1. What is the main language spoken in the home?

English ☐ | Other (please specify) ____________________

G2. Altogether, how many adults live in the same house as the twins (including yourself)?

One ☐ | Two ☐ | Three ☐ | Four or more: ______ (please give number)

G3. How many bedrooms does your household have, including bedsitting rooms and spare rooms?

One ☐ | Two ☐ | Three ☐ | Four or more: ______ (please give number)

G4. How many cars or vans are normally available for use by you or any members of your household?

None ☐ | One ☐ | Two ☐ | Three or more: ______ (please give number)

G5. Do you currently own or rent the accommodation you live in?

Own without mortgage	Own with mortgage	Rent privately	Rent from local authority
☐	☐	☐	☐

G6. Thinking of the income of the household as a whole, which category represents the <u>total</u> income of your <u>whole household</u> before deduction from income tax, National Insurance etc.

Up to £15,000 per year	☐	Between £52,500 and £60,000 per year	☐
Between £15,000 and £22,500 per year	☐	Between £60,000 and £67,500 per year	☐
Between £22,500 and £30,000 per year	☐	Between £67,500 and £75,000 per year	☐
Between £30,000 and £37,500 per year	☐	Between £75,000 and £82,500 per year	☐
Between £37,500 and £45,000 per year	☐	Between £82,500 and £90,000 per year	☐
Between £45, 000 and £52,500 per year	☐	More than £90,000 per year	☐

G7. Do you feel your family income is enough?

More than enough ☐ | Enough ☐ | Not enough ☐

G8. Please give the date on which you completed this booklet? ___ / ____ / ____ day/month/year

Please continue with BOOKLET 2 to tell us more about your twins

Thank you

for filling out this booklet.

PLEASE continue with BOOKLET 2 to tell us more about your twins

Space for any additional comments you would like to make :

A.3 The Home Environment Interview (HEI) administered when the twins were age 4 (T6).

GEMINI HOME ENVIRONMENT MEASURE

Highlighted text in yellow is text interviewer needs to read out loud, other text is for coding purposes and may not need to be read out loud

Section A - GENERAL INFORMATION QUESTIONS

Today's date: __ / __ / 2010

Family ID Number: <family ID>

(Mark: researcher will type gemini ID: could you then use named contact and twin names, date of birth, street name, house number, post code, town, as highlighted spaces in red)

A1. Please can I speak to <Named Contact>? *(try to speak to main contact but continue anyway)*

If first phone call:
Hello, this is <researcher name> calling on behalf of the Gemini twin study. Instead of a questionnaire, we are carrying out this part of the study over the phone. Is now a good time to talk?

If not convenient, arrange another time that is convenient and record this in the call attempts excel spreadsheet. If the participant doesn't want to do the interview, also record this in the call attempts spreadsheet.

If yes, proceed as below.
We have the twins' names registered as <twin1 name> and <twin2 name>, is that correct and what you would usually call them? Is <twin1 name> the first born twin and <twin2 name> the second born?

If yes to names and birth order: click 'NEXT' button.
If no to names/birth order: check Gemini ID and insert correct names (in the correct order):

twin 1: ……… twin 2 ……………..

I would like to ask you some questions about <twin1 name> and <twin2 name> and your home. Ideally we need to talk to the person who is responsible for the majority of the food shopping and childcare within the home. Do you think you will be in a position to answer these questions?

If FOLLOW-UP phone call:
Hello, this is <researcher name> calling on behalf of the Gemini twin study. We spoke recently and you agreed to take part in a telephone interview. Is now a good time to talk?

1. If OK to talk and speaking to <named contact>: click 'NEXT button'
2. If OK to talk and NOT speaking to <named contact> fill in name below and click 'NEXT' button.

Could I take your name?

First Name ………………..   Last Name ………………...

3. If NOT OK to talk, arrange a convenient time to call back, make a note of this time and click 'BACK'.

Thank you for taking the time to talk, your responses are very valuable to us. The interview should take around half an hour to complete. Just to give you some background, the aim of this interview is to get a picture of the environment young children are growing up in. There are no right or wrong answers so please feel free to be as open and honest as you like. If there are any questions you need me to clarify, or any other information you think would be relevant then please feel free to stop me at any time. Any information obtained will be kept confidential and anonymous.

A2. Please could you confirm the twin's date of birth? [<Date of Birth>]
If different, check Gemini ID and insert correct date of birth ____ / ____ / 2007

A3. Please could you confirm your relationship with <twin1 name> and <twin2 name>?

☐ Mother

☐ Father

☐ Guardian

☐ Same sex partner

☐ Grandparent

☐ Nanny

☐ Other, please specify: ………………………………………………………………

A4. Please could you confirm the following home address? Read out the address below. Change the details if not correct.

Address : <House number> …<Street name> ……………………………………
<Town>……………………………
……………………………………

Postcode : <Postcode> ………………………………

Were there any changes? Yes ☐ No ☐

A5. How many adults, including yourself, currently live in your home? Only include people who are aged 18 years or older and who live in your home all of the time.

………….. Adults

A6. Does this include…

Your husband?	Yes ☐	No ☐
Your wife?	Yes ☐	No ☐
Your partner?	Yes ☐	No ☐

For female participants ask: Does this include your husband? If yes, select no for wife and partner. If no, then ask 'your partner?'
For male participants ask: Does this include your wife? If yes, select no for husband and partner. If no, then ask 'your partner?'

If no to all three, skip G4.5 and G4.6.

A7. How many children, under 18 years of age, not including <twin1 name> and <twin2 name>, currently live in your home?

………….. Children

A8. Since the birth of <twin1 name> and <twin2 name>, have any additional children joined the household? *If no, skip A9.*

Yes ☐ No ☐

A9. Please can you give the name, date of birth and sex of each additional child? Complete the table below accordingly.

	Child's name	Date of Birth	Sex
1			male ☐ female ☐
2			male ☐ female ☐
3			male ☐ female ☐
4			male ☐ female ☐

Additional comments about changes to family circumstances.

Section B - CHILDCARE

The first section is about your twin's childcare arrangements.

B1. Are your twins usually looked after together?

Yes ☐ No ☐

If looked after together:

B2. What are the regular arrangements for <twin1 name> and <twin2 name> to be looked after, either while you are at work or for any other reasons? For example, do they attend nursery or do you stay at home full time to care for them?

This is an open question. Tick one of the coding options. If the participant says looked after by a relative – clarify whether this is inside or outside the twins' home.

If the participant mentions more than one arrangement here, make sure you ask about each arrangement in turn.

☐ Stay at home full time to care for the twins.

☐ Partner stays at home full time to care for the twins.

☐ In the twins' home by grandparent

☐ In the twins' home by other relative

☐ In the twins' home by non-relative (including nannies and au pairs)

☐ Outside the twins' home by grandparent

☐ Outside the twins' home by other relative

☐ Outside the twins' home by non-relative (including childminder)

☐ Nursery / Preschool

☐ Other, please specify: …………………………………………………….

B3. In general, about how many hours per week do you use this arrangement for <twin1 name> and <twin2 name>?
ENTER WEEKLY HOURS RANGE 0-80. If the participant says it varies, request she/he estimates the average. If the participant says a number of hours plus a half then round down e.g. 15 and 1/2 hours would be 15 hours. Otherwise, round up or down accordingly e.g. 15 and 3/4 hours would be 16. If 'stay at home full time to care for twins' is selected, enter 0 hours.
………………………….. Hours per week

B4. Do you make any other regular arrangements for looking after <twin1 name> and <twin2 name>?

Yes ☐ No ☐ If No, continue to Section C.

IF Yes
B5. What is the other arrangement for <twin1 name> and <twin2 name>?
Coding options as above: . …………..

B6. In general, about how many hours per week did you use this arrangement for <twin1 name> and <twin2 name>?
ENTER WEEKLY HOURS RANGE 0-80. If the participant says it varies, request she/he estimates the average. If the participant says a number of hours plus a half then round down e.g. 15 and 1/2 hours would be 15 hours. Otherwise, round up or down accordingly e.g. 15 and 3/4 hours would be 16. If 'stay at home full time to care for twins' is selected, enter 0 hours.
………………………….. Hours per week

Do you make any other regular arrangements for looking after <twin1 name> and <twin2 name>?

Yes ☐ No ☐ If No, continue to Section C.

Repeat B-5-6 until answer is No.

If looked after separately:

B7. What are the regular arrangements for <twin1 name> to be looked after, either while you are at work or for any other reasons? For example, does <twin1 name> attend nursery or do you stay at home full time to care for <twin1 name>?

This is an open question. Tick one of the coding options. If the participant says looked after by a relative – clarify whether this is inside or outside the twins' home.

If the participant mentions more than one arrangement here, make sure you ask about each arrangement in turn.

☐ Stay at home full time to care for <twin1 name>.

☐ Partner stays at home full time to care for <twin1 name>.

☐ In the twins' home by grandparent

☐ In the twins' home by other relative

☐ In the twins' home by non-relative (including nannies and au pairs)

☐ Outside the twins' home by grandparent

☐ Outside the twins' home by other relative

☐ Outside the twins' home by non-relative (including childminder)

☐ Nursery / Preschool

☐ Other, please specify: …………………………………………………

B8. What are the regular arrangements for <twin2 name> to be looked after, either while you are at work or for any other reasons? For example, does <twin2 name> attend nursery or do you stay at home full time to care for <twin2 name>?

This is an open question. Tick one of the coding options. If the participant says looked after by a relative – clarify whether this is inside or outside the twins' home. If the participant mentions more than one arrangement here, make sure you ask about each arrangement in turn.

☐ Stay at home full time to care for <twin2 name>.

☐ Partner stays at home full time to care for <twin2 name>.

☐ In the twins' home by grandparent

☐ In the twins' home by other relative

☐ In the twins' home by non-relative (including nannies and au pairs)

☐ Outside the twins' home by grandparent

☐ Outside the twins' home by other relative

☐ Outside the twins' home by non-relative (including childminder)

☐ Nursery / Preschool

☐ Other, please specify: …………………………………………………

B9. In general, about how many hours per week do you use this arrangement for <twin1 name>?

ENTER WEEKLY HOURS RANGE 0-80. If the participant says it varies, request she/he estimates the average. If the participant says a number of hours plus a half then round down e.g. 15 and 1/2 hours would be 15 hours. Otherwise, round up or down accordingly e.g. 15 and 3/4 hours would be 16. If ‘stay at home full time to care for twins’ is selected, enter 0 hours.
………………………….. Hours per week

In general, about how many hours per week do you use this arrangement for <twin2 name>?
………………………….. Hours per week

B10. Do you make any <u>other</u> regular arrangements for looking after <twin1 name>?
Yes ☐ No ☐

Do you make any <u>other</u> regular arrangements for looking after <twin2 name>?
Yes ☐ No ☐ If both no, continue to Section C.

IF Yes
B11. What is the arrangement for <twin1 name>?
Coding options as above: . …………..

What is the arrangement for <twin2 name>?
Coding options as above: . …………..

B12. In general, about how many hours per week did you use this arrangement for <twin1 name>?
ENTER WEEKLY HOURS RANGE 01-80. If the participant says it varies, request she/he estimates the average. If the participant says a number of hours plus a half then round down e.g. 15 and 1/2 hours would be 15 hours. Otherwise, round up or down accordingly e.g. 15 and 3/4 hours would be 16.'

………………………….. Hours per week

In general, about how many hours per week did you use this arrangement for <twin2 name>?

………………………….. Hours per week

Repeat B10-B11-B12 until answer to B10 is No for both twins.

Section C – HOUSE AND NEIGHBOURHOOD

The next few questions are about where you live.

C1. Which of the following options best describes the type of home you live in?
Read out each of the options below.

☐ Flat (which floor……)
☐ Semi-detached house
☐ Terraced house
☐ Detached house

☐ Or other, please describe: …………..…………………………………………………

C2. Do you have stairs in your home?

Yes ☐ No ☐

C3. Would you say that your home is on a busy street with lots of traffic?

Yes ☐ No ☐

Any comments on this section (C1-C3): ……………………………….……

I'm now going to ask some questions about how satisfied you are with where you live. For each question please choose a score from 1 to 5. A score of 1 means strongly dissatisfied, 2 means somewhat dissatisfied, 3 means neither satisfied nor dissatisfied, 4 means somewhat satisfied and 5 means strongly satisfied.

To make sure the participant is ranking correctly, for the first question of each set of questions where there are a number of response options, repeat their response back to them e.g. if participant says 5, interviewer says 'so that's 5, strongly satisfied?' etc.

C4. How satisfied are you with the quality of schools in your neighbourhood? This includes preschool and nursery.

1 2 3 4 5

C5. How satisfied are you with access to entertainment in your neighbourhood such as restaurants and cinemas?

1 2 3 4 5

C6. How satisfied are you with the safety of your neighbourhood?

1 2 3 4 5

C7. How satisfied are you with the level of traffic in your neighbourhood?

1 2 3 4 5

C8.1 How satisfied are you with the number of food shops in your neighbourhood?

1 2 3 4 5

C8.2 How satisfied are you with the quality of food shops in your neighbourhood?

1 2 3 4 5

C9.1 How satisfied are you with the number of restaurants in your neighbourhood? This includes all types of restaurants, sit-in or take-away.

1 2 3 4 5

C9.2 How satisfied are you with the quality of restaurants in your neighbourhood? Again this includes all types of restaurants, sit-in or take-away.

1 2 3 4 5

C10. How satisfied are you with your neighbourhood as a place to raise children?

1 2 3 4 5

C11. How satisfied are you with your neighbourhood as a place to live?

1 2 3 4 5

C12. How easy it is to walk in your neighbourhood?
1 2 3 4 5

C13. How easy it is to bicycle in your neighbourhood?
1 2 3 4 5

Section D – PHYSICAL ACTIVITY ENVIRONMENT

The next section is about activity facilities available to you.

D1. Are there any parks or outdoor recreation areas close to your home?

Yes ☐ No ☐ Don't know ☐ *If no or don't know skip D2.*

D2. Do you use any of these with <twin1 name> and <twin2 name> on a regular basis?

Yes ☐ No ☐

D3. Are there any in-door recreation centres close to your home, for example a gym or indoor soft play?

Yes ☐ No ☐ Don't know ☐ *If no or don't know skip D4.*

D4. Do you use any of these with <twin1 name> and <twin2 name> on a regular basis?

Yes ☐ No ☐

D5. Do you take <twin1 name> and <twin2 name> to any other regular play sessions where they can be physically active, for example toddler activity classes or soft play areas?

Yes ☐ No ☐

D6. Do you have a garden or outdoor space that <twin1 name> and <twin2 name> can play in? This includes shared garden space for people living in flats, but does not include park space, even if it is very close to home.

Yes ☐ No ☐

If no skip D7, D8, D10 and D12.

D7. Would you say that your garden or outdoor space is small, medium or large?

small ☐ medium ☐ large ☐

D8. Do you have any usable play equipment such as swings, slides, climbing frames, trampolines in your garden or outdoor space? Usable means that it is ready to use. For example, swings are well grounded and have chairs.

Yes ☐ No ☐

D9. Do <twin1 name> and <twin2 name> have a usable tricycle, bike, scooter or wheeled toy? Usable means that it is ready to use. For example, bikes have tires that are pumped up and chains that are not broken.

Yes (both) ☐ No ☐ Yes <twin1 name> ☐ Yes <twin2 name> ☐

For the next two questions, please choose a score from 1 to 5: 1 means strongly disagree, 2 means somewhat disagree, 3 means neither agree nor disagree, 4 means somewhat agree, 5 means strongly agree.

D10. To what extent would you agree that <twin1 name> and <twin2 name> have adequate room to play actively in your garden or outdoor space? By 'actively' we mean anything that involves physically moving about during playing such as running, jumping, or climbing on things.
For the first question, to make sure the participant is ranking correctly, repeat their response back to them e.g. if participant says 5, interviewer says 'so that's 5, strongly agree?' etc.
1 2 3 4 5 (5=strongly agree)

D11. To what extent would you agree that <twin1 name> and <twin2 name> have adequate room to play actively inside the home? Only say what we mean by actively if the participant has not been asked D10, which also explains this. A possible response may be that there is space in some rooms, but not in others. Get the participant to consider this with their response. For example, if there is only space in one room, the answer might be 4, somewhat agree.
1 2 3 4 5 (5=strongly agree)

For the next two questions, again please choose a score from 1 to 5: 1 means never, 2 means rarely, 3 means some of the time, 4 means most of the time, 5 means all of the time.

D12. How often would you say that <twin1 name> and <twin2 name> are allowed to play actively in your garden or outdoor space?
For the first question, to make sure the participant is ranking correctly, repeat their response back to them e.g. if participant says 5, interviewer says 'so that's 5, all of the time?' etc.
A potential response may be that the twins are only allowed to play outside if an adult is present. If play is never restricted within that parameter, tick 5 all of the time. Another potential response is that outdoor play depends on the weather. If so, ask the participant to consider this with their response.
Explanations for D12 and D13 are irrelevant e.g.it might be that participants rarely allow their twins to play actively inside the home because they do not feel that it is safe. This response should remain as 2 rarely.
1 2 3 4 5

D13. How often would you say that <twin1 name> and <twin2 name> are allowed to play actively inside the home?
1 2 3 4 5

Section E – CHILDREN'S ACTIVITY

The next section is about your twin's activity.

E1. Compared to other children of the same age and sex, how physically active are <twin1 name> and <twin2 name>? Please choose a score from 1 to 5 for each child separately: 1 means much less active, 2 means somewhat less active, 3 means about average, 4 means somewhat more active, 5 means much more active.
<twin1 name>: 1 2 3 4 5
<twin2 name>: 1 2 3 4 5

E2. Do you think <twin1 name> gets enough physical activity?

Yes ☐ No ☐

Do you think <twin2 name> gets enough physical activity?

Yes ☐ No ☐

E3. Do you know how many minutes of physical activity per day health professionals recommend for young children?

____ mins (enter 99 if Don't know)

If the participant asks, the answer is 60 minutes per day.

E4. Do you know how many minutes of physical activity per day health professionals recommend for adults?

____ mins (enter 99 if Don't know)

If the participant asks, the answer is 30 minutes per day.

Your child's free time choices

The next questions are about how much <twin1 name> and <twin2 name> enjoy specific activities. I will ask the questions for <twin1 name> first and then repeat the activities for <twin2 name>.

For each activity, please choose a score from 1 to 5: 1 means does not enjoy it at all, 2 means enjoys it a little, 3 means neither likes nor dislikes, 4 means enjoys it a lot, and 5 means loves it. Select NA if child never engages in activity.

How much does <twin1 name> enjoy the following or similar activities? Read each activity choice in turn. Wait for the participant's response before reading out the next activity choice. For the first question, to make sure the participant is ranking correctly, repeat their response back to them e.g. if participant says 5, interviewer says 'so that's 5, loves it?' etc.

E5.1. Doing jigsaws or puzzles:	1	2	3	4	5	NA
E5.2. Drawing and making things:	1	2	3	4	5	NA
E5.3. Watching TV:	1	2	3	4	5	NA
E5.4. Playing computer games:	1	2	3	4	5	NA
E5.5. Riding a bicycle or playing with wheeled toy:	1	2	3	4	5	NA
E5.6. Walking:	1	2	3	4	5	NA
E5.7. Playing ball games:	1	2	3	4	5	NA
E5.8. Climbing on things:	1	2	3	4	5	NA
E5.9. Running:	1	2	3	4	5	NA
E5.10. Dancing:	1	2	3	4	5	NA

How much does <twin2 name> enjoy the following (or similar) activities? Again, for each question, please choose a score from 1 to 5. Read each activity choice in turn. Wait for the participant's response before reading out the next activity choice. Select NA if child never engages in activity.

E6.1. Doing jigsaws or puzzles:	1 2 3 4 5 NA
E6.2. Drawing and making things:	1 2 3 4 5 NA
E6.3. Watching TV:	1 2 3 4 5 NA
E6.4. Playing computer games:	1 2 3 4 5 NA
E6.5. Riding a bicycle or playing with wheeled toy:	1 2 3 4 5 NA
E6.6. Walking:	1 2 3 4 5 NA
E6.7. Playing ball games:	1 2 3 4 5 NA
E6.8. Climbing on things:	1 2 3 4 5 NA
E6.9. Running:	1 2 3 4 5 NA
E6.10. Dancing:	1 2 3 4 5 NA

Section F – PARENTAL MODELING OF ACTIVITY

The questions in this section refer to the parent(s) or primary caregiver(s) who live in the same home as the twins. This may or may not be the biological parent(s).

For each question, again please choose a score from 1 to 5. 1 means never, 2 means rarely, 3 means sometimes, 4 means often, 5 means very often.

Note that scores of <twin1 name> are automatically copied to <twin2 name>. If parent indicates a difference between twins, score can be adjusted for <twin2 name>. Always score <twin1 name> first and then <twin2 name>.

F1. How often do you or your <husband/wife/partner> encourage <twin1 name> and <twin2 name> to do physical activity? For the first question, to make sure the participant is ranking correctly, repeat their response back to them e.g. if participant says 5, interviewer says 'so that's 5, very often?' etc. If parents say 1 because they don't need to as their twins are already physically active, still keep response as 1. In other words, it doesn't matter what the reason is.

1 2 3 4 5
If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F2. How often do you or your <husband/wife/partner> do physical activity or play sports with <twin1 name> and <twin2 name>?
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F3. How often do you or your <husband/wife/partner> provide transport to a place where <twin1 name> and <twin2 name> can do physical activity? By this we mean provide transport by car (or other vehicle) rather than by foot.
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F4. How often do you or your <husband/wife/partner> watch <twin1 name> and <twin2 name> participate in physical activity?
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F5. How often do you or your <husband/wife/partner> tell <twin1 name> and <twin2 name> that being physically active is good for their health?
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F6. How often do you or your <husband/wife/partner> set goals for <twin1 name> and <twin2 name> to do physical activity? For example, how often do you set goals to go to the park as a family every Saturday or for the twins to play outside for half an hour at least once a day?
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F7. How often do you or your <husband/wife/partner> plan for <twin1 name> and <twin2 name> to do physical activity? For example, how often do you plan your week to make sure the twins have time for activity, such as walking to and from nursery every Monday?
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F8. How often do you or your <husband/wife/partner> keep track of how much physical activity <twin1 name> and <twin2 name> do?
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F9. How often do you or your <husband/wife/partner> try to be active in front of <twin1 name> and <twin2 name>?
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

F10. How often do you or your <husband/wife/partner> try to show enthusiasm about being active?
1 2 3 4 5

F11. How often do you or your <husband/wife/partner> show <twin1 name> and <twin2 name> how much you enjoy being active?
1 2 3 4 5

If different arrangement for twins: <twin2 name>: 1 2 3 4 5

Section G - MEDIA

The next section is about the media equipment you have in your home

G1. How many working TV's do you have in your home? Include TV's that are temporarily broken if there is a plan to get them fixed.
…….. (enter 99 if Don't know, enter 0 if none) *If 0, skip G2 and G6*

G2. Do you have cable or satellite? This does not include freeview.

Yes ☐ No ☐

G3. How many working VCR or DVD players do you have in your home? Include VCR's or DVD players that are temporarily broken if there is a plan to get them fixed. Also include DVD players within computers if they are used to watch films on.
…... (enter 99 if Don't know, enter 0 if none, if 0 to G1 and 0 to G3, skip G4)

G4.1 How long do <twin1 name> and <twin2 name> watch TV or DVDs during the following times of a typical weekday (Monday to Friday)? Only include TV viewing **in the home**. Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes. Note that scores of <twin1 name> are automatically copied to <twin2 name>. If parent indicates a difference between twins, score can be adjusted for <twin2 name>. Always score <twin1 name> first and then <twin2 name>. For G4.1 – G4.6, read out each of the times (e.g. morning (6am to 12 noon)) in turn and wait for the participant's response before reading out the next time.

Morning (6am to 12 noon) ……. hours ……. minutes per day
Afternoon (12am to 6pm) …….. hours ……. minutes per day
Evening (6pm to midnight) ……. hours ……. minutes per day

If different arrangement for twins, enter answers for <twin1 name> above and for <twin2 name> below:

Morning (6am to 12 noon) ……. hours ……. minutes per day
Afternoon (12am to 6pm) …….. hours ……. minutes per day
Evening (6pm to midnight) ……. hours ……. minutes per day

G4.2 How long do <twin1 name> and <twin2 name> watch TV or DVDs during the following times of a typical weekend day? Only include TV viewing **in the home**.
Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes. Note that scores of <twin1 name> are automatically copied to <twin2 name>. If parent indicates a difference between twins, score can be adjusted for <twin2 name>. Always score <twin1 name> first and then <twin2 name>.

Morning (6am to 12 noon) ……. hours ……. minutes per day
Afternoon (12am to 6pm) …….. hours ……. minutes per day
Evening (6pm to midnight) ……. hours ……. minutes per day

If different arrangement for twins, enter answers for <twin1 name> above and for <twin2 name> below:

Morning (6am to 12 noon) ……. hours ……. minutes per day
Afternoon (12am to 6pm) …….. hours ……. minutes per day
Evening (6pm to midnight) ……. hours ……. minutes per day

G4.3 How long do you watch TV or DVDs during the following times of a typical weekday (Monday to Friday)? Only include TV viewing **in the home**. Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes.

Morning (6am to 12 noon) ……. hours ……. minutes per day
Afternoon (12am to 6pm) …….. hours ……. minutes per day
Evening (6pm to midnight) ……. hours ……. minutes per day

G4.4 How long do you watch TV or DVDs during the following times of a typical weekend day? Only include TV viewing **in the home**. Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes.

Morning (6am to 12 noon) ……. hours ……. minutes per day
Afternoon (12am to 6pm) …….. hours ……. minutes per day
Evening (6pm to midnight) ……. hours ……. minutes per day

G4.5 How long does your <husband/wife/partner> watch TV or DVDs during the following times of a typical weekday (Monday to Friday)? Only include TV viewing **in the home**. Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes.

Morning (6am to 12 noon) ……. hours ……. minutes per day
Afternoon (12am to 6pm) …….. hours ……. minutes per day
Evening (6pm to midnight) ……. hours ……. minutes per day

G4.6 How long does your <husband/wife/partner> watch TV or DVDs during the following times of a typical weekend day? Only include TV viewing **in the home**. Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes.

Morning (6am to 12 noon) ……. hours ……. minutes per day
Afternoon (12am to 6pm) …….. hours ……. minutes per day
Evening (6pm to midnight) ……. hours ……. minutes per day

G5. Do <twin1 name> and <twin2 name> share a bedroom?

Yes ☐ No ☐

G6. Do <twin1 name> and <twin2 name> have a working TV in their bedroom? Include TV's if it is a shared bedroom and the TV belongs to another child.

Yes ☐ No ☐

If different arrangement for twins: <twin2 name>: Yes ☐ No ☐

G7. How many working computers or laptops do you have in your home? Include computers or laptops that are temporarily broken if there is a plan to get them fixed.
…….. (enter 0 if none) *If 0, skip G8*

G8. Do <twin1 name> and <twin2 name> have a computer or laptop in their bedroom? Include computers if it is a shared bedroom and the computer belongs to another child.

Yes ☐ No ☐

If different arrangement for twins: <twin2 name>: Yes ☐ No ☐

G9. How many working games consoles, such as Play Station, Nintendo DS, Wii do you have in your home? Include game consoles that are temporarily broken if there is a plan to get them fixed.

…….. (enter 0 if none) *If 0, skip G10, if 0 to G1, G7, and G9, skip G11-G13*

G10. Do <twin1 name> and <twin2 name> have a games console in their bedroom? Include games consoles if it is a shared bedroom and the computer belongs to another child.

Yes ☐ No ☐

If different arrangement for twins: <twin2 name>: Yes ☐ No ☐

G11. Do you have any rules around TV watching or computer use?

Yes ☐ No ☐

If yes, please could you describe these rules?

G12. Do you ever reward good behaviour with extra TV or computer time?

Yes ☐ No ☐

If different arrangement for twins: <twin2 name>: Yes ☐ No ☐

G13. Do you ever reduce TV or computer time if <twin1 name> or <twin2 name> is naughty?

Yes ☐ No ☐

If different arrangement for twins: <twin2 name>: Yes ☐ No ☐

G14. Do <twin1 name> and <twin2 name> ever eat while watching TV?

Yes ☐ No ☐ *If No skip G15-G18*

If different arrangement for twins: <twin2 name>: Yes ☐ No ☐

G15. How many days per week do <twin1 name> and <twin2 name> eat breakfast while watching TV?
Note that for G15-G18 the scores of <twin1 name> are automatically copied to <twin2 name>. If parent indicates a difference between twins, score can be adjusted for <twin2 name>. Always score <twin1 name> first and then <twin2 name>.

0 1 2 3 4 5 6 7

If different arrangement for twins: <twin2 name>: 0 1 2 3 4 5 6 7

G16. How many days per week do <twin1 name> and <twin2 name> eat a midday meal while watching TV?
0 1 2 3 4 5 6 7

If different arrangement for twins: <twin2 name>: 0 1 2 3 4 5 6 7

G17. How many days per week do <twin1 name> and <twin2 name> eat an evening meal while watching TV?
0 1 2 3 4 5 6 7

If different arrangement for twins: <twin2 name>: 0 1 2 3 4 5 6 7

G18. How many days per week do <twin1 name> and <twin2 name> eat snacks while watching TV?
0 1 2 3 4 5 6 7

If different arrangement for twins: <twin2 name>: 0 1 2 3 4 5 6 7

The next section is about your twin's sleep.

G19. When do <twin1 name> and <twin2 name> usually go to bed in the evening?
Write hour : minutes e.g. 6:15pm or 18:15pm.
Note that for G19-G21 the scores of Mia are automatically copied to Lee. If parent indicates a difference between twins, score can be adjusted for Lee. Always score Mia first and then Lee.
<twin1 name>: …….. : ……..
<twin2 name>: …….. : ……..

G20. How long does it take to put <twin1 name> and <twin2 name> to sleep in the evening? By this we mean how long it takes for the twins to fall asleep once they are in bed and ready to sleep.
Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes.
<twin1 name>: …….. hours …….. minutes
<twin2 name>: …….. hours …….. minutes

G21. When do <twin1 name> and <twin2 name> usually wake up in the morning?
Write hour : minutes using the 24 hour clock e.g. 6:15am should be 6:15.
<twin1 name>: …….. : ……..
<twin2 name>: …….. : ……..

G22. How long does <twin1 name> usually sleep during the daytime? Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes.

…….. hours …….. minutes per day

G23. How long does <twin2 name> usually sleep during the daytime? Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour, put 1 hour and 0 minutes.

…….. hours …….. minutes per day

G24. Does <twin1 name> usually wake up at night?

Yes ☐ No ☐

G25. Does <twin2 name> usually wake up at night?

Yes ☐ No ☐

If no for G24 and G25 skip to G28.and G29.

If yes for G24:

G26.1 How many nights in a normal week does <twin1 name> wake up?
0 1 2 3 4 5 6 7

G26.2 On the nights when <twin1 name> wakes up how many times does this happen?
……..

G26.3 How long per wake-up time does <twin1 name> stay awake at night?
Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour put 1 hour and 0 minutes.
…….. hours ……..minutes

If yes for G25:

G27.1 How many nights in a normal week does <twin2 name> wake up?
0 1 2 3 4 5 6 7

G27.2 On the nights when <twin2 name> wakes up how many times does this happen?
……..

G27.3 How long per wake-up time does <twin2 name> stay awake at night?
Write hours and minutes. If less than one hour e.g. 15 minutes put 0 hours and 15 minutes. If 1 hour put 1 hour and 0 minutes.
…….. hours ……..minutes

G28. Do you consider <twin1 name>'s sleep as a problem? The response options are 1 not at all, 2 a small problem, or 3 a serious problem.

Not at all ☐ A small problem ☐ or A serious problem ☐

G29. Do you consider <twin2 name>'s sleep as a problem? Again, the response options are 1 not at all, 2 a small problem, or 3 a serious problem (read this sentence aloud again if necessary).

Not at all ☐ A small problem ☐ or A serious problem ☐

Sections H - N: FOOD AVAILABLILTY

The next section is about food and drink that is currently in your home. For the food and drink that we ask about, please include all items that are in your home even if your twins do not eat or drink them themselves. If you are unsure of any of the answers, please have a look to see what is in your home.

Fruit

H.1.1. Do you have any **fresh fruit** in your home now?

Yes ☐ No ☐

H.1.2. If yes, what types of **fresh fruit** do you have in your home now?
This is an open question. As the participant lists the fresh fruit they have, tick the matching options in the table or add any other fresh fruit to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered fresh fruit in your fridge, in a fruit bowl and in your cupboards?

Fresh fruit

List of standard fruits to choose from (see below) as well as a free-entry box for less common items.

	Yes/No
Apples	
Bananas	
Cherries	
Grapefruit	
Grapes	
Kiwi	
Mangoes	
Melon	
Nectarines	
Oranges	
Peaches	
Pears	
Pineapple	
Plums	
Strawberries	

Other fresh fruit	Number of other items

H.2.1. Do you have any **tinned or jarred fruit** in your home now?

Yes ☐ No ☐

H.2.2. If yes, what types of **tinned or jarred fruit** do you have in your home now?
This is an open question. As the participant lists the tinned or jarred fruit they have, tick the matching options in the table or add any other tinned or jarred fruit to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered tinned or jarred fruit in your fridge and in your cupboards?

Tins / jars of fruit

List of standard fruits to choose from as well as a free-entry box for less common items.

	Yes/No
Cherries	
Fruit salad/cocktail	
Grapefruit	
Mandarin orange	
Peaches	
Pears	
Pineapple	
Plums	
Raspberries	
Strawberries	
Other	

Other tinned fruit	Number of other items

H.3.1. Do you have any **dried fruit**, such as raisins, dried apricots, or dates in your home now?

Yes ☐ No ☐

H.3.2. If yes, what types of **dried fruit** do you have in your home now?
This is an open question. As the participant lists the dried fruit they have, tick the matching options in the table or add any other dried fruit to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered dried fruit in a fruit bowl and in your cupboards?

Dried fruit

List of standard fruits to choose from as well as a free-entry box for less common items.

	Yes/No
Apples	
Apricots	
Banana chips	
Currants	
Dates	
Dried mixed fruit	
Prunes	
Raisins	
Sultanas	

Other dried fruit	Number of other items

H.4.1. Do you have any **frozen fruit** in your home now?

Yes ☐ No ☐

H.4.2. If yes, what types of **frozen fruit** do you have in your home now? This is an open question. As the participant lists the frozen fruit they have, tick the matching options in the table or add any other frozen fruit to the free entry box which says other.

Frozen fruit

List of standard fruits to choose from as well as a free-entry box for less common items.

	Yes/No
Mixed berries	
Raspberries	
Strawberries	

Other frozen fruit	Number of other items

H.5.1. Would you say that the amount of **fruit** you currently have in your home is more than usual, less than usual, or about the same?

Less than usual ☐ The same ☐ More than usual ☐

H.5.2. Without opening any fridge or cupboard doors, is there **any kind of fruit** in your home now; displayed out in the open? A possible response may be that some fruit is behind a door, but it is a glass door and the fruit can be seen. If so, report YES. Another response could be that some fresh fruit is out, but that it is stored very high and can only be viewed with a stool. Is so, report NO.

Yes ☐ No ☐

H.5.3. Would it be possible for <twin1 name> and <twin2 name> to get any **fruit** by themselves, without your help? By this, we mean whether it would be physically possible for the twins to get any fruit by themselves.

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

H.5.4 Are <twin1 name> and <twin2 name> allowed to get any **fruit** by themselves, without your help? By this, we mean whether the twins are allowed to physically get any fruit by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get fruit by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

H.5.5 Do <twin1 name> and <twin2 name> ever get any fruit by themselves, without your help? By this, we mean whether the twins physically get any fruit by themselves (even if they always ask the parent first). If the participant says 'no, they always come and ask first,' check whether or not the twins then go and physically get fruit by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

<twin1 name>: Yes ☐ No ☐

<twin2 name>: Yes ☐ No ☐

H.6. On average, in the last month how often have <twin1 name> and <twin2 name> eaten fruit?
This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐

<u>**Vegetables**</u>

K.1.1. Do you have any **fresh vegetables** in your home now? This includes salad items such as lettuce, cucumber, and tomato.

Yes ☐ No ☐

K.1.2. If yes, what types of **fresh vegetables** do you have in your home now?
This is an open question. As the participant lists the fresh vegetables they have, tick the matching options in the table or add any other fresh vegetables to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered fresh vegetables in your fridge and in your cupboards?

Fresh vegetables

List of standard vegetables to choose from as well as a free-entry box for less common items.

	Yes/No
Broccoli	
Brussel sprouts	
Cabbage	
Carrots	
Cauliflower	

Celery	
Corn on the cob	
Cucumber	
Lettuce	
Mushrooms	
Onions	
Peppers	
Runner beans/green beans	
Swede	
Tomatoes	

Other fresh vegetables	Number of other items

K.2.1. Do you have any **tinned or jarred vegetables** in your home now?

Yes ☐ No ☐

K.2.2. If yes, what types of **tinned or jarred vegetables** do you have in your home now?
This is an open question. As the participant lists the tinned or jarred vegetables they have, tick the matching options in the table or add any other tinned or jarred vegetables to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered tinned or jarred vegetables in your fridge and in your cupboards?

Tins of vegetables

List of standard vegetables to choose from as well as a free-entry box for less common items.

	Yes/No
Baked beans	
Bamboo shoots	
Beetroot	
Broad beans	
Carrots	
Mixed vegetables	
Mushrooms	
Peas	
Pease pudding	
Pickled onion	
Pickled gherkins	
Runner beans/green beans	
Sweetcorn	
Tomatoes	

Other tinned vegetables	Number of other items

K.3.1. Do you have any **frozen vegetables** in your home now?

Yes ☐ No ☐

K.3.2. If yes, what types of **frozen vegetables** do you have in your home now?
This is an open question. As the participant lists the frozen vegetables they have, tick the matching options in the table or add any other frozen vegetables to the free entry box which says other.

Frozen vegetables

List of standard vegetables to choose from as well as a free-entry box for less common items.

	Yes/No
Broad beans	
Brussel sprouts	
Cabbage	
Cauliflower	
Mange tout	
Mixed vegetables	
Peas	
Peppers	
Runner beans/green beans	
Spinach	
Sweet corn	

Other frozen vegetables	Number of other items

K.4.1. Would you say that the amount of **vegetables** you currently have in your home is more than usual, less than usual, or about the same?

Less than usual ☐ The same ☐ More than usual ☐

K.4.2. Do you have any ready to eat **fresh vegetables** on a shelf in the fridge or on the kitchen counter now? These include baby carrots, cherry tomatoes, or vegetables that you have sliced to make them ready to eat.

Yes ☐ No ☐

K.4.3. Would it be possible for <twin1 name> and <twin2 name> to get any **vegetables** by themselves without your help? By this, we mean whether it would be physically possible for the twins to get any vegetables by themselves.

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

K.4.4. Are <twin1 name> and <twin2 name> allowed to get any **vegetables** by themselves, without your help? By this, we mean whether the twins are allowed to physically get any vegetables by themselves (even if they always have to ask the parent first). If the participant says ‘no, they always have to come and ask first,’ check whether or not the twins then go and physically get vegetables by themselves e.g. say ‘so once they’ve asked, do you go and get it for them or do they get it by themselves?’

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

K.4.5. Do <twin1 name> and <twin2 name> ever get any **vegetables** by themselves, without your help? By this, we mean whether the twins physically get any vegetables by themselves (even if they always ask the parent first). If the participant says ‘no, they always come and ask first,’ check whether or not the twins then go and physically get vegetables by themselves e.g. say ‘so once they’ve asked, do you go and get it for them or do they get it by themselves?’

<twin1 name>: Yes ☐ No ☐

<twin2 name>: Yes ☐ No ☐

K.5. On average, in the last month how often have <twin1 name> and <twin2 name> eaten vegetables?

This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say ‘everyday’, prompt for a fuller response e.g. ‘so is that once a day, 2-3 times a day or 4 or more times a day?’

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐

Savoury snacks

L.1.1. Do you have any **savoury snacks** for example peanuts, crisps, tortillas and cheesy biscuits in your home now? Do not include seeds or cheese.

Yes ☐ No ☐

L.1.2. If yes, what types of **savoury snacks** do you have in your home now?
This is an open question. As the participant lists the savoury snacks they have, tick the matching options in the table or add any other savoury snacks to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered savoury snacks in your fridge and in your cupboards?

Savoury snacks

List of standard Savoury snacks to choose from as well as a free-entry box for less common items.

	Yes/No
Breadsticks	
Cheese biscuits	
Cheese straws	
Crisps	
Peanuts	
Pork scratchings	
Tortilla chips	

Other savoury snacks	Number of other items

L.1.3. Would you say that the amount of **savoury snacks** you currently have in your home is more than usual, less than usual, or about the same?

Less than usual ☐ The same ☐ More than usual ☐

L.2.1. Without opening any fridge or cupboard doors, are there any kind of **savoury snacks** in your home now; displayed out in the open? A possible response may be that some savoury snacks are behind a door, but it is a glass door and the snacks can be seen. If so, report YES. Another response could be that some savoury snacks are out, but that they are stored very high and can only be viewed with a stool. Is so, report NO.

Yes ☐ No ☐

L.2.2. Would it be possible for <twin1 name> and <twin2 name> to get any **savoury snacks** by themselves, without your help? By this, we mean whether it would be physically possible for the twins to get any savoury snacks by themselves.

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

L.2.3. Are <twin1 name> and <twin2 name> allowed to get any **savoury snacks** by themselves, without your help? By this, we mean whether the twins are allowed to physically get any savoury snacks by themselves (even if they always have to ask the parent first). If the participant says ‘no, they always have to come and ask first,’ check whether or not the twins then go and physically get savoury snacks by themselves e.g.

say ‘so once they’ve asked, do you go and get it for them or do they get it by themselves?’

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

L.2.4. Do <twin1 name> and <twin2 name> ever get any **savoury snacks** by themselves, without your help? By this, we mean whether the twins physically get any savoury snacks by themselves (even if they always ask the parent first). If the participant says ‘no, they always come and ask first,’ check whether or not the twins then go and physically get savoury snacks by themselves e.g. say ‘so once they’ve asked, do you go and get it for them or do they get it by themselves?’

<twin1 name>: Yes ☐ No ☐

<twin2 name>: Yes ☐ No ☐

L.2.5. On average, in the last month how often have <twin1 name> and <twin2 name> eaten savoury snacks? This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say ‘everyday’, prompt for a fuller response e.g. ‘so is that once a day, 2-3 times a day or 4 or more times a day?’

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐

Sweet snacks

M.3.1. Do you have any **sweet snacks** for example cakes, biscuits or ice-cream in your home now?

Yes ☐ No ☐

M.3.2. If yes, what types of **sweet snacks** do you have in your home now? Do not include sweets or chocolate.

This is an open question. As the participant lists the sweet snacks they have, tick the matching options in the table or add any other sweet snacks to the free entry box which says other.

When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered sweet snacks in your fridge and in your cupboards?

Sweet snacks
List of standard sweet snacks to choose from as well as a free-entry box for less common items.

	Yes/No
Biscuits	
Buns	
Cakes	
Ice-cream	
Ice-lollies	
Pastries	

Other sweet snacks	Number of other items

M.3.3. Would you say that the amount of **sweet snacks** you currently have in your home is more than usual, less than usual, or about the same?

Less than usual ☐ The same ☐ More than usual ☐

M.4.1. Without opening any fridge or cupboard doors, are there any kind of **sweet snacks** in your home now displayed out in the open? A possible response may be that some sweet snacks are behind a door, but it is a glass door and the snacks can be seen. If so, report YES. Another response could be that some sweet snacks are out, but that they are stored very high and can only be viewed with a stool. Is so, report NO.

Yes ☐ No ☐

M.4.2. Would it be possible for <twin1 name> and <twin2 name> to get any **sweet snacks** by themselves, without your help? By this, we mean whether it would be physically possible for the twins to get any sweet snacks by themselves.

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

M.4.3. Are <twin1 name> and <twin2 name> allowed to get any **sweet snacks** by themselves, without your help? By this, we mean whether the twins are allowed to physically get any sweet snacks by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get sweet snacks by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

M.4.4. Do <twin1 name> and <twin2 name> ever get any **sweet snacks** by themselves, without your help? By this, we mean whether the twins physically get any sweet snacks by themselves (even if they always ask the parent first). If the participant says 'no, they always come and ask first,' check whether or not the twins then go and physically get sweet snacks by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

<twin1 name>: Yes ☐ No ☐

<twin2 name>: Yes ☐ No ☐

M.4.5. On average, in the last month how often have <twin1 name> and <twin2 name> eaten sweet snacks?' This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐

Confectionery

N.1.1. Do you have any **confectionery** in your home now? This includes sweets and chocolate.

Yes ☐ No ☐

N.1.2. If yes, what types of **confectionery** do you have in your home now?
This is an open question. As the participant lists the confectionery they have, tick the matching options in the table or add any other confectionery to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered confectionery in your fridge, in a bowl and in your cupboards?

Confectionery

List of standard confectionery to choose from as well as a free-entry box for less common items.

	Yes/No
Chocolate	
Sweets	

Other confectionery	Number of other items

N.1.3. Would you say that the amount of **confectionery** you currently have in your home is more than usual, less than usual, or about the same?

Less than usual ☐ The same ☐ More than usual ☐

N.2.1. Without opening any fridge or cupboard doors, is there any kind of **confectionery** in your home now displayed out in the open? A possible response may be that some confectionery is behind a door, but it is a glass door and the confectionery can be seen. If so, report YES. Another response could be that some confectionery is out, but that it is stored very high and can only be viewed with a stool. Is so, report NO.

Yes ☐ No ☐

N.2.2. Would it be possible for <twin1 name> and <twin2 name> to get any **confectionery** by themselves, without your help? By this, we mean whether it would be physically possible for the twins to get any confectionery by themselves.

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

N.2.3. Are <twin1 name> and <twin2 name> allowed to get any **confectionery** by themselves, without your help? By this, we mean whether the twins are allowed to physically get any confectionery by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get confectionery by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

N.2.4. Do <twin1 name> and <twin2 name> ever get any **confectionery** by themselves, without your help? By this, we mean whether the twins physically get any confectionery by themselves (even if they always ask the parent first). If the participant says 'no, they always come and ask first,' check whether or not the twins then go and physically get confectionery by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

<twin1 name>: Yes ☐ No ☐

<twin2 name>: Yes ☐ No ☐

N.2.5. On average, in the last month how often have <twin1 name> and <twin2 name> eaten confectionery? This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

Never or less than	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day

	once a month							
<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐

Section O – FAST FOOD

O.1.1. On average, in the last month how often have <twin1 name> and <twin2 name> eaten fast food from places such as McDonald's, KFC, Burger King, and Subway…? This includes both eating in and taking food away from fast food places. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐

O.1.2. On average, in the last month how often have <twin1 name> and <twin2 name> eaten other convenience foods for their main meal? This includes food that requires no preparation such as ready-made pizza, microwaveable meals, and takeaway food such as fish and chips, Chinese, and Indian… This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐

Section P - DRINKS

P.1.1. Do you have any *non-alcoholic* **drinks** other than water in your home now?

If no to P1.1, skip P1.2. and P1.4. – P2.1. (but do ask P1.3. and P2.2.)

Yes ☐ No ☐

P.1.2. If yes, what types of non-alcoholic drinks do you have in your home now? This is an open question. As the participant lists the drinks they have, allocate each drink listed to one of the types in the table and add the number of bottles or cartons. May need to prompt to determine whether each drink is sugar sweetened or not. When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered non-alcoholic drinks in your fridge and in your cupboards? Also need to prompt to make sure the participant has covered all non-alcoholic drink types e.g. if they don't mention milk say 'do you have any milk in your home now?'

<table>
<tr><td></td><td colspan="3">Sugar sweetened:
(Yes/No)</td><td colspan="3">No added sugar/diet:
(Yes/No)</td></tr>
<tr><td>Fruit juice e.g. orange, apple</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td>Squash/cordial e.g. Robinson's blackcurrant cordial</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td>Fizzy pop e.g. coke, lemonade</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td>Ready made fruit flavoured drinks e.g. Ribena, Oasis</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td>Smoothies</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td></td><td colspan="2">Skimmed:
(yes/no)</td><td colspan="2">Semi-skimmed:
(yes/no)</td><td colspan="2">Full-fat:
(yes/no)</td></tr>
<tr><td>Milk</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

P.1.3. Would you say that the amount of non-alcoholic **drinks** you currently have in your home is more than usual, less than usual, or about the same?

Less than usual ☐ The same ☐ More than usual ☐

P.1.4. Without opening any fridge or cupboard doors, are there any non-alcoholic drinks in your home now; displayed out in the open? A possible response may be that some drinks are behind a door, but it is a glass door and the drinks can be seen. If so, report YES. Another response could be that some drinks are out, but that they are stored very high and can only be viewed with a stool. Is so, report NO.

Yes ☐ No ☐

P.1.5. If yes, what types of non-alcoholic drinks are displayed out in the open?
This is an open question. As the participant lists the drinks they have, tick the matching drink type in the table. May need to prompt the participant to determine whether each drink is sugar sweetened or not. For example, if the participant just says 'coke' interviewer says 'is that diet coke?' If the participant just says 'orange juice' interviewer says 'is that with added sugar?' etc.

	Sugar sweetened: (yes/no)		No added sugar/diet: (yes/no)
Fruit juice e.g. orange, apple			
Squash/cordial e.g. Robinson's blackcurrant cordial			
Fizzy pop e.g. coke, lemonade			
Ready made fruit flavoured drinks e.g. Ribena, Oasis			
Smoothies			
	Skimmed: (yes/no)	Semi-skimmed: (yes/no)	Full-fat: (yes/no)
Milk			

P.1.6. Would it be possible for <twin1 name> and <twin2 name> to get any non-alcoholic drinks by themselves, without your help? By this, we mean whether it would be physically possible for the twins to get any non-alcoholic drinks by themselves.

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

P.1.7. If yes, what types of non-alcoholic drinks would be possible for <twin1 name> and <twin2 name> to get by themselves, without your help?
This is an open question. As the participant lists the drinks they have, tick the matching drink type in the table. May need to prompt the participant to determine whether each drink is sugar sweetened or not).

	Sugar sweetened: (yes/no)	No added sugar/diet: (yes/no)
Fruit juice e.g. orange, apple		
Squash/cordial e.g. Robinson's blackcurrant cordial		
Fizzy pop e.g. coke, lemonade		
Ready made fruit flavoured drinks e.g. Ribena, Oasis		
Smoothies		

	Skimmed: (yes/no)	Semi-skimmed: (yes/no)	Full-fat: (yes/no)
Milk			

P.1.8. Are <twin1 name> and <twin2 name> allowed to get any non-alcoholic drinks by themselves, without your help? By this, we mean whether the twins are allowed to physically get any non-alcoholic drinks by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get non-alcoholic drinks by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

Yes ☐ No ☐

If different for twins: <twin2 name>: Yes ☐ No ☐

P.1.9. If yes, what types of non-alcoholic drinks are <twin1 name> and <twin2 name> allowed to get by themselves, without your help?

This is an open question. As the participant lists the drinks they have, tick the matching drink type in the table. May need to prompt the participant to determine whether each drink is sugar sweetened or not.

	Sugar sweetened: (yes/no)	No added sugar/diet: (yes/no)
Fruit juice e.g. orange, apple		
Squash/cordial e.g. Robinson's blackcurrant cordial		
Fizzy pop e.g. coke, lemonade		
Ready made fruit flavoured drinks e.g. Ribena, Oasis		
Smoothies		

	Skimmed: (yes/no)	Semi-skimmed: (yes/no)	Full-fat: (yes/no)
Milk			

P.2.0. Do <twin1 name> and <twin2 name> ever get any non-alcoholic drinks by themselves, without your help? By this, we mean whether the twins physically get any non-alcoholic drinks by themselves (even if they always ask the parent first). If the participant says 'no, they always come and ask first,' check whether or not the twins then go and physically get non-alcoholic drinks by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

<twin1 name>: Yes ☐ No ☐

<twin2 name>: Yes ☐ No ☐

P.2.1. If yes, what types of non-alcoholic drinks do <twin1 name> and <twin2 name> get by themselves, without your help?
This is an open question. As the participant lists the drinks they have, tick the matching drink type in the table. May need to prompt the participant to determine whether each drink is sugar sweetened or not.

<table>
<tr><td></td><td colspan="2">Sugar sweetened: (yes/no)</td><td colspan="2">No added sugar/diet: (yes/no)</td></tr>
<tr><td>Fruit juice e.g. orange, apple</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Squash/cordial e.g. Robinson's blackcurrant cordial</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Fizzy pop e.g. coke, lemonade</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Ready made fruit flavoured drinks e.g. Ribena, Oasis</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Smoothies</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td>Skimmed: (yes/no)</td><td colspan="2">Semi-skimmed: (yes/no)</td><td>Full-fat: (yes/no)</td></tr>
<tr><td>Milk</td><td></td><td colspan="2"></td><td></td></tr>
</table>

P.2.2. On average, in the last month how often have <twin1 name> and <twin2 name> drunk… Read each drink type in turn and wait for the participant's response before moving onto the next drink type. Fpr sugar-sweetened and sugar-free drinks, use a relevant example from the responses given e.g. 'sugar-sweetened drinks such as coke.' Ask for all drinks whether they are in the home or not. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', the interviewer should prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

	Once	Once

		Never or less than once a month	1-3 times a month	a week	2-4 times a week	5-6 times a week	a day	2-3 times a day	4 or more times a day
Sugar-sweetened drinks	<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
	<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐
Sugar-free drinks	<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
	<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐
Fruit juice	<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
	<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐
Milk	<twin1 name>	☐	☐	☐	☐	☐	☐	☐	☐
	<twin2 name>	☐	☐	☐	☐	☐	☐	☐	☐

Section Q - MEALTIMES

Note that for Q1.1 – Q5 the scores of <twin1 name> are automatically copied to <twin2 name>. If parent indicates a difference between twins, score can be adjusted for <twin2 name>. Always score <twin1 name> first and then <twin2 name>.

Q1.1. How many days a week do <twin1 name> and <twin2 name> eat **breakfast** at home? Weekly estimates include week days and weekend days. Breakfasts that are prepared at home, but not eaten at home do not count.

0 1 2 3 4 5 6 7 (days a week) *(If 7 skip M1.2)*
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q1.2. How many days a week do <twin1 name> and <twin2 name> eat **breakfast** elsewhere for example at nursery or preschool? This includes food prepared at home, foods purchased on the way to nursery or preschool and food prepared by the nursery or preschool – provided they are eaten outside the home.

0 1 2 3 4 5 6 7 (days a week)
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q1.3. How many days a week do your family sit at a table to eat **breakfast** together? This includes occasions when it is just <twin1 name> or <twin2 name> and yourself. A possible response might be that they sit down as a family to eat breakfast, but not at a dining table. This is not included.
0 1 2 3 4 5 6 7 (days a week)

If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q2.1. How many days a week do <twin1 name> and <twin2 name> eat a **midday meal** at home? Midday meals that are prepared at home, but not eaten at home do not count.
0 1 2 3 4 5 6 7 (days a week) *(If 7 skip M2.2)*
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q2.2. How many days a week do <twin1 name> and <twin2 name> eat a **midday meal** elsewhere for example at nursery or preschool? This includes food prepared at home, foods purchased on the way to nursery or preschool and food prepared by the nursery or preschool – provided they are eaten outside the home.
0 1 2 3 4 5 6 7 (days a week)
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q2.3. How many days a week do your family sit at a table to eat a **midday meal** together? This includes occasions when it is just <twin1 name> or <twin2 name> and yourself. A possible response might be that they sit down as a family to eat a midday meal, but not at a dining table. This is not included.

0 1 2 3 4 5 6 7 (days a week)
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q3.1. How many days a week do <twin1 name> and <twin2 name> eat an **evening meal** at home? Evening meals that are prepared at home, but not eaten at home do not count.
0 1 2 3 4 5 6 7 (days a week) *(If 7 skip M3.2)*
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q3.2. How many days a week do <twin1 name> and <twin2 name> eat an **evening meal** elsewhere for example at nursery or preschool? This includes food prepared at home, foods purchased on the way to nursery or preschool and food prepared by the nursery or preschool – provided they are eaten outside the home.
0 1 2 3 4 5 6 7 (days a week)
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q3.3. How many days a week do your family sit at a table to eat an **evening meal** together? This includes occasions when it is just <twin1 name> or <twin2 name> and yourself. A possible response might be that they sit down as a family to eat an evening meal, but not at a dining table. This is not included.

0 1 2 3 4 5 6 7 (days a week)
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q4.1. How many days a week do <twin1 name> and <twin2 name> eat **snacks** at home? Snacks that are prepared at home, but not eaten at home do not count.
0 1 2 3 4 5 6 7 (days a week) *(If 7 skip M4.2)*
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q4.2. How many days a week do <twin1 name> and <twin2 name> eat **snacks** elsewhere for example at nursery or preschool? This includes snacks prepared at home, snacks purchased on the way to nursery or preschool and snacks prepared by the nursery or preschool – provided they are eaten outside the home.
0 1 2 3 4 5 6 7 (days a week)
If different for twins: <twin2 name>: 0 1 2 3 4 5 6 7

Q5. Where are most meals eaten in your home? This is an open question. Write down the response in the space below. A possible response might be that it is varied, or dependent on the meal. Ask participants to think about meals not eaten at home, and meals eaten during the weekend so that they can best estimate which place food is most commonly eaten.

……………………………………………………………………………………………

Section R – FOOD SHOPPING

R1.1. How often do you shop for food? This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information the interviewer should prompt for a fuller response. For example, if the participant says 'monthly big trip', the interviewer should say 'so is that with few small trips or no small trips?'

☐ Monthly, big trip, no small trips

☐ Monthly, big trip, few small trips

☐ Every other week, big trip, no small trips

☐ Every other week, big trip, few small trips

☐ Weekly, big trip, no small trips

☐ Weekly, big trip, few small trips

☐ As and when, no big trip, all small trips as needed

R1.2. How often do <twin1 name> and <twin2 name> help you shop for food? For example, you may get them to pick their own foods, or give them their own shopping list. Please choose a score from 1 to 5: 1 means never, 2 means rarely, 3 means some of the time, 4 means most of the time, 5 means all of the time? Participants may respond before you get a chance to read them the options. Let them finish and then say, 'ok, can you tell me whether this happens 1 never, 2 rarely…etc.'

1 2 3 4 5 (5=all of the time)
If different arrangement for twins: <twin2 name>: 1 2 3 4 5

R1.3. How many days has it been since you last shopped for food?
…… days

R1.4. Was the last shop small or big?

Small ☐ Big ☐

Section S – ADDITIONAL GENERAL INFORMATION QUESTIONS

Finally, the last few questions are about your twin's growth.

Height and Weight

S1. Do you have any height or weight measurements for <twin1 name> or <twin2 name> that you have taken since …? These are the most recent measurements we have.

Yes ☐ No ☐

S4. Would now be a convenient time to take the twins' height and weight measurements?

If yes, Using the height chart and scales we have sent, please can you take today's heights and weights for each of the twins and then read them out to me? Please remember to measure and weigh the twins in indoor clothes without shoes.

Once the twins have been measured and weighed add the measurements to the table at the bottom of the page.

If no, Would you be able to take these measurements tomorrow?

If yes, Please use the height chart and scales we have sent to take the twins heights and weights. Remember to measure and weigh the twins in indoor clothes without shoes. Once you have taken these measurements, please send them to us by email, give them over the telephone, or add them on the Gemini website.

How would you like to give these measurements?

If email, please email to Gemini@public-health.ucl.ac.uk
(make sure participant includes their Gemini ID number and the date the measurements were taken).

If telephone, please call 020 7679 1723.

If Gemini website, please go to www.attitudestohealth.co.uk/gemini and click where it says enter height/weight measurements.

If no, when would be a convenient time for you to take these measurements? Repeat the text beneath tomorrow's measurements, making sure you record how participants will give the measurements and when they will give them.

(Table online is similar to the one below but includes both height and weight measurements.)

	1st born				**2nd born**			
Date measured	kgs		lbs	oz	kgs		lbs	oz
___/____/_____ DD MM YYYY	_____	or	______	______	_____	or	______	______
___/____/_____ DD MM YYYY	_____	or	______	______	_____	or	______	______
___/____/_____ DD MM YYYY	_____	or	______	______	_____	or	______	______

____/_____/______ DD MM YYYY	______	or	_______	_______	______	or	_______	_______	
____/_____/______ DD MM YYYY	______	or	_______	_______	______	or	_______	_______	
____/_____/______ DD MM YYYY	______	or	_______	_______	______	or	_______	_______	

That's the end of the interview now. Thank you very much for your time. Do you have any questions or comments?

Add any comments here.

A.4 Gemini questionnaire at age 5 (T7), items included are those on growth measurements, children's appetite and parental feeding practices

Family ID Number ☐☐☐☐☐☐☐

WELCOME TO

gemini

health and development in twins

Five Year Booklet

Your Twins

IF POSSIBLE THIS QUESTIONNAIRE IS TO BE COMPLETED BY THE PARENT WHO HAS COMPLETED PREVIOUS GEMINI QUESTIONNAIRES

Health Behaviour Research Centre
Department of Epidemiology & Public Health
UCL
1-19 Torrington Place
London, WC1E 6BT
gemini@ucl.ac.uk

YOUR TWINS' GROWTH

We would like to update the information on your twins' growth since we last contacted you.

A1. **If you have taken any measurements of your twins' heights or weights since we last contacted you please enter them below.**

If you haven't measured your twins' heights recently please use the height chart and instructions we have sent to add today's heights (no shoes).

Use the scales we sent you to add today's weights (indoor clothes, no shoes).

		Height				Weight			
Date measured		**cms**		**feet**	**inches**	**kgs**		**stones**	**lbs**
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born		or				or		
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born		or				or		
___/___/_____ DD MM YYYY	1st born	____	or	____	____	____	or	____	____
	2nd born	____	or	____	____	____	or	____	____

APPETITE

These questions are about your twins' appetites at the moment.

How would you describe your twins' eating styles on a typical day?

			Never	Rarely	Sometimes	Often	Always
C9.	**My child loves food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C10.	**My child eats more when worried**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C11.	**My child wants to eat (e.g. asks) when he/she sees certain foods**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C12.	**My child has a big appetite**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C13.	**My child finishes his/her meal quickly**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
C14.	My child is interested in food	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C15.	My child is always asking for a drink	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C16.	My child refuses new foods at first	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C17.	My child eats slowly	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C18.	My child eats less when angry	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C19.	My child enjoys tasting new foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C20.	My child wants to eat (e.g. asks) when he/she <u>smells</u> certain foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C21.	My child eats less when he/she is tired	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C22.	My child is always asking for food	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C23.	My child eats more when annoyed	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C24.	If allowed to, my child would eat too much	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
C25.	My child eats more when anxious	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C26.	My child enjoys a wide variety of foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C27.	My child leaves food on his/her plate at the end of a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C28.	My child takes more than 30 minutes to finish a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C29.	Given the choice, my child would eat most of the time	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C30.	My child looks forward to mealtimes	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C31.	My child gets full before his/her meal is finished	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C32.	My child enjoys eating	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C33.	My child eats more than usual if he/she really enjoys the taste of a food	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C34.	My child eats more when he/she is happy	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C35.	My child is difficult to please with meals	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
C36.	My child eats less when upset	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C37.	My child gets full up easily	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C38.	My child eats more when he/she has nothing else to do	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C39.	Even if my child is full up he/she finds room to eat his/her favourite food	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C40.	If given the chance, my child would drink continuously throughout the day	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C41.	My child cannot eat a meal if he/she has had a snack just before	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C42.	If given the chance, my child would always be having a drink	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C43.	My child is interested in tasting food he/she hasn't tasted before	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C44.	My child wants to eat (e.g. reaches out or asks for food) when he/she sees others eating	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C45.	My child decides that he/she doesn't like a food without even tasting it	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C46.	If given the chance my child would always have food in his/her mouth	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
C47.	My child eats more and more slowly during the course of a meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

HOW YOU FEED YOUR TWINS

The following questions are about how you feed your twins day-to-day.
If the described behaviour does not apply to you as you never do this, please tick "never".

			Never	Rarely	Sometimes	Often	Always
E1.	I allow my child to choose which foods to have for meals	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E2.	I give my child something to eat to make him/her feel better when he/she is feeling upset	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E3.	I keep track of the high fat foods that my child eats	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E4.	I ask other people not to feed my child unhealthy foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E5.	I encourage my child to eat a wide variety of foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E6.	I decide how many snacks my child should have	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E7.	I use foods that my child likes as a way to get him/her to eat "healthy" foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E8.	If my child misbehaves I withhold his/her favourite food	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E9.	I praise my child if he/she eats fruit or vegetables	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E10.	I give my child something to eat to make him/her feel better when he/she has hurt himself/herself	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E11.	I let my child decide when he/she would like to have his/her meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E12.	I encourage my child to eat fruit or vegetables	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E13.	I use puddings as a bribe to get my child to eat his/her main course	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E14.	I present fruit or vegetables in an attractive way to my child	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

			Never	Rarely	Sometimes	Often	Always
E15.	**I give my child something to eat to make him/her feel better when he/she is angry**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E16.	**I try not to eat unhealthy foods when my child is around**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E17.	**I keep track of the sugary foods that my child eats**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E18.	**I reward my child with something to eat when he/she is well-behaved**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E19.	**I let my child eat between meals whenever he/she wants**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E20.	**I give my child something to eat to make him/her feel better when he/she is worried**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E21.	**I decide what my child eats between meals**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E22.	**I avoid buying unhealthy foods and bringing them into the house**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E23.	**I keep track of the foods my child's been eating when he/she is not with me (e.g. with a childminder or family member)**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
E24.	**I praise my child if he/she eats a new food**	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

		Never	Rarely	Sometimes	Often	Always
E25. I avoid going to cafes or restaurants with my child that sell unhealthy foods	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E26. I give my child something to eat to occupy him/her if he/she is feeling bored	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E27. My child should always eat all of the food on his/her plate	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E28. I show my child how much I enjoy eating healthy foods	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E29. I have to be especially careful to make sure my child eats enough	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E30. I model healthy eating for my child by eating healthy foods myself	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E31. If I did not guide or regulate my child's eating, he/she would eat much less than he/she should	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E32. I try to eat healthy foods in front of my child, even if they are not my favourite	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E33. I insist my child eats some fruit or vegetables, even if he/she doesn't want them	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E34. I try to show enthusiasm about eating healthy foods	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E35. If my child says "I'm not hungry", I try to get him/her to eat anyway	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐

		Never	Rarely	Sometimes	Often	Always
E36. I allow my child to wander around during a meal	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E37. My child watches TV during meals	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E38. My child has a set mealtime and snack routine	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E39. I sit down with my child when he/she eats meals	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
E40. In order to get my child to behave him/herself I promise him/her something to eat	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐

		Not at all 1	2	3	4	5	6	Strictly 7
E41. I limit my child's access to sugary foods	1st born	☐	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐	☐
E42. I limit my child's access to high fat foods	1st born	☐	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐	☐
E43. I limit the portion sizes of sugary foods that I give to my child	1st born	☐	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐	☐
E44. I limit the portion sizes of high fat foods that I give to my child	1st born	☐	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐	☐

E45. If you limit your child's access to some foods, what is the most important reason?

	I do not limit access to food	For physical health	For dental health	For weight control	Other, please describe	
1st born	☐	☐	☐	☐	☐	____________
2nd born	☐	☐	☐	☐	☐	____________

A.5 Gemini questionnaire at age 12 (T9), items included below are those relevant to this thesis.

Your Attitude Towards Your Twins' Eating

The following questions are about how you interact with your twins day-to-day around meals and snacks. If the described behaviour does not apply to you as you never do this, please tick "never".

			Never	Rarely	Some times	Often	Always
F1.	I allow my child to choose which foods to have for meals	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F2.	I give my child something to eat to make him/her feel better when he/she is feeling upset	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F3.	I keep track of the high fat foods that my child eats	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F4.	I encourage my child to eat a wide variety of foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F5.	I use foods that my child likes as a way to get him/her to eat "healthy" foods	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F6.	If my child misbehaves, I withhold his/her favourite food	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F7.	I praise my child if he/she eats fruit or vegetables	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F8.	I give my child something to eat to make him/her feel better when he/she has been hurt	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F9.	I let my child decide when he/she would like to have his/her meal	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F10.	I encourage my child to eat fruit or vegetables	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐
F11.	I use puddings/desserts as a bribe to get my child to eat his/her main course	1st born	☐	☐	☐	☐	☐
		2nd born	☐	☐	☐	☐	☐

		Never	Rarely	Some times	Often	Always
F12. I present fruit or vegetables in an attractive way to my child	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F13. I give my child something to eat to make him/her feel better when he/she is feeling angry	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F14. I try not to eat unhealthy foods when my child is around	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F15. I keep track of the sugary foods that my child eats	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F16. I reward my child with something to eat when he/she is well-behaved	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F17. I let my child eat between meals whenever he/she wants	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F18. I give my child something to eat to make him/her feel better when he/she is worried	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F19. I decide what my child eats between meals as far as possible	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F20. I avoid buying unhealthy foods and bringing them into the house	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F21. I praise my child if he/she eats a new food	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F22. I avoid going to cafes or restaurants with my child that sell unhealthy foods	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F23. I give my child something to eat to occupy him/her if he/she is feeling bored	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐

		Never	Rarely	Some times	Often	Always
F24. My child should always eat all of the food on his/her plate	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F25. I have to be especially careful to make sure my child eats enough	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F26. I model healthy eating for my child by eating healthy foods myself	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F27. If I did not guide or regulate my child's eating, he/she would eat much less than he/she should	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F28. I try to eat healthy foods in front of my child, even if they are not my favourite	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F29. I insist my child eats some fruit or vegetables, even if he/she doesn't want them	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F30. I try to show enthusiasm about eating healthy foods	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F31. If my child says "I'm not hungry", I try to get him/her to eat anyway	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F32. I insist my child eats meals at the table	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F33. My child watches TV or uses a media device (e.g. tablet or phone) during meals	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F34. My child has a set mealtime	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F35. As often as I can I eat together with my child	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐
F36. In order to get my child to behave him/herself I promise him/her something to eat	1st born	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐

F37. I limit my child's access to sugary foods as far as possible	1st born	☐	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐	☐
F38. I limit my child's access to high fat foods	1st born	☐	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐	☐
F39. I limit the portion sizes of sugary foods that I give to my child as far as possible	1st born	☐	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐	☐
F40. I limit the portion sizes of high fat foods that I give to my child as far as possible	1st born	☐	☐	☐	☐	☐	☐	☐
	2nd born	☐	☐	☐	☐	☐	☐	☐

F41. If you limit your child's access to some foods, what is the most important reason?

	I do not limit access to food	For physical health	For dental health	For weight control	Other, please describe
1st born	☐	☐	☐	☐	☐ ______________
2nd born	☐	☐	☐	☐	☐ ______________

A.6 Home Environment Interview (HEI) administered when the twins were aged 12 (T10).

GEMINI - HOME ENVIRONMENT INTERVIEW

Section A - GENERAL INFORMATION QUESTIONS

Today's date: __ / __ / 2019/20 **[DateEntered]**

Family ID Number: [familyID]

A1. Please can I speak to [motherfirst]? *(try to speak to main contact but continue anyway)*

If first phone call:
Hello, this is [researcher_name] calling on behalf of the Gemini twin study. We would like to take this opportunity to personally thank you for being part of this study for the past 12 years! Your continued support and involvement has helped this study grow into the largest twin study in the world!

We recently contacted you by post to tell you about our exciting new round of data collection and in this letter we mentioned that we would be calling some families to conduct interviews over the telephone. You are being contacted as you might remember that we contacted you over the telephone 8 years ago to collect information about the home environment. The information you provided in that phone call was very important to us and we are hoping to collect this information again with you.

Would you be willing to take part in this study and answer some questions about your home? The interview should take about 30 minutes to complete is now a good time to talk?

If not convenient:

1. Arrange another time that is convenient and record this in the call attempts excel spreadsheet (S:\FPHS_BSH_Gemini\GEMINI\Data Entry\T10 Home Environment\Excel Files).
2. Log this on REDCap with corresponding Gemini Family ID.

If the participant doesn't want to do the interview, also record this in the call attempts spreadsheet. Put note not to contact again.

If yes, proceed as below.
We have the twins' names registered as [twin1_name] and [twin2_name], is that correct and what you would usually call them? Is [twin1_name] the first born twin and [twin2_name] the second born?

If yes to names and birth order: click 'NEXT' button.
If no to names/birth order: check Gemini ID and insert correct names (in the correct order):

twin 1: ……… twin 2 ……………..

I would like to ask you some questions about [twin1_name] and [twin2_name] and your home. Ideally, we need to talk to the person who is responsible for the majority of the food shopping and childcare within the home. Do you think you will be in a position to answer these questions?

If FOLLOW-UP phone call:
Hello, this is [researcher_name] calling on behalf of the Gemini twin study. Can I check that I am speaking to [motherFirst]?

We contacted you recently about taking part in a telephone interview about your home. We have on our records that you agreed to take part in our telephone interview, this should take around 30 minutes to complete.

Is now still a good time to talk?

1. If OK to talk and speaking to [motherfirst]: click 'NEXT button'
2. If OK to talk and NOT speaking to [motherfirst] fill in name below and click 'NEXT' button.

Could I take your name?

First Name ……………….. Last Name ………………...

3. If NOT OK to talk, arrange a convenient time to call back, make a note of this time and click 'BACK'.

Thank you for taking the time to talk, your responses are very valuable to us. The interview should take around forty minutes to complete. Just to give you some background, the aim of this interview is to get a picture of the environment children are growing up in. There are no right or wrong answers so please feel free to be as open and honest as you like. If there are any questions you need me to clarify, or any other information you think would be relevant then please feel free to stop me at any time. Any information obtained will be kept confidential and anonymous.

A5. Please could you confirm the twin's date of birth? [<Date of Birth>] **[twinbirth]**
If different, check Gemini ID and insert correct date of birth ____ / ____ / 2007
[amenddob]

A6. Please could you confirm your relationship with [twin1_name] and [twin2_name]?
[contactRelation]

1☐ Mother

2☐ Father

3☐ Guardian

4☐ Same sex partner

5☐ Grandparent

6☐ Nanny

7☐ Other, please specify: ………**[contactOther]**…………………………………………

A7. Please could you confirm the following home address? Read out the address below. Change the details if not correct.

Address : <House number> …<Street name>
……**[address1]**………………………
<Town>………**[address2]**……………………………………………
…………………**[address3]**……………………
Postcode : <Postcode> ………………………………

A8. Were there any changes? Yes ☐ **1** No ☐ **0 [confirmaddress]**

A5. How many adults, including yourself, currently live in your home? Only include people who are aged 18 years or older and who live in your home all of the time.

………….. Adults **[adultsinhome]**

A6. Does this include…

Your husband? Yes ☐ **1** No ☐ **0 [husbandInHome]**

Your wife? Yes ☐ **1** No ☐ **0 [wifeInHome]**

Your partner? Yes ☐ **1** No ☐ **0 [partnerInHome]**

For female participants ask: Does this include your husband? If yes, select no for wife and partner. If no, then ask 'your partner or your wife?'
For male participants ask: Does this include your wife? If yes, select no for husband and partner. If no, then ask 'your partner or your husband?'

A7. How many children, under 18 years of age, not including [twin1_name] and [twin2_name], currently live in your home? **[childreninhome]**

………….. Children

A8. Since the birth of [twin1_name] and [twin2_name], have any additional children joined the household? **[additionalchildren]**

Yes ☐ **1** No ☐ **0**

A9. Any additional comments about changes to family circumstances **[commentscircumstances]**

SECTION B - SOCIODEMOGRAPHIC INFORMATION

The next few questions are about where you live.

B1. Which of the following options best describes the type of home you live in? Read out each of the options below. **[hometype]**

1 ☐ Flat (which floor……) **[flatfloor]**

2 ☐ Semi-detached house

3 ☐ Terraced house

4 ☐ Detached house

5 ☐ Or other, please describe: …………**[hometypeother]**………………………………………

B2. Do you have stairs in your home? **[stairs]**

Yes ☐ **1** No ☐ **0**

B3. How many bedrooms does your household have, including bedsitting and spare rooms? **[bedrooms]**

1 ☐ One

2 ☐ Two

3 ☐ Three

4 ☐ Four

5 ☐ Five or more. Please provide number if more……… **[bedroomsfiveormore]**

B4. How many cars or vans are normally available for use by you or any members of your household? **[cars]**

0 ☐ None

1 ☐ One

2 ☐ Two

3 ☐ Three

4 ☐ Four

5 ☐ Five or more. Please provide number if more……… **[carsfiveormore]**

B5. Do you currently own or rent the accommodation you live in? **[householdtenure]**

1 ☐ Own without mortgage

2 ☐ Own with mortgage

3 ☐ Rent privately

4 ☐ Rent from local authority

B6. Thinking of the income of the household, which category represents the total income of your whole household before deduction from income tax, National insurance, etc. **[income]**

1 ☐ Up to £15,000 per year

2 ☐ Between £15,000 and £22,500 per year

3 ☐ Between £22,500 and £30,000 per year

4 ☐ Between £30,000 and £37,500 per year

5 ☐ Between £37,500 and £45,000 per year

6 ☐ Between £45,000 and £60,000 per year

7 ☐ Between £60,000 and £67,500 per year
8 ☐ Between £67,500 and £75,000 per year
9 ☐ Between £75,000 and £82,500 per year
10 ☐ Between £82,500 and £90,000 per year
11 ☐ Between 90,000 and 100,000
12 ◻ More than 100,000 per year

B7. Do you have any educational qualifications? (please tick all that apply or equivalents) **[qualification]**

0 ◻ No qualifications
1 ◻ CSE, GCSE or 'O' Level
2 ◻ Vocational qualification (GNVQ, BTEC)
3 ◻ 'A' or 'AS' level
4 ◻ Higher National Certificate (HNC) or Diploma (HND)
5 ◻ Undergraduate degree
6 ◻ Postgraduate qualification (Masters, PhD)
7 ◻ Other. Please specify… **[othereducation]**

B8. Do you currently have a job? **[employmentstatus]**

0 ☐ No **1** ☐ On maternity leave **2** ☐ Yes, part-time **3**☐ Yes, full-time

B9. If yes, what is your FULL job title? (please describe) **[jobtitle]** ………………………………..

B10. Do you need any special qualifications for your job? **[qualificationsrequired]**
Yes ☐ **1** No ☐ **0** Unsure ☐ **99**

If YES, please describe: ……………………………………… **[jobqualification]**

B9.1. What is your marital status? **[marital]**

0 ☐ Single
1 ☐ Married or cohabiting
2 ☐ Divorced
3 ☐ Widowed

B11. Does your partner have any educational qualifications? (please tick all that apply or equivalents) **[partnerqualification_ses]**

0 ◻ No qualifications
1 ◻ CSE, GCSE or 'O' Level
2 ◻ Vocational qualification (GNVQ, BTEC)
3 ◻ 'A' or 'AS' level
4 ◻ Higher National Certificate (HNC) or Diploma (HND)
5 ◻ Undergraduate degree
6 ◻ Postgraduate qualification (Masters, PhD)

B12. Does your partner currently have a job? **[emplotmentstatus_2]**
3 ☐ Yes, full-time
2 ☐ Yes, part-time
0 ☐ No

1 ☐ Stay at home to look after the children

If yes, what is your partners FULL job title? (please describe) **[jobtitle_2]**
....

B13. Does your partner need any special qualifications for their job? **[qualificationrequired_2]**

Yes ☐ **1** No ☐ **0** Unsure ☐ **99**

If YES, please describe: ………………………………………. **[jobqualification_2]**

Section C – PHYSICAL ACTIVITY ENVIRONMENT

The next section is about activity facilities available to you.

C1 Are there any parks or outdoor recreation areas close to your home? **[parks]**
If the participant asks what we mean by 'close' say that we mean parks or outdoor recreation areas that they believe are within a reasonable walking distance from their home or a short drive away

Yes ☐ **1** No ☐ **0** Don't know ☐ **99** *If no or don't know skip C2.*

C2 Do you use any of these with [twin1_name] and [twin2_name] on a regular basis? If the participant asks what we mean by regular say that we mean at least every other week. **[useparks]**

Yes ☐ **1** No ☐ **0**

C3 Are there any in-door recreation centres close to your home, for example a gym or indoor soft play? If the participant asks what we mean by 'close' say that we mean indoor recreation centres that they believe are within a reasonable walking distance from their home or a short drive away. **[indoorrecreation]**

Yes ☐ **1** No ☐ **0** Don't know ☐ **99** *If no or don't know skip C4.*

C4 Do you use any of these with [twin1_name] and [twin2_name] on a regular basis? If the participant asks what we mean by regular say that we mean at least every other week. **[useindoor]**

Yes ☐ **1** No ☐ **0**

C5 Do you take [twin1_name] and [twin2_name] to any other regular sessions where they can be physically active, for example sports clubs, swimming lessons or other activities? Activity classes such as ballet, swimming and other places where the twins can be active such as adventure parks, woods etc. are included. **[otherregularactivity]**

Yes ☐ **1** No ☐ **0**

C6 Do you have a garden or outdoor space that [twin1_name] and [twin2_name] can play in? This includes shared garden space for people living in flats, but does not include park space, even if it is very close to home. **[garden]**

Yes ☐ **1** No ☐ **0**

If no skip C7, C8, C10 and C12.

C7 Would you say that your garden or outdoor space is small, medium or large? This is a subjective question. The participant should say what they feel the size of their garden is. **[gardensize]**

Small ☐ **1** medium ☐ **2** large ☐ **3**

C8 Do you have any usable play equipment such as swings, slides, climbing frames, trampolines in your garden or outdoor space? Usable means that it is ready to use. For example, swings are well grounded and have chairs. **[gardenequipment]**

Yes ☐ **1** No ☐ **0**

If yes, what types of play equipment do you have in your garden (or outdoor space)? **[whatequipment]**

C9 Do [twin1_name] and [twin2_name] have a usable bike, scooter, rollerblades, or skateboard? Usable means that it is ready to use. For example, bikes have tires that are pumped up and chains that are not broken. **[bike]**

Yes (both) ☐ **1** No ☐ **0** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3**

For the next two questions, please choose a score from 1 to 5: 1 means strongly disagree, 2 means somewhat disagree, 3 means neither agree nor disagree, 4 means somewhat agree, 5 means strongly agree.

C10 To what extent would you agree that [twin1_name] and [twin2_name] have adequate room to play actively in your garden or outdoor space? By 'actively' we mean anything that involves physically moving about during playing such as running, jumping, or climbing on things. If the participant asks what we mean by 'actively' say we mean anything that involves physically moving about during playing such as running, jumping, or climbing on things. For the first question, to make sure the participant is ranking correctly, repeat their response back to them e.g. if participant says 5, interviewer says 'so that's 5, strongly agree?' etc. **[adequateoutdoors]**

1 2 3 4 5 (5=strongly agree)
1 2 3 4 5

C11 To what extent would you agree that [twin1_name] and [twin2_name] have adequate room to play actively inside the home? Only say what we mean by actively if the participant has not been asked C10, which also explains this. A possible response may be that there is space in some rooms, but not in others. Get the participant to consider this with their response. For example, if there is only space in one room, the answer might be 4, somewhat agree. **[adequateindoor]**

1 2 3 4 5 (5=strongly agree)

1 2 3 4 5

For the next two questions, again please choose a score from 1 to 5: 1 means never, 2 means rarely, 3 means some of the time, 4 means most of the time, 5 means all of the time.

C12 How often would you say that [twin1_name] and [twin2_name] are allowed to be physically active in your garden or outdoor space? **[allowedoutdoors]**

For the first question, to make sure the participant is ranking correctly, repeat their response back to them e.g. if participant says 5, interviewer says 'so that's 5, all of the time?' etc.

A potential response may be that the twins are only allowed to play outside if an adult is present. If play is never restricted within that parameter, tick 5 all of the time. Another potential response is that outdoor play depends on the weather. If so, ask the participant to consider this with their response.

Explanations for C12 and C13 are irrelevant e.g.it might be that participants rarely allow their twins to play actively inside the home because they do not feel that it is safe. This response should remain as 2 rarely.

1 2 3 4 5

1 2 3 4 5

C13 How often would you say that [twin1_name] and [twin2_name] are allowed to be physically active inside the home? **[allowedindoors]**

1 2 3 4 5

1 2 3 4 5

Section D – PARENTAL MODELING OF ACTIVITY

The questions in this section refer to the parent(s) or primary caregiver(s) who live in the same home as the twins. This may or may not be the biological parent(s).

For each question, again please choose a score from 1 to 5. 1 means never, 2 means rarely, 3 means sometimes, 4 means often, 5 means very often. For each question, please indicate whether your response is the same or different for [twin1_name] and [twin2_name]. Throughout this section, physical activity means any kind of physical activity including moderate e.g. walking and vigorous e.g. running.

Always score [twin1_name] first and then [twin2_name].

D1. How often do you or your [husband_wife_partner] encourage [twin1_name] and [twin2_name] to do physical activity? For the first question, to make sure the participant is ranking correctly, repeat their response back to them e.g. if participant says 5, interviewer says 'so that's 5, very often?' etc. If parents say 1 because they don't need to as their twins are already physically active, still keep response as 1. In other words, it doesn't matter what the reason is.

1 2 3 4 5

1 2 3 4 5 **[encourageactivity1]**

If different arrangement for twins: [twin2_name]: 1 2 3 4 5

1 2 3 4 5

[encourageactivity1]

D2. How often do you or your [husband_wife_partner] do physical activity or play sports with [twin1_name] and [twin2_name]? **[howoftenactivity1]**

1 2 3 4 5

1 2 3 4 5

If different arrangement for twins: [twin2_name]: 1 2 3 4 5

[howoftenactivity2] **1 2 3 4 5**

D3. How often do you or your [husband_wife_partner] provide transport to a place where [twin1_name] and [twin2_name] can do physical activity? By this we mean provide transport by car (or other vehicle) rather than by foot. **[transportactivity1]**

1 2 3 4 5

1 2 3 4 5

If different arrangement for twins: [twin2_name]: 1 2 3 4 5

[transportactivity2] **1 2 3 4 5**

D4. How often do you or your [husband_wife_partner] watch [twin1_name] and [twin2_name] participate in physical activity? **[watchactivity1]**

1 2 3 4 5

1 2 3 4 5

If different arrangement for twins: [twin2_name]: 1 2 3 4 5

[watchactivity2 **1 2 3 4 5**

D5. How often do you or your [husband_wife_partner] tell [twin1_name] and [twin2_name] that being physically active is good for their health? **[tellactivitygood1]**

1 2 3 4 5

1 2 3 4 5

If different arrangement for twins: [twin2_name]: 1 2 3 4 5

[tellactivitygood2] **1 2 3 4 5**

D6. How often do you or your [husband_wife_partner] plan for [twin1_name] and [twin2_name] to do physical activity? For example, how often do you plan your week to make sure the twins have time for activity, such as walking to and from school every Monday? **[planactivity1]**

1 2 3 4 5

1 2 3 4 5

If different arrangement for twins: [twin2_name]: 1 2 3 4 5

[planactivity2] **1 2 3 4 5**

D7. How often do you or your [husband_wife_partner] try to be active in front of [twin1_name] and [twin2_name]? **[infrontactive1]**

This includes occasions where the child sees their parent(s) preparing to exercise, even if they are not able to actually see them exercise.

1 2 3 4 5

1 2 3 4 5

If different arrangement for twins: [twin2_name]: 1 2 3 4 5

[infrontactive2] **1 2 3 4 5**

D8. How often do you or your [husband_wife_partner] show [twin1_name] and [twin2_name] how much you enjoy being active? **[enjoyactive2]**

1 2 3 4 5

1 2 3 4 5

If different arrangement for twins: [twin2_name]: 1 2 3 4 5

[enjoyactive2] **1 2 3 4 5**

D9. Compared to other children of the same age and sex, how physically active are [twin1_name] and [twin2_name]? Please choose a score from 1 to 5 for each child separately: 1 means much less active, 2 means somewhat less active, 3 means about average, 4 means somewhat more active, 5 means much more active.

<twin1 name>: 1 2 3 4 5

1 2 3 4 5 **[compareactivitytwin1]**

<twin2 name>: 1 2 3 4 5

1 2 3 4 5 **[compareactivitytwin2]**

D10. Do you think [twin1_name] gets enough physical activity? **[enoughactivity]**

Yes ☐ **1** No ☐ **0**

D11. Do you think [twin2_name] gets enough physical activity? **[enoughactivity2]**

Yes ☐ **1** No ☐ **0**

Section E - MEDIA ENVIRONMENT

The next section is about the media equipment you have in your home

E1. How many working TVs (including Smart TVs) do you have in your home? Include TVs that are temporarily broken if there is a plan to get them fixed. A smart TV is defined as a TV that connects directly to the internet and does not need a computer, additional box or games console to go online. **[workingtvs]**

…….. (enter 99 if Don't know, enter 0 if none)

E2. How many working DVD/Blu-Ray players/streaming devices (e.g. Amazon Prime, nowTV) or digital video recorders (e.g. Sky+, NowTV, Virgin, YouView, Freeview+) do you have in your home? Include DVD/Blu-ray players or streaming devices that are temporarily broken if there is a plan to get them fixed. Also include DVD players within computers or games consoles if they are used to watch films on.

[blueraydvdstreaming]

…... (enter 99 if Don't know, enter 0 if none)

E3.1 On average, how long do you watch TV programmes, movies, or on demand media services (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. computer/laptop/tablet) on a typical weekday (Monday to Friday), at this time of year? Only include viewing **in the home**. **[maternalviewingeveryday]**

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E3.2 On average, how long does your [husband/wife/partner] watch TV programmes, movies, or on demand media services (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. computer/laptop/tablet) on a weekday (Monday to Friday), at this time of year? This includes time spent watching online videos via services such as YouTube, Facebook, etc. Only include viewing **in the home**.

[partnertvvewingweekday]

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E3.3 On average, how long do you watch TV programmes, movies, or online media (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. computer/laptop/tablet) on a typical weekend day, at this time of year? This includes time spent watching online videos via services such as YouTube, Facebook, etc. Only include viewing **in the home**. **[maternalviewingweekend]**

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E3.4 On average, how long does your [husband/wife/partner] watch TV programmes, movies, or online media (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. TV/computer/laptop/tablet) on a typical weekend day, at this time of year? This includes time spent watching online videos via services such as YouTube, Facebook, etc. Only include viewing **in the home**. **[partnertvvewingweekend]**

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E3.5 On average, how long do [twin1_name] and [twin2_name] watch TV programmes, movies, or online media (e.g. Netflix, Amazon Prime, YouTube videos) on an electronic device (e.g. desktop computer/laptop/tablet computer) on a typical weekday (Monday to Friday), at this time of year? Only include viewing **in the home**. This includes time spent watching online videos via services such as YouTube, Facebook, etc. Write hours and minutes (HH:MM) e.g. if one hour 15 minutes, enter 01:15.

E3.5.1 [twin1_name] ……. hours ……. minutes per day **[viewingweekday1]**

E3.5.2 [twin2_name] ……. hours ……. minutes per day **[viewingweekday2]**

E3.6 On average, how long do [twin1_name] and [twin2_name] watch TV programmes, movies, or online media services (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. TV/desktop computer/laptop/tablet computer) on a typical weekend day, at this time of year? This includes time spent watching online videos via services such as YouTube, Facebook, etc. Only include viewing **in the home**. Write hours and minutes (HH:MM) e.g. if one hour 15 minutes, enter 01:15.

E3.6.1 [twin1_name] ……. hours ……. minutes per day **[viewingweekend1]**

E3.6.2 [twin2_name] ……. hours ……. minutes per day **[viewingweekend2]**

E4. Do [twin1_name] and [twin2_name] share a bedroom? **[sharebedroom]**

Yes □ No □ **0**

E5. How many working desktop computers or laptops or tablet computers (iPad, Kindle fire, Google Nexus, Samsung Galaxy tab) do you have in your home? Include computers or laptops that are temporarily broken if there is a plan to get them fixed. **[electronicdevices]**

…….. (enter 0 if none)

E6. How many working games consoles, such as Play Station, Nintendo DS, Wii do you have in your home? Include game consoles that are temporarily broken if there is a plan to get them fixed. **[gamesconsoles]**

…….. (enter 0 if none)

E7. How many working mobile phones, including smartphone – (iPhone/Samsung /Sony Xperia/ Blackberry, etc.) do you have in your home? Include mobile phones that are temporarily broken if there is a plan to get them fixed. **[howmanyphones]**

…….. (enter 0 if none) *If 0 to E5, E6, E7, skip E8.1-8.6.*

E8.1 On average, how long do you spend playing video games on a typical weekday (Monday to Friday), at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**. *If respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.* **[maternalconsoleweekday]**

……. hours ……. minutes per day

E8.2 On average, how long does your [husband/wife/partner] spend playing video games on a typical weekday (Monday to Friday), at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**. **[partnerconsoleweekday]**

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E8.3 On average, how long do you spend playing video games on a weekend day, at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**. *For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.* **[maternalconsoleweekend]**

……. hours ……. minutes per day

E8.4 On average, how long does your [husband/wife/partner] spend playing video games on a weekend day, at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**. **[partnerconsoleweekend]**

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E8.5 On average, how long do [twin1_name] and [twin2_name] spend playing video games on a typical weekday (Monday to Friday), at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**.

E8.5.1 [twin1_name] ……. hours ……. minutes per day **[videogamesweekday]**

E8.5.2 [twin2_name] ……. hours ……. minutes per day **[videogamesweekday2]**

E8.6 On average, how long does [twin1_name] and [twin2_name] spend playing video games on a typical weekend day, at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**. Write hours and minutes (HH:MM) e.g. if one hour 15 minutes, enter 01:15.

E8.6.1 [twin1_name] ……. hours ……. minutes per day **[videogamesweekend1]**

E8.6.2 [twin2_name] ……. hours ……. minutes per day **[videogamesweekend2]**

PARENTAL RULES AND POLICIES AROUND MEDIA USE

E9. Do [twin1_name] and [twin2_name] have access to and use the following electronic devices in their bedroom? Read out the response options and list for both twins

Type of device	**Response options**
TV/Smart TV **[tvbedroom]**	Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**
Computer or laptop **[laptopbedroom]**	Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**
Tablet **[tabletbedroom]**	Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**
Mobile phone/smartphone **[mobilebedroom]**	Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**
Games console **[consolebedroom]**	Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**

E10.1 Do you have any rules around TV watching? **[tvrules]**

Yes ☐ **1** No ☐ **0** *If No, skip to E11.1*

E10.2 If yes, what rules around TV watching do you have? This is an open response. The participant should provide the rules they have, and the researcher categorizes the responses as best they can. Prompt the participant to check that they have not forgotten anything. **[describetvrules]**

1 ☐ Rules about what they are allowed to watch on TV

2 ☐ Rules about when/what times they are allowed to watch TV

3 ☐ Rules about how much time they are allowed to spend watching TV

4 ☐ Rules around watching TV whilst at the dinner table

5 ☐ Regularly check what is being watched on TV watching

6 ☐ Limit access to inappropriate content via parental pin controls on TV

7 ☐ Other (see below)

If other, please could you specify these rules? **[whatOtherRulesTV]**

E11.1 Do you have any rules around computer use? **[computerrules]**

Yes ☐ **1** No ☐ **0** *If no, skip E12.1*.

E11.2 If yes, what rules around computer use do you have? This is an open response. The participant should provide the rules they have, and the researcher categorizes the responses as best they can. Prompt the participant to check that they have not forgotten anything. **[describecomputerrules]**

1 ☐ Rules about what they use the computer for

2 ☐ Rules about when/what times of the day they are able to use the computer

3 ☐ Rules about the amount of time allowed to use the computer

4 ☐ Rules around what websites they are allowed access

5 ☐ Regularly check what they are doing on the computer

6 ☐ Limit access to inappropriate content via parental control on computer

7 ☐ Other (see below)

If other, please could you specify these rules? **[whatOtherRulesComputer]**

E11.3 Do you ever reward good behaviour with extra TV or computer time? **[rewardtv]**

Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**

E11.4 Do you ever reduce TV or computer time if [twin1_name] or [twin2_name] is naughty? **[reducetv]**

Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**

E12.1. Do you have any rules around mobile phone or tablet use? **[mobilerules]**

Yes ☐ **1** No ☐ **0**

E12.2 If yes, what rules around mobile phone or tablet use do you have? **[describemobilerules]**

1 ☐ Rules about types of website or apps they can download/use

2 ☐ Parental controls used to block or monitor use

3 ☐ Monitor access to websites and check browser history

4 ☐ Rules about how much time they can spend on phone or tablet

5 ☐ Rules about when they can use phone or tablet

6 ☐ Other rules

If other, please could you describe these rules? **[whatOtherRulesMobile]**

E12.3 Do you ever reward good behaviour with extra mobile phone or tablet use? **[rewardmobile]**

Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**

E12.4 Do you ever reduce mobile phone or tablet computer time if [twin1_name] or [twin2_name] is naughty? **[reducemobile]**

Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**

E13. Do [twin1_name] and [twin2_name] eat while watching TV or using an electronic device? This includes meals and snacks that are eaten in front of TV or an electronic device.

[twin1_name] Yes ☐ **1** No ☐ **0** **[deviceeat1]**

[twin2_name] Yes ☐ **1** No ☐ **0** **[deviceeat2]**

If No for E13 a skip E13.1-E13.6

E13.1. How many days per week do [twin1_name] and [twin2_name] eat breakfast while watching TV or using an electronic device?
Always score [twin1_name] first and then [twin2_name].
0 1 2 3 4 5 6 7
0 1 2 3 4 5 6 7 [tvbreakfast1]
If different arrangement for twins: [twin2_name]: 0 1 2 3 4 5 6 7
[tvbreakfast2] **0 1 2 3 4 5 6 7**

E13.2 How many days per week do [twin1_name] and [twin2_name] eat a midday meal while watching TV or using an electronic device? Only two options as they will be at school during the weekdays **[lunchtv1]**
0 1 2
0 1 2

If different arrangement for twins: [twin2_name]: 0 1 2
[lunchtv2] **0 1 2**

E13.3. How many days per week do [twin1_name] and [twin2_name] eat an evening meal while watching TV or using an electronic device? **[dinnertv1]**
0 1 2 3 4 5 6 7
0 1 2 3 4 5 6 7
If different arrangement for twins: [twin2_name]: 0 1 2 3 4 5 6 7
[dinnertv2] **0 1 2 3 4 5 6 7**

E13.4. How many days per week do [twin1_name] and [twin2_name] eat snacks while watching TV or using an electronic device? **[snackstv1]**
0 1 2 3 4 5 6 7
0 1 2 3 4 5 6 7
If different arrangement for twins: [twin2_name]: 0 1 2 3 4 5 6 **7**
[snackstv2] **0 1 2 3 4 5 6 7**

Section F – CHILDREN'S SOCIAL MEDIA USE

The next section is about your twin's online activities and use of social media.

F1. Do [twin1_name] and [twin2_name] have their own social media accounts and/or have access to other's accounts? **[socialmediaaccess1]**

Yes, own account ☐ **1** Yes, access to other's account ☐ **2** No ☐ **0** I don't know ☐ **3**

If different arrangement for twins: [twin2_name]: **[socialmediaaccess2]**

Yes, own account ☐ **1** Yes, access to other's account ☐ **2** No ☐ **0** I don't know ☐ **3**

If No skip to F3

F2. If yes, which of the following social media platforms do [twin1_name] and [twin2_name] use and have access to? (Ask parent to choose as many that apply)

[twin1_name] **[socialmediaaccount1]**	**[twin2_name]** **[socialmediaaccount2]**
1 ☐ Snapchat	**1** ☐ Snapchat
2 ☐ Facebook	**2** ☐ Facebook
3 ☐ YouTube	**3** ☐ YouTube
4 ☐ Instagram	**4** ☐ Instagram
5 ☐ Vimeo	**5** ☐ Vimeo
6 ☐ Twitter	**6** ☐ Twitter
7 ☐ Tiktok	**7** ☐ Tiktok
8 ☐ WhatsApp	**8** ☐ WhatsApp
9 ☐ Other	**9** ☐ Other

If other, please specify [twin1_name] _______________ **[othersocialaccount1]**
[twin2_name] _______________ **[othersocialaccount2]**

F3. Do you have any rules about your twin's online activities? **[rulesonline]**

Yes (both) ☐ **1** Yes [twin1_name] ☐ **2** Yes [twin2_name] ☐ **3** No ☐ **0**

F4. If yes, what rules around your child's online activities do you have? This is an open response. The participant should provide the rules they have, and the researcher categorizes the responses as best they can. Prompt the participant to check that they have not forgotten anything. **[describeonlinerules]**

1 Rules about the types of websites or apps they can use ☐

2 Rules about amount of time spent online (e.g. time of day and amount of time) ☐

3 Rules about who can contact online (e.g. no strangers, do not share personal info) ☐

4 Rules about use of social media/ social networking, sites (e.g. Facebook, Instagram) ☐

5 Rules about use of Instant Messaging ☐

6 Use parental controls and filters to restrict access to content online ☐

7 Check browser history after use ☐

8 Rules about making online purchases ☐

9 Rules about behaviour online ☐

10 Only allowed to access content supervised ☐

11 Other rules ☐

If other, please could you describe these rules? **[otherrulesonline]**

SECTION G – K: FOOD ENVIRONMENT

The next section is about food and drink that is currently in your home. For the food and drink that we ask about, please include all items that are in your home even if your twins do not eat or drink them themselves. If you are unsure of any of the answers, please have a look to see what is in your home.

Section G - Fruit

G1.1. Do you have any **fresh fruit** in your home now? **[freshfruitnow]**

Yes ☐ **1** No ☐ **0**

G1.2. If yes, what types of **fresh fruit** do you have in your home now? **[whatfreshfruits]**
This is an open question. As the participant lists the fresh fruit they have, tick the matching options in the table or add any other fresh fruit to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered fresh fruit in your fridge, in a fruit bowl and in your cupboards?

Fresh fruit
List of standard fruits to choose from (see below) as well as a free-entry box for less common items.

	Yes 1 No 0
1 Apples [freshApples]	
2 Bananas [freshBananas]	
3 Blueberries [freshBlueberries]	
4 Cherries [freshCherries]	
5 Grapefruit [freshGrapefruit]	
6 Grapes [freshGrapes]	
7 Kiwi [freshKiwi]	
8 Mangoes [freshMangoes]	
9 Melon [freshMelon]	
10 Nectarines [freshNectarines]	
11 Tangerines [freshTangerines]	
12 Oranges [freshOranges]	
13 Satsumas [freshSatsumas]	
14 Peaches [freshPeaches]	
15 Pears [freshPears]	
16 Pineapple [freshPineapple]	
17 Plums [freshPlums]	
18 Raspberries [freshRaspberries]	
19 Strawberries [freshStrawberries]	
20 Blackberries [freshBlackberries]	
21 Lemons [freshLemons]	
22 Limes [freshLimes]	
23 Gooseberries [freshGooseberries]	
24 Apricots [freshApricots]	
25 Rhubarb [freshRhubarb]	
26 Figs [freshFigs]	

27 Other fresh fruit [whatFreshFruits]	Number of other items

G2.1. Do you have any **tinned or jarred fruit** in your home now? [tinnedfruitnow]

Yes ☐ 1 No ☐ 0

G2.2. If yes, what types of **tinned or jarred fruit** do you have in your home now? [whattinnedfruits]

This is an open question. As the participant lists the tinned or jarred fruit they have, tick the matching options in the table or add any other tinned or jarred fruit to the free entry box which says other.

When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered tinned or jarred fruit in your fridge and in your cupboards?

Tins / jars of fruit
List of standard fruits to choose from as well as a free-entry box for less common items.

	Yes 1 No 0
1 Cherries **[tinnedCherries]**	
2 Fruit salad/cocktail **[tinnedFruitsalad]**	
3 Grapefruit **[tinnedGrapefruit]**	
4 Mandarin orange **[tinnedManadin]**	
5 Peaches **[tinnedPeaches]**	
6 Pears **[tinnedPears]**	
7 Plums **[tinnedPlums]**	
8 Pineapple **[tinnedPineapple]**	
9 Raspberries **[tinnedRaspberries]**	
10 Strawberries **[tinnedStrawberries]**	
11 Other **[tinnedOther]**	

Other tinned fruit **[whatTinnedFruits]**	Number of other items

G3.1. Do you have any **dried fruit**, such as raisins, dried apricots, or dates in your home now? **[driedfruitnow]**

Yes ☐ **1** No ☐ **0**

G3.2. If yes, what types of **dried fruit** do you have in your home now? **[whatdriedfruit]**
This is an open question. As the participant lists the dried fruit they have, tick the matching options in the table or add any other dried fruit to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered dried fruit in a fruit bowl and in your cupboards?

Dried fruit
List of standard fruits to choose from as well as a free-entry box for less common items.

	Yes 1 No 0
1 Apples **[driedApples]**	
2 Banana chips **[driedBanana]**	
3 Dried strawberries **[driedStrawberries]**	
4 Currants **[driedCurrants]**	
5 Raisins **[driedRaisins]**	
6 Sultanas **[driedSultanas]**	
7 Apricots **[driedApricots]**	

8 Dates [driedDates]	
9 Prunes [driedPrunes]	
10 Dried mixed fruit [driedMixedfruit]	
11 Dried mango [driedMango]	
12 Dried pineapple [driedPineapple]	
13 Figs [driedFigs]	
14 Cranberries [driedCranberries]	
15 Other [driedOther]	

Other dried fruit [whatDriedFruits]	Number of other items

G4.1. Do you have any **frozen fruit** in your home now? [frozenfruitnow]

Yes ☐ 1 No ☐ 0

G4.2. If yes, what types of **frozen fruit** do you have in your home now? [whatfrozenfruits] This is an open question. As the participant lists the frozen fruit they have, tick the matching options in the table or add any other frozen fruit to the free entry box which says other.

Frozen fruit

List of standard fruits to choose from as well as a free-entry box for less common items.

	Yes 1 No 0
1 Mixed berries [frozenMixedberries]	
2 Raspberries [frozenRaspberries]	
3 Strawberries [frozenStrawberries]	
4 Blueberries [frozenBlueberries]	
5 Mango [frozenMango]	
6 Other [frozenOther]	

Other frozen fruit [whatFrozenFruits]	Number of other items

G5.1. Would you say that the amount of **fruit** you currently have in your home is more than usual, less than usual, or about the same? [amountfruit]

Less than usual ☐ 1 The same ☐ 2 More than usual ☐ 3

G5.2. Without opening any fridge or cupboard doors, is there **any kind of fruit** in your home now; displayed out in the open? A possible response may be that some fruit is behind a door, but it is a glass door and the fruit can be seen. If so, report YES. Another response could be that some fresh fruit is out, but that it is stored very high and can only be viewed with a stool. Is so, report NO. **[fruitdisplayed]**

Yes ☐ **1** No ☐ **0**

G5.3 Are [twin1_name] and [twin2_name] allowed to get any **fruit** by themselves, without asking you or your [husband_wife_partner] first? By this, we mean whether the twins are allowed to physically get any fruit by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get fruit by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

[fruitallowed1] Yes ☐ **1** No ☐ **0**

[fruitallowed2] If different for twins: [twin2_name]: Yes ☐ **1** No ☐ **0**

G6. On average, how often do <twin1 name> and <twin2 name> eat fruit? This includes fruit that is eaten between meals and fruit that is eaten as part of a meal. Fruit juice is not included. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name>	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
<twin2 name>	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**

Section H - Vegetables

H1.1. Do you have any **fresh vegetables** in your home now? This includes salad items such as lettuce, cucumber, and tomato. **[freshvegetablenow]**

Yes ☐ **1** No ☐ **0**

H.1.2. If yes, what types of **fresh vegetables** do you have in your home now? **[whatfreshveg]**
This is an open question. As the participant lists the fresh vegetables they have, tick the matching options in the table or add any other fresh vegetables to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered fresh vegetables in your fridge and in your cupboards?

Fresh vegetables
List of standard vegetables to choose from as well as a free-entry box for less common items.

	Yes **1** No **0**
1 Broccoli **[freshBroccoli]**	
2 Brussel sprouts **[freshBrusselSprouts]**	
3 Carrots **[freshCarrots]**	
4 Peppers **[freshPeppers]**	
5 Cabbage **[freshCabbage]**	
6 Cauliflower **[freshCauliflower]**	
7 Celery **[freshCelery]**	
8 Corn on the cob **[freshCornonthecob]**	
9 Baby sweetcorn **[freshBabysweetcorn]**	
10 Lettuce **[freshLettuce]**	
11 Tomatoes **[freshTomatoes]**	
12 Runner beans **[freshRunnerbeans]**	
13 Mushrooms **[freshMushrooms]**	
14 Salad **[freshSalad]**	
15 Onions **[freshOnions]**	
16 Sugar snap peas **[freshSugarsnappeas]**	
17 Mangetout **[freshMangetout]**	
18 Cucumber **[freshCucumber]**	
19 Green beans **[freshGreenbeans]**	
20 Aubergine **[freshAubergine]**	
21 Lentils **[freshLentils]**	
22 Other **[freshvegother]**	

Other fresh vegetables **[whatFreshVegetables]**	Number of other items

H2.1 Do you have any **tinned or jarred vegetables** in your home now for example tinned tomatoes, sweetcorn, or jarred beetroot, in your home now? This includes tinned pulses such as chickpeas, kidney beans and lentils? **[tinnedvegetablenow]**

Yes ☐ **1** No ☐ **0**

H.2.2. If yes, what types of **tinned or jarred vegetables** do you have in your home now? **[whattinnedveg]**
This is an open question. As the participant lists the tinned or jarred vegetables they have, tick the matching options in the table or add any other tinned or jarred vegetables to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered tinned or jarred vegetables in your fridge and in your cupboards?

Tins of vegetables

List of standard vegetables to choose from as well as a free-entry box for less common items.

	Yes 1 No 0
1 Baked beans **[tinnedBakedbeans]**	
2 Bamboo shoots **[tinnedBambooshoots]**	
3 Sweetcorn **[tinnedSweetcorn]**	
4 Beetroot **[tinnedBeetroot]**	
5 Broad beans **[tinnedBroadbeans]**	
6 Peas **[tinnedPeas]**	
7 Carrots **[tinnedCarrots]**	
8 Mixed vegetables **[tinnedMixedvegetables]**	
9 Pease pudding **[tinnedPeasepudding]**	
10 Pickled onion **[tinnedPickledonion]**	
11 Pickled gherkins **[tinnedGherkins]**	
12 Tomatoes **[tinnedTomatoes]**	
13 Cannellini beans **[tinnedCannellinibeans]**	
14 Black beans **[tinnedBlackbeans]**	
15 Kidney beans **[tinnedKidneybeans]**	
16 Chickpeas **[tinnedChickpeas]**	
17 Lentils **[tinnedLentils]**	
18 Butter beans **[tinnedButterbeans]**	

19 Other tinned vegetables **[whatTinnedVegetables]**	Number of other items

H3.1. Do you have any **frozen vegetables** in your home now? **[frozenvegnow]**

Yes ☐ **1** No ☐ **0**

H3.2. If yes, what types of **frozen vegetables** do you have in your home now? **[whatfrozenveg]**

This is an open question. As the participant lists the frozen vegetables they have, tick the matching options in the table or add any other frozen vegetables to the free entry box which says other.

Frozen vegetables

List of standard vegetables to choose from as well as a free-entry box for less common items.

	Yes 1 No 0
1 Broad beans **[frozenBroadbeans]**	

1 Brussel sprouts **[frozenBrusselsprouts]**	
1 Cabbage **[frozenCaggage]**	
1 Cauliflower **[frozenCauliflower]**	
1 Peas **[frozenPeas]**	
1 Runner beans **[frozenRunnerbeans]**	
1 Green beans **[frozenGreenbeans]**	
1 Mixed vegetables **[frozenMixedvegetables]**	
1 Brocolli **[frozenBrocolli]**	
1 Spinach **[frozenSpinach]**	
1 Courgette **[frozenCourgette]**	
1 Sweet potato **[frozenSweetpotato]**	
1 Soya beans **[frozenSoyabeans]**	
1 Corn on the cob **[frozenCorncob]**	
1 Other **[frozenvegOther]**	

Other frozen vegetables **[otherfrozenveg]**	Number of other items

H4.1. Would you say that the amount of **vegetables** you currently have in your home is more than usual, less than usual, or about the same? **[amountveg]**

Less than usual ☐ **1** The same ☐ **2** More than usual ☐ **3**

H4.2. Do you have any ready to eat **fresh vegetables** on a shelf in the fridge or on the kitchen counter now? These include baby carrots, cherry tomatoes, or vegetables that you have sliced to make them ready to eat. **[vegetabledisplayed]**

Yes ☐ **1** No ☐ **0**

H4.3. Are [twin1_name] and [twin2_name] allowed to get any **vegetables** by themselves, without asking you or your [husband/wife/partner] first? By this, we mean whether the twins are allowed to physically get any vegetables by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get vegetables by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?' **[vegallowedhelp1]**

Yes ☐ **1** No ☐ **0**

If different for twins: [twin2_name]: Yes ☐ **1** No ☐ **0 [vegallowedhelp2]**

H.5. On average, how often do [twin1_name] and [twin2_name] eat vegetables? This includes salad items such as cucumber, lettuce and tomato but not potatoes. Vegetables that are eaten between meals and vegetables that are eaten as part of a meal are included. **[howoftenveg1] & [howoftenveg2]**

This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name>	☐ 1	☐2	☐3	☐ 4	☐5	☐6	☐7	☐8
<twin2 name>	☐ 1	☐2	☐3	☐ 4	☐5	☐6	☐7	☐8

If the participant does not indicate whether their response is the same or different for <twin1name> and <twin2 name>, prompt them to check.

Section I – Salty snacks

I1.1. Do you have any **salty snacks** for example peanuts, crisps, tortillas and savoury biscuits (e.g. mini cheddars) in your home now? Do not include seeds or cheese. **[saltysnacknow]**

Yes ☐ **1** No ☐ **0**

I1.2. If yes, what types of **salty snacks** do you have in your home now? Snacks like plain rice cakes, oatcakes, and breadsticks are not included.
This is an open question. As the participant lists the salty snacks they have, tick the matching options in the table or add any other salty snacks to the free entry box which says other. *Snacks like plain crackers, rice cakes breadsticks and oatcakes are not included. Dairy based snacks e.g. cheese products are also not included.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered salty snacks in your fridge and in your cupboards?

Salty snacks [whatsaltysnacks]

List of standard Salty snacks to choose from as well as a free-entry box for less common items.

	Yes **1** No **0**
1 Savoury biscuits (e.g. mini cheddars) **[saltySavouryBiscuits]**	
2 Crisps (doritos, pringles, wotsits) **[saltyCrisps]**	
3 Salted peanuts and other nuts **[saltyPeanutsandothernuts]**	
4 Pork scratchings **[saltyPorkscratchings]**	
5 Tortilla chips **[saltyTortillachips]**	
7 Popcorn **[saltyPopcorn]**	
8 Bombay mix **[saltyBombaymix]**	
9 Other **[saltyother]**	

Other salty snacks **[whatSaltySnacks]**	Number of other items

I1.3. Would you say that the amount of **salty snacks** you currently have in your home is more than usual, less than usual, or about the same? **[amountsavourysnacks]**

Less than usual ☐ **1** The same ☐ **2** More than usual ☐ **3**

I2.1. Without opening any fridge or cupboard doors, are there any kind of **salty snacks** in your home now; displayed out in the open? A possible response may be that some salty snacks are behind a door, but it is a glass door and the snacks can be seen. If so, report YES. Another response could be that some salty snacks are out, but that they are stored very high and can only be viewed with a stool. Is so, report NO. **[saltysnackdisplayed]**

Yes ☐ **1** No ☐ **0**

I2.2. Are [twin1_name] and [twin2_name] allowed to get any **salty snacks** by themselves, without asking you or your [husband/wife/partner] first? By this, we mean whether the twins are allowed to physically get any salty snacks by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get salty snacks by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

[allowedsaltysnacks1] [twin1_name]: Yes ☐ **1** No ☐ **0**

[allowedsaltysnacks2] [twin2_name]: Yes ☐ **1** No ☐ **0**

I2.3. On average, how often do [twin1_name] and [twin2_name] eat savoury snacks such as peanuts, crisps, tortillas and cheesy biscuits? This includes savoury snacks that are eaten between meals and savoury snacks that are eaten as part of a meal such as crisps with lunch. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name> **[howoftensalty1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
<twin2 name> **[howoftensalty2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**

Section J - Sweet snacks

J1.1 Do you have any **sweet snacks** for example cakes, biscuits or ice-cream in your home now? **[sweetsnacksnow]**

Yes ☐ **1** No ☐ **0**

J1.2 If yes, what types of **sweet snacks** do you have in your home now? Do not include sweets or chocolate, these are confectionary.

This is an open question. As the participant lists the sweet snacks they have, tick the matching options in the table or add any other sweet snacks to the free entry box which says other.

When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered sweet snacks in your fridge and in your cupboards? **[whatsweetsnacks]**

Sweet snacks

List of standard sweet snacks to choose from as well as a free-entry box for less common items.

	Yes **1** No **0**
1 Biscuits **[sweetBiscuits]**	
2 Buns **[sweetBuns]**	
3 Cakes **[sweetCakes]**	
4 Ice-cream **[sweetIcecream]**	
5 Ice-lollies **[sweetIcelollies]**	
6 Pastries **[sweetPasteries]**	
7 Flapjacks **[sweetFlapjacks]**	
8 Custard **[sweetCustard]**	
9 Malt loaf **[sweetMaltloaf]**	
10 Scones **[sweetScones]**	
11 Crumbles **[sweetApplecrumble]**	
12 Muffin **[sweetMuffin]**	
13 Brownies **[sweetBrownie]**	
14 Pie **[sweetPie]**	
15 Tarts **[sweetTart]**	
16 Trifle **[sweetTrifle]**	
17 Other **[sweetOther]**	

Other sweet snacks **[whatSweetSnacks]**	Number of other items

J1.3 Would you say that the amount of **sweet snacks** you currently have in your home is more than usual, less than usual, or about the same? **[amountsweetsnacks]**

Less than usual ☐ **1** The same ☐ **2** More than usual ☐ **3**

J2.1 Without opening any fridge or cupboard doors, are there any kind of **sweet snacks** in your home now displayed out in the open? A possible response may be that some sweet snacks are behind a door, but it is a glass door and the snacks can be seen. If so, report YES. Another response could be that some sweet snacks are out, but that they are stored very high and can only be viewed with a stool. Is so, report NO. **[sweetsnackdisplayed]**

Yes ☐ **1** No ☐ **0**

J2.2 Are [twin1_name] and [twin2_name] allowed to get any **sweet snacks** by themselves, asking you or your [husband/wife/partner] first? By this, we mean whether the twins are allowed to physically get any sweet snacks by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get sweet snacks by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

[allowedsweetsnacks1] [twin1_name]:	Yes ☐ **1**	No ☐ **0**
[allowedsweetsnacks2] [twin2_name]:	Yes ☐ **1**	No ☐ **0**

J2.3 On average, how often do <twin1 name> and <twin2 name> eat sweet snacks such as cakes, biscuits, and ice-cream? This includes sweet snacks that are eaten between meals and sweet snacks that are eaten as part of a meal such as ice-cream for dessert. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name> **[howoftensweet1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
<twin2 name> **[howoftensweet2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**

Section K - Confectionery

K1.1. Do you have any **confectionery** in your home now? This includes sweets and chocolate. **[confectionerynow]**

Yes ☐ **1** No ☐ **0**

K1.2. If yes, what types of **confectionery** do you have in your home now?

This is an open question. As the participant lists the confectionery they have, tick the matching options in the table or add any other confectionery to the free entry box which says other.
When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered confectionery in your fridge, in a bowl and in your cupboards? **[whatconfectionery]**

Confectionery

List of standard confectionery to choose from as well as a free-entry box for less common items.

	Yes **1** No **0**
1 Chocolate **[confectioneryChocolate]**	
2 Sweets (e.g. pastels, mints, liquorice) **[confectionerySweets]**	
3 Marshmallows **[confectioneryMarshmallows]**	
4 Toffee **[confectioneryToffee]**	
5 Fudge **[confectioneryFudge]**	
6 Yogurt/chocolate coated raisins or fruit **[confectioneryYogurtcoatedfruit]**	
7 Other **[confectioneryOther]**	

Other confectionery **[whatConfectionery]**	Number of other items

K.1.3. Would you say that the amount of **confectionery** you currently have in your home is more than usual, less than usual, or about the same? **[amountconfectionery]**

Less than usual ☐ **1** The same ☐ **2** More than usual ☐ **3**

K.2.1. Without opening any fridge or cupboard doors, is there any kind of **confectionery** in your home now displayed out in the open? A possible response may be that some confectionery is behind a door, but it is a glass door and the confectionery can be seen. If so, report YES. Another response could be that some confectionery is out, but that it is stored very high and can only be viewed with a stool. Is so, report NO. **[confectionerydisplayed]**

Yes ☐ **1** No ☐ **0**

K.2.2. Are [twin1_name] and [twin2_name] allowed to get any **confectionery** by themselves, without asking you or your [husband/wife/partner] first? By this, we mean whether the twins are allowed to physically get any confectionery by themselves (even if they always have to ask the parent first). If the participant says ‘no, they always have to come and ask first,’ check whether or not the twins then go and physically get confectionery by themselves e.g. say ‘so once they’ve asked, do you go and get it for them or do they get it by themselves?’

[confectioneryallowed1] [twin1_name]: Yes ☐ **1** No ☐ **0**

[confectioneryallowed2] [twin2_name]: Yes ☐ **1** No ☐ **0**

K2.3. On average, how often do [twin1_name] and [twin2_name] eat confectionery such as chocolate and fruit sweets? This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say ‘everyday’, prompt for a fuller response e.g. ‘so is that once a day, 2-3 times a day or 4 or more times a day?’

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name> **[howoftenconfectionery1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
<twin2 name> **[howoftenconfectionery2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**

K3.1. On average, in the last month how often have [twin1_name] and [twin2_name] eaten fast food from places such as McDonald’s, KFC, Burger King, and Subway…? This includes both eating in and taking food away from fast food places. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say ‘everyday’, prompt for a fuller response e.g. ‘so is that once a day, 2-3 times a day or 4 or more times a day?’

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name> **[howoftenfastfood1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
<twin2 name> **[howoftenfastfood2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**

K3.2. On average, in the last month how often have <twin1 name> and <twin2 name> eaten other convenience foods for their main meal? This includes food that requires no preparation such as ready-made pizza, microwaveable meals. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say ‘everyday’, prompt for a fuller response e.g. ‘so is that once a day, 2-3 times a day or 4 or more times a day?’

	Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
<twin1 name> **[howoftenconvenience1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
<twin2 name> **[howoftenconvenience2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**

<u>Section M - DRINKS</u>

M1.1. Do you have any *non-alcoholic* **drinks** other than water in your home now? Examples are fruit juice, squash, fizzy pop, ready-made fruit flavoured drinks, smoothies, and milk. **[drinksnow]**

If no to M1.1, skip M1.2. and M1.4. – M2.1. (but do ask M1.3. and M2.2.)

Yes ☐ **1** No ☐ **0**

M1.2. If yes, what types of non-alcoholic drinks do you have in your home now? This is an open question. As the participant lists the drinks they have, allocate each drink listed to one of the types in the table and add the number of bottles or cartons. May need to prompt to determine whether each drink is sugar sweetened or not. When the participant finishes, prompt her/him by reminding her/him of places she/he may have forgotten: Have you remembered non-alcoholic drinks in your fridge and in your cupboards? Also need to prompt to make sure the participant has covered all non-alcoholic drink types e.g. if they don't mention milk say 'do you have any milk in your home now?' **[whatdrinkstype]**

Drinks

List of standard drinks to choose from as well as a free-entry box for less common items.

	Yes **1** No **0**
1 Fruit juice e.g. orange, apple **[sugarDrinkFruitJuice]**	
2 Squash/cordial, sugar free e.g. Robinson's blackcurrant cordial **[sugarFreeSquash]**	
3 Squash/cordial, with sugar e.g. Robinson's blackcurrant cordial **[sugarDrinksSquash]**	
4 Fizzy pop (e.g. coke, lemonade, iron bru) **[sugarDrinksFizzy]**	
5 Sugar free fizzy pop (e.g. diet coke, diet lemonade, diet fanta) **[sugarFreeFizzy]**	
6 Energy drinks (e.g. monster, red bull) **[sugarDrinksEnergy]**	
7 Energy drinks, sugar free (e.g. monster, red bull) **[sugarFreeEnergy]**	
8 Flavoured milk drinks (with sugar) **[sugarDrinksFlavouredmilk]**	
9 Flavoured milk drinks, sugar free **[sugarFreeFlavouredmilk]**	
10 Skimmed milk **[milkDrinkSkimmed]**	
11 Semi-skimmed milk **[milkDrinkSemi]**	
12 Full fat milk **[milkDrinkSemi]**	
13 Protein/sports drinks **[ProteinSportsDrink]**	
14 Ready-made flavoured drinks, with sugar (e.g. ribena, fruit shoot) **[sugarFreeReadymade]**	
15 Ready-made flavoured drinks, sugar free (e.g. ribena, fruit shoot) **[sugarFreeReadymade]**	
16 Smoothies **[sugarDrinkSmoothies]**	
17 Other **[drinksOther]**	

Other drinks [whatDrinks]	Number of other items

M1.3. Would you say that the amount of non-alcoholic **drinks** you currently have in your home is more than usual, less than usual, or about the same?

Less than usual ☐ 1 The same ☐ 2 More than usual ☐ 3

M2.1. Without opening any fridge or cupboard doors, are there any non-alcoholic drinks in your home now; displayed out in the open? A possible response may be that some drinks are behind a door, but it is a glass door and the drinks can be seen. If so, report YES. Another response could be that some drinks are out, but that they are stored very high and can only be viewed with a stool. Is so, report NO.

Yes ☐ 1 No ☐ 0

M2.2. If yes, what types of non-alcoholic drinks are displayed out in the open? This is an open question. As the participant lists the drinks they have, tick the matching drink type in the table. May need to prompt the participant to determine whether each drink is sugar sweetened or not. For example, if the participant just says 'coke' interviewer says 'is that diet coke?' If the participant just says 'orange juice' interviewer says 'is that with added sugar?' etc.

Drinks [whatdrinksdisplayed]

List of standard drinks to choose from as well as a free-entry box for less common items.

	Yes 1 No 0
1 Fruit juice e.g. orange, apple **[sugarDrinksJuiceDisplaced]**	
2 Squash/cordial, sugar free e.g. Robinson's blackcurrant cordial **[sugarFreeSquashDisplayed]**	
3 Squash/cordial, with sugar e.g. Robinson's blackcurrant cordial **[sugarDrinksSquashDisplayed]**	
4 Fizzy pop (e.g. coke, lemonade, iron bru) **[sugarDrinksFizzyDisplayed]**	
5 Sugar free fizzy pop (e.g. diet coke, diet lemonade, diet fanta) **[sugarFreeFizzyDisplayed]**	
6 Energy drinks (e.g. monster, red bull) **[sugarDrinksEnergyDisplayed]**	
7 Energy drinks, sugar free (e.g. monster, red bull) **[sugarFreeEnergyDisplayed]**	

8 Flavoured milk drinks (with sugar) **[sugarDrinksFlavouredmilkDisplayed]**	
9 Flavoured milk drinks, sugar free **[sugarFreeFlavouredmilkDisplayed]**	
10 Skimmed milk **[milkSkimmedDisplayed]**	
11 Semi-skimmed milk **[milkSemiDisplayed]**	
12 Full fat milk **[milkFullDisplayed]**	
13 Protein/sports drinks **[sugarDrinksProteinDisplayed]**	
14 Ready-made flavoured drinks, with sugar (e.g. ribena, fruit shoot) **[sugarDrinksFlavouredDisplayed]**	
15 Ready-made flavoured drinks, sugar free (e.g. ribena, fruit shoot) **[sugarFreeFlavouredDisplayed]**	
16 Smoothies **[sugarDrinksSmoothies]**	
17 Other **[drinksOtherDisplayed]**	

Other drinks **[whatDisplayedDrinks]**	Number of other items

M2.3. Are [twin1_name] and [twin2_name] allowed to get any non-alcoholic drinks by themselves, without asking you or your [husband/wife/partner] first? By this, we mean whether the twins are allowed to physically get any non-alcoholic drinks by themselves (even if they always have to ask the parent first). If the participant says 'no, they always have to come and ask first,' check whether or not the twins then go and physically get non-alcoholic drinks by themselves e.g. say 'so once they've asked, do you go and get it for them or do they get it by themselves?'

[allowed drinks1] Yes ☐ **1** No ☐ **0**

[allowed drinks2] If different for twins: [twin2_name]: Yes ☐ **1** No ☐ **0**

M2.4. If yes, what types of drinks are <twin1 name> and <twin2 name> allowed to get by themselves, without asking you first?
We are referring to non-alcoholic drinks other than water. This is an open question. As the participant lists the drinks they have, tick the matching drink type in the table. May need to prompt the participant to determine whether each drink is sugar sweetened or not.

Drinks [whatalloweddrinks]

List of standard drinks to choose from as well as a free-entry box for less common items.

	Yes **1** No **0**
1 Fruit juice e.g. orange, apple **[sugarDrinksJuiceAllowed]**	
2 Squash/cordial, sugar free e.g. Robinson's blackcurrant cordial **[sugarFreeSquashAllowed]**	
3 Squash/cordial, with sugar e.g. Robinson's blackcurrant cordial **[sugarDrinksSquashAllowed]**	
4 Fizzy pop (e.g. coke, lemonade, iron bru) **[sugarDrinksAllowed]**	

5 Sugar free fizzy pop (e.g. diet coke, diet lemonade, diet fanta) **[sugarFreeFizzyAllowed]**	
6 Energy drinks (e.g. monster, red bull) **[sugarDrinksEnergyAllowed]**	
7 Energy drinks, sugar free (e.g. monster, red bull) **[sugarFreeEnergyAllowed]**	
8 Flavoured milk drinks (with sugar) **[sugarDrinksFlavouredmilkAllowed]**	
9 Flavoured milk drinks, sugar free **[sugarFreeFlavouredmilkAllowed]**	
10 Skimmed milk **[milkSkimmedAllowed]**	
11 Semi-skimmed milk **[milkSemiAllowed]**	
12 Full fat milk **[milkFullAllowed]**	
13 Protein/sports drinks **[sugarDrinksProteinAllowed]**	
14 Ready-made flavoured drinks, with sugar (e.g. ribena, fruit shoot) **[sugarDrinksFlavouredAllowed]**	
15 Ready-made flavoured drinks, sugar free (e.g. ribena, fruit shoot) **[sugarFreeFlavouredAllowed]**	
16 Smoothies **[sugarDrinksSmoothiesAllowed]**	
17 Other **[otherdrinksAllowed]**	

Other drinks **[whatOtherDrinksAllowed]**	Number of other items

M3. On average, in the last month how often have <twin1 name> and <twin2 name> drunk…

Read each drink type in turn and wait for the participant's response before moving onto the next drink type. For sugar-sweetened and sugar-free drinks, use a relevant example from the responses given e.g. 'sugar-sweetened drinks such as coke.' Ask for all drinks whether they are in the home or not. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information e.g. they may say 'everyday', the interviewer should prompt for a fuller response e.g. 'so is that once a day, 2-3 times a day or 4 or more times a day?'

		Never or less than once a month	1-3 times a month	Once a week	2-4 times a week	5-6 times a week	Once a day	2-3 times a day	4 or more times a day
Sugar-sweetened drinks (e.g. coke lemonade, squash/cordial with sugar)	<twin1 name> **[sugarsweetenedoften1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
	<twin2 name> **[sugarsweetenedoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
Sugar-free drinks (ready-made flavoured drinks,squash/cordial, coke zero, diet coke)	<twin1 name> **[sugarfreeoften1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
	<twin2 name> **[sugarfreeoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
Fruit juice (e.g. orange juice, apple juice)	<twin1 name> **[fruitjuiceoften1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
	<twin2 name> **[fruitjuiceoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**

Protein drinks (e.g. Quaker breakfast drink, protein shake)	<twin1 name> **[proteinoften1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
	<twin2 name> **[proteinoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
Energy drinks (Red bull, Relentless)	<twin1 name> **[energyoften1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
	<twin2 name> **[energyoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
Milk (including on cereal or with coffee/tea)	<twin1 name> **[milkoften1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
	<twin2 name> **[milkoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
Flavoured milk (e.g. Strawberry, chocolate, etc.)	<twin1 name> **[flavmilkoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
	<twin2 name> **[flavmilkoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
Smoothies	<twin1 name> **[smoothiesoften1]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**
	<twin2 name> **[smoothiesoften2]**	☐ **1**	☐**2**	☐**3**	☐ **4**	☐**5**	☐**6**	☐**7**	☐**8**

Section N - MEALTIMES

This next section asks about meal times in your household.

Note that for N1 – N3 the scores of [twin1_name] are automatically copied to [twin2_name]. If parent indicates a difference between twins, score can be adjusted for [twin2_name]. Always score [twin1_name] first and then [twin2_name].

N1.1. How many days a week do your family sit at a table to eat **breakfast** together? This includes occasions when it is just [twin1_name] or [twin2_name] and yourself. A possible response might be that they sit down as a family to eat breakfast, but not at a dining table. This is not included. **[breakfasttable1]**

0 1 2 3 4 5 6 7 (days a week)
0 1 2 3 4 5 6 7
If different for twins: [twin2_name]: 0 1 2 3 4 5 6 7
[breakfasttable2] **0 1 2 3 4 5 6 7**

N2. On a weekend, how many days do your family sit at a table to eat a **midday meal** together? This includes occasions when it is just [twin1_name] or [twin2_name] and yourself. A possible response might be that they sit down as a family to eat a midday meal, but not at a dining table. This is not included. **[lunchtable1]**

0 1 2 (weekend days)
0 1 2
If different for twins: [twin2_name]: 0 1 2
[lunchtable1] **0 1 2**

N3. How many days a week do your family sit at a table to eat an **evening meal** together? This includes occasions when it is just [twin1_name] or [twin2_name] and yourself. A possible response might be that they sit down as a family to eat an evening meal, but not at a dining table. This is not included. **[eveningmealtable1]**

0 1 2 3 4 5 6 7 (days a week)
0 1 2 3 4 5 6 7

If different for twins: [twin2_name]: 0 1 2 3 4 5 6 7
[eveningmealtable2] **0 1 2 3 4 5 6 7**

N3.2. Where are most meals eaten in your home? **[mostmealseaten]**
This is an open question. Write down the response in the space below. A possible response might be that it is varied, or dependent on the meal. Ask participants to think about meals not eaten at home, and meals eaten during the weekend so that they can best estimate which place food is most commonly eaten.

……………………………………………………………………………………………………

N4.1 Do you have any rules around family mealtimes? **[familymealrules]**

Yes ☐ **1** No ☐ **0**

N4.2 If yes, what rules around family mealtimes do you have? **[rulesfamilymeals]**

1 Rules about electronic devices at mealtimes (e.g. no TV, mobile phones, computers) ☐

2 Rules about where meals are eaten (e.g. at table, not in room, in front of TV) ☐

3 Rules about what should be eaten (e.g. vegetables) ☐

4 Rules about finishing meal (e.g. always clean plate) ☐

5 Rules about second servings ☐

6 Rules about mealtime manners (e.g. cutlery) ☐

7 Other ☐

If other, please specify **[whatOtherRulesMeal]**

Section O – FOOD SHOPPING

O1.1. How often do you shop for food? This includes food shopping carried out in the shops and online via home delivery or click & collect. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information the interviewer should prompt for a fuller response. For example, if the participant says, 'monthly shop', the interviewer should say 'so is that with few small trips or no small trips? And do you do your food shopping online or in person?' **[howoftenfoodshop]**

1 ☐ Monthly, big trip or online order, no small trips/orders

2 ☐ Monthly, big trip or online order, few small trips/orders

3 ☐ Every other week, big trip or online order, no small trips/orders

4 ☐ Every other week, big trip or online order, few small trips/orders

5 ☐ Weekly, big trip or online order, no small trips/orders

6 ☐ Weekly, big trip or online order, few small trips/orders

7 ☐ As and when, no big trip or online orders, all small trips as needed

O1.2. How many days has it been since you last shopped for food? **[dayssincefoodshop]**
…… days

O1.3. Was the last shop small or big? **[lastshopsize]**

Small ☐ **1** Big ☐ **2**

Section P – ADDITIONAL GENERAL INFORMATION QUESTIONS

Finally, the last few questions are about your twin's growth.

Height and Weight

P1. Do you have any height or weight measurements for [twin1_name] or [twin2_name] that you have taken since …? These are the most recent measurements we have.

Yes ☐ **1** No ☐ **0**

P2. Would now be a convenient time to take the twins' height and weight measurements?

If yes, Using the height chart and scales we have sent, please can you take today's heights and weights for each of the twins and then read them out to me? Please remember to measure and weigh the twins in indoor clothes without shoes.

Once the twins have been measured and weighed add the measurements to the table at the bottom of the page.

If no, Would you be able to take these measurements tomorrow?

If yes, Please use the height chart and scales we have sent to take the twins heights and weights. Remember to measure and weigh the twins in indoor clothes without shoes. Once you have taken these measurements, please send them to us by email, give them over the telephone, or add them on the Gemini website.

How would you like to give these measurements?

If email, please email to Gemini@ucl.ac.uk (make sure participant includes their Gemini ID number and the date the measurements were taken).

If telephone, please call 020 7679 1723.

If no, when would be a convenient time for you to take these measurements? Repeat the text beneath tomorrow's measurements, making sure you record how participants will give the measurements and when they will give them.

Twin ID	Date measured	Height	Weight

That's the end of the interview now. Thank you very much for your time. Do you have any questions or comments?

Add any comments here.

A.7 Child Eating Behaviour Questionnaire (CEBQ), administered at T1 (15 months), T5 (age 5), T9 (age 12).

ID:

Child Eating Behaviour Questionnaire (CEBQ)

Please read the following statements and tick the boxes most appropriate to your child's eating behaviour.

	Never	Rarely	Some -times	Often	Always	
My child loves food	☐	☐	☐	☐	☐	EF
My child eats more when worried	☐	☐	☐	☐	☐	EOE
My child has a big appetite	☐	☐	☐	☐	☐	SR*
My child finishes his/her meal quickly	☐	☐	☐	☐	☐	SE*
My child is interested in food	☐	☐	☐	☐	☐	EF
My child is always asking for a drink	☐	☐	☐	☐	☐	DD
My child refuses new foods at first	☐	☐	☐	☐	☐	FF
My child eats slowly	☐	☐	☐	☐	☐	SE
My child eats less when angry	☐	☐	☐	☐	☐	EUE
My child enjoys tasting new foods	☐	☐	☐	☐	☐	FF*
My child eats less when s/he is tired	☐	☐	☐	☐	☐	EUE
My child is always asking for food	☐	☐	☐	☐	☐	FR
My child eats more when annoyed	☐	☐	☐	☐	☐	EOE
If allowed to, my child would eat too much	☐	☐	☐	☐	☐	FR
My child eats more when anxious	☐	☐	☐	☐	☐	EOE
My child enjoys a wide variety of foods	☐	☐	☐	☐	☐	FF*
My child leaves food on his/her plate at the end of a meal	☐	☐	☐	☐	☐	SR
My child takes more than 30 minutes to finish a meal	☐	☐	☐	☐	☐	SE

	Never	Rarely	Some -times	Often	Always	
Given the choice, my child would eat most of the time	☐	☐	☐	☐	☐	FR
My child looks forward to mealtimes	☐	☐	☐	☐	☐	EF
My child gets full before his/her meal is finished	☐	☐	☐	☐	☐	SR
My child enjoys eating	☐	☐	☐	☐	☐	EF
My child eats more when she is happy	☐	☐	☐	☐	☐	EUE
My child is difficult to please with meals	☐	☐	☐	☐	☐	FF
My child eats less when upset	☐	☐	☐	☐	☐	EUE
My child gets full up easily	☐	☐	☐	☐	☐	SR
My child eats more when s/he has nothing else to do	☐	☐	☐	☐	☐	EOE
Even if my child is full up s/he finds room to eat his/her favourite food	☐	☐	☐	☐	☐	FR
If given the chance, my child would drink continuously throughout the day	☐	☐	☐	☐	☐	DD
My child cannot eat a meal if s/he has had a snack just before	☐	☐	☐	☐	☐	SR
If given the chance, my child would always be having a drink	☐	☐	☐	☐	☐	DD
My child is interested in tasting food s/he hasn't tasted before	☐	☐	☐	☐	☐	FF*
My child decides that s/he doesn't like a food, even without tasting it	☐	☐	☐	☐	☐	FF
If given the chance, my child would always have food in his/her mouth	☐	☐	☐	☐	☐	FR
My child eats more and more slowly during the course of a meal	☐	☐	☐	☐	☐	SE

SCORING OF THE CEBQ

(Never=1, Rarely=2, Sometimes=3, Often=4, Always=5)

Food responsiveness	=	item mean FR
Emotional over-eating	=	item mean EOE
Enjoyment of food	=	item mean EF
Desire to drink	=	item mean DD
Satiety responsiveness	=	item mean SR
Slowness in eating	=	item mean SE
Emotional under-eating	=	item mean EUE
Food fussiness	=	item mean FF

*Reversed items

Wardle, J, Guthrie CA, Sanderson, S and Rapoport, L. Development of the Children's Eating Behaviour Questionnaire. *Journal of Child Psychology and Psychiatry.* **42,** 2001, 963-970.

NB: There is an error in the text of this paper concerning the scoring of the CEBQ which is given as 0 - 4. In fact responses were scored 1- 5 and the means and standard deviations given in the tables reflect this.

A.8 Decision tracking document for HEI update

This document outlines the updates to the original Home Environment Interview (HEI) with reasons for the question's modification. All modifications are listed with their corresponding location in the original HEI.

Section A - GENERAL INFORMATION QUESTIONS

A1-A5. Unchanged.

A6. This question currently asks about living circumstances, the question and responses are fine. However, the wording underneath this question may need modification to ensure it is inclusion and in line with the legalization of gay marriage that occurred since the development of the HEI. Please see tracked changes on update document for full details.

A7-9. Unchanged.

Section B – CHILDCARE

This section has been removed as it was not used in the 4-year scoring. and I do not think that the questions are gathering information that we need.

***as Section B has been removed the letter used for each of the sections will be changed accordingly e.g. original HEI section C will now become section B, original HEI section D will now become section C.*

Section C – HOUSE AND NEIGHBOURHOOD -> Updated to Section B – HOUSE AND NEIGHBOURHOOD

C1-C3. -> **B1-B2**

C3-13. -> B3-13. Question removed as they were not used in the composite scoring and therefore unnecessary. Questions taken from the baseline questionnaire have instead been added to gather the sociodemographic information that was used to generate the SES-composite score. We are collecting this information again to gain an update of the SEP of Gemini families and to ascertain whether anything has changed overtime. The questions capture information about maternal educational qualifications, occupational status, marital status, partners education and occupational status, household tenure, household income, number of bedrooms, number of cars, postcode will be used for the Index of multiple deprivation.

Section D – PHYSICAL ACTIVITY ENVIRONMENT -> Updated to Section C – PHYSICAL ACTIVITY ENVIRONMENT

D1-D4. -> **C1-C4**. Wording unchanged

D5. -> **C5.** Previous question asked parents if they took children to regular play sessions to be physically active, e.g. toddler activity classes or soft play areas. The wording has been modified to ensure the question is appropriately framed to ask about children aged 11-12. "for example, sports clubs, swimming lessons or other activities?" see tracked changes on HEI update document.

D6-D13. -> C6-C9. Wording unchanged.

D9. Question wording updated as the previous question asked about whether the twins had a “usable tricycle, bike, scooter or wheeled toy”. This was changed to “have a useable bike, scooter, roller blades or skateboard” to be more relevant to the children aged 11-12

D10-D13 -> C10-C13. Wording unchanged.

Section E – CHILDREN’S ACTIVITY -> Updated to Section D – CHILDREN’S ACTIVITY

E1 – E2. -> D1-D4. Removal of these questions as they are not used in the composite scoring and therefore not necessary for the purpose of the HEI.

E5.1-E5.2. -> **D5.1-D5.2.** Removal of this section as these questions are not used in the composite scoring and are not relevant to what we are interested in within this HEI**.** Feedback from Steph confirmed that the removal of this section would not be detrimental to the overall measurement of the home environment.

Section F – PARENTAL MODELING OF ACTIVITY -> Updated to Section D – PARENTAL MODELLING OF ACTIVITY

F1-F5. -> D1-D5. Unchanged.

F6 Removed question as not used in the composite score.

F7. -> D**6.** In the example for this question it currently mentions “walking to and from nursery”. Suggest modifying the wording of this to “walking to and from school” so that it is age appropriate for the twins.

F8. Removed question as not used in the composite score.

F9. -> D7**.** Unchanged.

F10. Removed question as not used in the composite score and the question is covered in the next question.

F11 -> D8. Wording unchanged.

Questions E1.-E2. from the previous section on children’s activity were moved to here to capture context and parental subjective view of their twins’ activity levels. Renamed to D9, D10 and D11.

D9. Compared to other children of the same age and sex, how physically active are [twin1_name] and [twin2_name]? Please choose a score from 1 to 5 for each child separately: 1 means much less active, 2 means somewhat less active, 3 means about average, 4 means somewhat more active, 5 means much more active.
<twin1 name>: 1 2 3 4 5
<twin2 name>: 1 2 3 4 5

D10. Do you think [twin1_name] gets enough physical activity?
Yes □ No □

D11. Do you think [twin2_name] gets enough physical activity?
Yes □ No □

Section G - MEDIA -> Updated to Section E – MEDIA

This section has been updated significantly in this 2019 version of the HEI as media was identified as a key factor associated with increased adiposity in childhood from the HE-adiposity systematic review. Furthermore, the changing technology landscape and rise in social media use means that it is important to add questions that capture the twins use of media as it is today within the home. This section aims to capture a broader range of electronic devices (e.g. mobile phone, tablet, etc.)

G1. -> E1. Question wording modified in accordance with the Ofcom Annual 'Child and Parent's Media Use' survey which was updated in 2015 to include smart TV and standard TV rather than just the standard TV.

G2. Removed as irrelevant

G3. -> **E2.** Question modified based on the OfCom question … "Do you have a digital video recorder (such as Sky+, nowTV, Virgin TiVo, YouView, Freeview+) and/or streaming stick (nowTV, Amazon fire TV, Roku Stick) that allows you to record/store TV programmes and pause/rewind live TV programmes"

New wording of questions is as follows

"**E2.** How many working DVD/Blu-Ray players/streaming devices (e.g. Amazon Prime, nowTV) or digital video recorders (e.g. Sky+, NowTV, Virgin, YouView, Freeview+) do you have in your home? Include DVD/Blu-ray players or streaming devices that are temporarily broken if there is a plan to get them fixed. Also include DVD players within computers or games consoles if they are used to watch films on.

…... (enter 99 if Don't know, enter 0 if none)

G4.1- G4.2. Questions that ask about twins' media usage have been moved to a new section come after the questions about mothers and partners media viewing.

G4.3-G4.6 -> E3.1-E3.6.2 Question moved to come before questions about twins' media viewing. The wording of these questions has also been updated from 'How long do you watch TV or DVDs…." to mirror the wording used in the Ofcom 2018 annual survey: "watch television programmes, movies or online media such as Netflix, Amazon Prime, NowTV, Youtube videos on a TV set". I have suggested a further modification of "on an electronic device (e.g. TV/computer/laptop/tablet computer)" to incorporate the change in how people watch TV shows and other media services, over recent years it has moved from people commonly viewing media via TV to predominantly viewing media through tablet or mobile devices or computers, rather than TV.

E3.1 On average, how long do you watch TV programmes, movies, or on demand media services (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. computer/laptop/tablet) on a typical weekday (Monday to Friday), at this time of year? Only include viewing **in the home**.

Modified the way that this is scored from the following options:

Morning (6am to 12 noon) ……. hours ……. minutes per day

Afternoon (12am to 6pm) …….. hours ……. minutes per day

Evening (6pm to midnight) ……. hours ……. minutes per day

Feedback from Emma Boyland, I modified the wording of this question further to split questions about time spent viewing media content into questions specifically around media sources that have commercial and non-commercial. However, feedback during cognitive interviewing with parents of 11-13-year olds suggested that it would be difficult to separate these out. The decision was made to have one question that looked at overall viewing, rather than trying to separate time viewing ad-based and non-ad based. Additionally, feedback from parents during cognitive interviews highlighted that parents found breaking down the day into time periods confusing. We think this is due to the way that the measure is administered – as it is over the telephone parents found it easier to just give the time for the full day. The interviewer should prompt around times e.g. 'does this including viewing in morning before school/work?'

New response scoring below:

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E3.2 On average, how long does your [husband/wife/partner] watch TV programmes, movies, or on demand media services (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. computer/laptop/tablet) on a weekday (Monday to Friday), at this time of year? This includes time spent watching online videos via services such as YouTube, Facebook, etc. Only include viewing **in the home**.

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E3.3 On average, how long do you watch TV programmes, movies, or online media (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. computer/laptop/tablet) on a typical weekend day, at this time of year? This includes time spent watching online videos via services such as YouTube, Facebook, etc. Only include viewing **in the home**.

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E3.4 On average, how long does your [husband/wife/partner] watch TV programmes, movies, or online media (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. TV/computer/laptop/tablet) on a typical weekend day, at this time of year? This includes time spent watching online videos via services such as YouTube, Facebook, etc. Only include viewing **in the home**.

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E3.5 On average, how long do [twin1_name] and [twin2_name] watch TV programmes, movies, or online media (e.g. Netflix, Amazon Prime, YouTube videos) on an electronic device (e.g. desktop computer/laptop/tablet computer) on a typical weekday (Monday to Friday), at this time of year? Only include viewing **in the home**. This includes time spent watching online videos via services such as YouTube, Facebook, etc. Write hours and minutes (HH:MM) e.g. if one hour 15 minutes, enter 01:15.

E3.5.1 [twin1_name] ……. hours ……. minutes per day

E3.5.2 [twin2_name] ……. hours ……. minutes per day

E3.6 On average, how long do [twin1_name] and [twin2_name] watch TV programmes, movies, or online media services (e.g. Netflix, Amazon Prime, YouTube) on an electronic device (e.g. TV/desktop computer/laptop/tablet computer) during the following times on a typical weekend day, at this time of year? This includes time spent watching online videos via services such as YouTube, Facebook, etc. Only include viewing **in the home**. Write hours and minutes (HH:MM) e.g. if one hour 15 minutes, enter 01:15.

E3.6.1 [twin1_name] ……. hours ……. minutes per day

E3.6.2 [twin2_name] ……. hours ……. minutes per day

Original HEI G5. -> E4. Wording unchanged.

G6. + G8 + G10. -> E9. These questions have been combined to generate a new question (E9.) that asks about the twins' use and access to different electronic devices in the bedroom. The way this question is scored has been modified to capture the number of devices available in child's bedroom and which devices they own, as shown below:

Type of device	[twin1_name]		[twin2_name]	
	Yes	No	Yes	No
1. TV/Smart TV	☐	☐	☐	☐
2. Computer or laptop	☐	☐	☐	☐
3. Tablet	☐	☐	☐	☐
4. Mobile phone/smartphone	☐	☐	☐	☐
5. Games console	☐	☐	☐	☐

The layout and question response options have been modified in this way to allow more devices to be incorporated into the response options e.g. now asks about TV, computer, tablet, mobile, games console. Question asks about child's ownership of mobile phones (standard or smart phone) as ownership of mobile phone increased to 74% in 2018 amongst 12-year olds. This question aims to specifically capture bedroom usage and have been moved to be asked with questions around parental rules/policies around media use

G7. -> **E5.** Question wording updated to include tablet computers. Amongst children aged 8-11 the ownership of tablet computers has risen from 2% in 2011 to 47% in 2018 (Ofcom, 2019). It is important for the updated home environment interview to capture this change in media use.

G9. -> E6. Unchanged

E7. New question incorporated to capture children's access to mobiles/smart phones in the home. The previous HEI did not cover this due to the age of the twins when administered and popularity and availability of phones 2010 was not as prevalent as it has become in the past 9 years.

E8.1-E8.6.2 Question added to capture the time spend playing non-active video games e.g. traditional games consoles or desktop computer/laptop. This question specifically asks about time spent on weekdays. Wording and scoring adapted from questions E4.1-E4.8. question added to capture parental modelling of sedentary behaviour and electronic media use via use of inactive video games on both weekdays and weekend days and the twins' own engagement in video game playing. Questions included below.

E8.1 On average, how long do you spend playing video games on a typical weekday (Monday to Friday), at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**. *If respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.* ……. hours ……. minutes per day

E8.2 On average, how long does your [husband/wife/partner] spend playing video games on a typical weekday (Monday to Friday), at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**.

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E8.3 On average, how long do you spend playing video games on a weekend day, at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**. *For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.*

……. hours ……. minutes per day

E8.4 On average, how long does your [husband/wife/partner] spend playing video games on a weekend day, at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**.

……. hours ……. minutes per day

For example, if respondent answers 1 hour 15 minutes, enter 01:15, if none enter 0.

E8.5 On average, how long do [twin1_name] and [twin2_name] spend playing video games on a typical weekday (Monday to Friday), at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**.

E8.5.1 [twin1_name] ……. hours ……. minutes per day

E8.5.2 [twin2_name] ……. hours ……. minutes per day

E8.6 On average, how long does [twin1_name] and [twin2_name] spend playing video games on a typical weekend day, at this time of year? This includes on a handheld device, games console or computer/laptop. Only include non-active game time (excl. games that require physical movement e.g. Wii) **in the home**. Write hours and minutes (HH:MM) e.g. if one hour 15 minutes, enter 01:15.

E8.6.1 [twin1_name] ……. hours ……. minutes per day

E8.6.2 [twin2_name] ……. hours ……. minutes per day

New additional questions added for update to capture **parental rules and policies around media use:**

E11.

Original HEI G11. -> E10.1 Modified question from asking about 'rules around TV watching or computer use' to specifically asking about 'rules around TV watching'. This was done as feedback from the cognitive interviews revealed that parents had different rules for computer use and TV watching. Parents stated that they felt they needed more specific rules around computer use but they did not feel that TV rules were required as they tended to watch TV as a family. Computer was less observed activity and parents viewed the children as more vulnerable on the computer.

Question as follows:

E10.1 Do you have any rules around TV watching?

Yes ☐ No ☐ *If No, skip E11.2*

Elaboration question added to capture the number of rules and what sorts of things the parents had rules about.

E10.2 If yes, what rules around TV watching do you have? This is an open response. The participant should provide the rules they have, and the researcher categorizes the responses as best they can. Prompt the participant to check that they have not forgotten anything.

☐ Rules about what they are allowed to watch on TV

☐ Rules about when/what times they are allowed to watch TV

☐ Rules about how much time they are allowed to spend watching TV

☐ Rules around watching TV whilst at the dinner table

☐ Regularly check what is being watched on TV watching

☐ Limit access to inappropriate content via parental pin controls on TV

☐ Other (see below)

If other, please could you specify these rules?

Additional question incorporated to capture computer rules separately to TV rules.

E11.1 Do you have any rules around computer use?

Yes ☐ No ☐ *If no, skip E12.1*.

E11.2 If yes, what rules around computer use do you have? This is an open response. The participant should provide the rules they have, and the researcher categorizes the responses as best they can. Prompt the participant to check that they have not forgotten anything.

☐ Rules about what they use the computer for

☐ Rules about when/what times of the day they are able to use the computer

☐ Rules about the amount of time allowed to use the computer

☐ Rules around what websites they are allowed access

☐ Regularly check what they are doing on the computer

☐ Limit access to inappropriate content via parental control on computer

☐ Other (see below)

If other, please could you specify these rules?

This modification to the responses in questions E10.2, E11.2 and E12.2 aim to capture more detailed information about the type and amount of rules/monitoring strategies that parent's use. Research has shown that monitoring of media use can have protective effects socially and physically (Gentile et al 2014). It would be interesting to be able to explore this in the Gemini cohort.

Original HEI G12-G13 -> E11.3-E11.4 Wording unchanged.

New question added - E12.1, E12.2 - these new question aims to capture parents rules/limit setting around mobile phones/tablets. First question is a simple Yes, No and then follow on question if answered yes to gain more detailed response. The rules are developed based on the questions/statements used in the Kaiser Family foundation questionnaire and Ofcom survey:

If yes, what rules around mobile phone or tablet use do you have?

Rules about types of website or apps they can download/use □
Parental controls used to block or monitor use □
Monitor access to websites and check browser history □
Rules about how much time they can spend on phone or tablet □
Rules about when they can use phone or tablet □
No, do not have any rules □
Other rules □

If you have any other rules, please could you describe these rules?

New questions added E12.3 and E12.4 used similar format to E11.3 and E11.4.
New question E13.4. Addition of question about parent rewarding child's behaviour with mobile/tablet use. This was not included in the previous home environment interview (HEI) due to the age of the children (4 yrs). Changes in technology use since 2010, when HEI was developed, has led to increase in ownership, access and use of mobile and tablets.

Do you ever reward good behaviour with extra mobile phone or tablet use?

Yes □ No □
If different arrangement for twins: <twin2 name>: Yes □ No □

E12.3-12.4 Question added with same wording as E11.3 and 11.4 but rather than TV/computer, it asks about mobile phone/ tablet computer.

Original HEI G14-18 -> E13.-13.4 Wording of these questions modified to ask about use of TV or an electronic device during meal time/eating occasions.

REMOVED SECTION ON CHILD SLEEP – this is outside of the scope the HEI. It was also not used in the composite score for the HEI. The T9 questionnaire also includes questions on sleep so it is not necessary to include this here.

To replace this section, I have incorporated measures of media use in children so that we can capture the twins' use of electronic media devices and which devices are used the most. The parent-report of this can then be assessed against the twins' own self-reported media use (T9 data collection twin questionnaires)

SECTION F – CHILDREN'S SOCIAL MEDIA USE

F1. Following input from Emma B and current figures of social media in 12-year-olds, question incorporated to capture access to social media accounts e.g. their own account or another person's account (parent/sibling/other family member)

F5. Do [twin1_name] and [twin2_name] have their own social media accounts and/or have access to other's accounts?

Yes, own account ☐ Yes, access to other's account ☐ No ☐ I don't know ☐

If different arrangement for twins: [twin2_name]:

Yes, own account ☐ Yes, access to other's account No ☐ I don't know ☐

If No skip to F3

F2. Incorporated a follow-on question from this to ask about the specific types of social media accounts the children have access to.

F6. If yes, which of the following social media platforms do [twin1_name] and [twin2_name] use and have access to? (Ask parent to choose as many that apply)

[twin1_name]	**[twin2_name]**
☐ Snapchat	☐ Snapchat
☐ Facebook	☐ Facebook
☐ YouTube	☐ YouTube
☐ Instagram	☐ Instagram
☐ Vimeo	☐ Vimeo
☐ Twitter	☐ Twitter
☐ Tiktok	☐ Tiktok
☐ WhatsApp	☐ WhatsApp
☐ Other	☐ Other

If other, please specify [twin1_name] _______________

[twin2_name] _______________

F3. & F4. Question added to capture parent rules and limit setting around online media use. This was not a feature captured in the original HEI due to the age of the twins and it not being a focus. However, in the next round of home environment data collection the Gemini twins will be 11-12 years old and advances in technology/societal changes that have occurred over the past decade has meant that media online and social media sites are now more prominent feature of everyday life and can have a negative in development during childhood (Vossen, Piotrowski, Valkenburg, 2014). It is therefore important to capture this in the updated HEI.

E14.3 Following input from Emma B question incorporated to capture access to social media accounts.

E14.4. As above, question incorporated to ascertain the types of social media platforms that the twins use on a regular basis.

Sections H - N: FOOD AVAILABLILTY. -> Updated to Sections G – K: FOOD ENVIRONMENT

The header for this section has been modified to also include ‘food environment’ as the section includes questions about parental policies around food.

Section G – Fruit

H.1.1-H.5.5. -> G1.1.1-G5.5. Unchanged.

H5.3. Removed – asks about twins asking for help to get fruit, not relevant for the twins at age 12 as they will be able to get food without help from parents.

Original H5.4. -> G5.3 Wording changed to from previous

Original: “Are <twin1 name> and <twin2 name> allowed to get any **fruit** by themselves, without your help?”

Updated: “Are <twin1 name> and <twin2 name> allowed to get any **fruit** by themselves, without asking you or your <husband/wife/partner> first?”

Original H5.5. Removed – asks about twins asking for help to get fruit, not relevant for the twins at age 12 as they will be able to get food without help from parents.

H.6. -> **G.6**. Unchanged.

Section K – Vegetables -> Updated to Section H - Vegetables

K.1.1. - K.4.2. -> H.1. – H4.2. Unchanged.

K4.3. Removed question as it is no longer relevant for the age of the twins. Question previously asked about getting vegetables without help from parents, but children aged 12 are unlikely to need assistance to get food themselves.

K4.4. -> **H4.3.** Wording modified to make more appropriate for age of the twins. The question now asks about whether the twins are allowed to get any vegetables by themselves without asking for permission from parent first. “without your help” changed to “without asking you first”

K4.5. Removed question as it is no longer relevant for the age of the twins. Question previously asked about getting vegetables without help from parents, but children aged 12 are unlikely to need assistance to get food themselves.

K.5. -> **H.5**. Unchanged.

Section L – Savoury snacks -> Updated to Section I Salty snacks

In this section the wording has been modified from ‘savoury snacks’ to ‘salty snacks’. This was done as feedback from the original HEI highlighted confusion from parents about what consisted a savoury snack. The nutritional value of some savoury snacks e.g. rice cakes, crackers, or Ryvita are very different to others savoury snacks such as wotsits, cheetos or Doritos. This section is trying to capture snack foods such as crisps.

L1.1. – L.2.1. -> I1.1-I.2.1. Unchanged

L2.2. Removed question as it is no longer relevant for the age of the twins. Question previously asked about getting vegetables without help from parents, but children aged 12 are unlikely to need assistance to get food themselves.

L2.3 -> I2.2. As with H4.2 the wording has been changed to make it more appropriate for 12-year olds. Modified from “…allowed to get any savoury snacks by themselves, without your help” to “…allowed to get any salty snacks by themselves, without asking you or your <husband/wife/partner> first?”

L2.4 Removed question as it is no longer relevant for the age of the twins. Question previously asked about getting vegetables without help from parents, but children aged 12 are unlikely to need assistance to get food themselves.

L2.5 -> I.2.3. Unchanged

Section M - Sweet snacks -> Updated to Section J Sweet Snacks

In this section the numbering starts at **M.3.1.** rather than **M.1.1**. It is unclear why this is (I think it must be an error?). I have amended the numbering to start at **J.1.1.**

M.3.1. -> J.1.1. Wording unchanged.

M.3.2. -> J.1.2. Wording unchanged.

M.3.3 -> J.1.3. Wording unchanged.

M.4.1 -> J.2.1. Wording unchanged.

M.4.2 Question removed as no longer relevant for the age group.

M.4.3 -> J.2.2. question asks about twins being allowed to get sweet snacks by themselves at home without parental help. The wording of this has been modified to make it more appropriate for the older age of the twins. Modified from “without your help” to “without asking you or your <husband/wife/partner> first”

M.4.4 Question removed as no longer relevant for the age group.

M.4.5 -> J.2.3. Unchanged.

Section N – Confectionery -> Updated to Section K - Confectionery

N1.1. – N.2.1. -> K1.1.- K.2.1. Unchanged.

N.2.2 Item removed. Question asked about twins being able to get food by themselves, this is no longer relevant for the age group.

N.2.3. -> K2.2. Question asks about twins being allowed to get sweet snacks by themselves at home without parental help. The wording of this has been modified to make it more appropriate for the older age of the twins. Modified from "without your help" to "without asking you or your <husband/wife/partner> first". Unlike the previous question that was removed, this question asks about whether the twins are 'allowed' to get food by themselves and the item is used in the original HEI composite scoring.

N.2.4. Question removed as no longer relevant for the age group.

Original N.2.5. -> K.2.3. Unchanged.
Section O – FAST FOOD -> Updated to Section L – FAST FOOD

unchanged.

Section P – DRINKS -> Updated to Section M - DRINKS

P1.1. -> **M1.1.** Unchanged.

P1.2. -> **M1.2.** Due to the older age of the twins and the changes in the types of drinks available on the market I have added the response option of Caffeinated energy drinks (e.g. monster, relentless, red bull). These are commonly consumed by adults and children and are associated with negative health effects. It is therefore important to capture this through the update of the HEI. In addition, response options have been added for Protein drinks, Fruit smoothies, and flavoured milk (strawberry, chocolate, vanilla).

P1.3-P1.4. – M1.3-M2.1 Unchanged.

P1.5. -> **M2.2** As with M1.2 added caffeinated energy drinks, protein drinks, fruit smoothies, and flavoured milk (strawberry, chocolate, vanilla). to the response options.

P1.6. & P.1.7. -> M2.3 & M2.4. Wording slightly modified from "without your help" to "without asking you or your <husband/wife/partner> first". Unlike the previous question that was removed, this question asks about whether the twins are 'allowed' to get food by themselves and the item is used in the original HEI composite scoring. As with M1.2 and M1.5. Caffeinated energy drinks, protein drinks, Fruit smoothies, and flavoured milk (strawberry, chocolate, vanilla). have been added as a response option.

P2.0-2.1. Removed not necessary to ask this question as 12-year olds are able to get drinks/food on their own without parental assistance. Unlike 4-year olds who are less able to get these without asking.

P2.2. -> M2 Again, energy drinks have been added as a response option to capture the twin's consumption of caffeinated energy drinks. Protein drinks, Fruit smoothies, and flavoured milk (strawberry, chocolate, vanilla) have been added as a response option.

Section Q – MEALTIMES -> Updated to Section N - MEALTIMES
Based on the scoring and Steph's thesis – it looks like only the questions relating to family mealtimes were included in the analysis. I therefore propose removing the other questions.

Q1.1. & **Q1.2.** Removed as not used in the analysis or 4-year composite scoring

Q1.3. -> N1.1 Wording unchanged.

Q2.1 -> N1.2 Wording modified to be age appropriate "How many days a week do [twin1_name] and [twin2_name] eat **breakfast** elsewhere for example at nursery or preschool" changed to "How many days a week do [twin1_name] and [twin2_name] eat **breakfast** elsewhere for example at school? This includes food prepared at home, foods purchased on the way to school and food prepared by the school – provided they are eaten outside the home" this was retained even though it is not included in the original composite score as many children aged 11-12 eat breakfast outside of home e.g. on the way to school so we felt that it would be useful to capture this information.

- Q2.2. I propose removing these questions, they were not included in the scoring for Steph's thesis or used in the composite score. Only questions relating to family meal time frequency were included.
Q2.3. – **N2.** Unchanged.

Q3.1-Q3.2. Like with Q2.2 these questions were not used in the home environment interview scoring and therefore I propose removing them as it is unlikely they will be used.

Q3.3. -> **N3.** Wording modified to make more age appropriate, modified from the original wording of "How many days a week do your family sit at a table to eat a **midday meal** together?" to "On a weekend, how many days do your family sit at a table to eat a **midday meal** together?" This modification was necessary as 12-year olds would not eat midday meal at home during the week as they will be at school so the original question would be irrelevant.

Q4.1. & Q4.2. I propose removing these questions, they were not included in the scoring for Steph's thesis or used in the composite score. Only questions relating to family meal time frequency were included.

Original Q5. -> **N4.1** This question was included in the original HHS, which this measure was developed from. Steph noted that this is not used in the composite score and location of eating is covered in the previous questions, so this question is redundant.

N4.2. This question has been added to ask about parental rules around mealtimes. The question aims to gain a greater insight into if rules are enforced at mealtimes, the type of rules that parents may employ with children aged 11-12 and whether this differs based on socioeconomic status of household (using SES-composite and individual components of SES-composite measure).

Section R – FOOD SHOPPING

The food shopping aspect was not used in the home environment composite score. It was used as an indicator of whether the food available in the home was typical or less due to not recently food shopping. This is captured throughout the food availability section via the question "is the food available usual, less than, or more than usual amount"

R1.1. -> O1.1. This question asks about the parent's food shopping habits. It currently only refers to traditional modes of shopping as online shopping was not a common feature of society when the HEI was developed. The question wording and categorisation has now been modified to incorporate online shopping via delivery or click and collect.

O1.1. How often do you shop for food? This includes food shopping carried out in the shops and online via home delivery or click & collect. This is an open question. Do not read the response options aloud but categorize the response accordingly. If the participant does not provide enough information the interviewer should prompt for a fuller response. For example, if the participant says, ‘monthly shop’, the interviewer should say ‘so is that with few small trips or no small trips? And do you do your food shopping online or in person?’

□ Monthly, big trip or online order, no small trips/orders

□ Monthly, big trip or online order, few small trips/orders

□ Every other week, big trip or online order, no small trips/orders

□ Every other week, big trip or online order, few small trips/orders

□ Weekly, big trip or online order, no small trips/orders

□ Weekly, big trip or online order, few small trips/orders

□ As and when, no big trip or online orders, all small trips as needed

R1.2-> O1.2 question removed as outside the scope of the HEI.

R1.3-R1.4 -> O1.2 - O1.3 Unchanged.

Section S – ADDITIONAL GENERAL INFORMATION QUESTIONS -> Section P – ADDITIONAL GENERAL INFORMATION QUESTIONS.

S.1. -> P.1.
S.4. -> P.2.

A.9 Invitation letter sent to Gemini families at age 12

Dear <<Mothers name>>,

We recently contacted you to tell you about our new round of data collection. We would like to take this opportunity to thank you for completing our new online questionnaire and for the computer task. Thanks to your continued participation, Gemini is now considered one of the most important resources for understanding how children's eating patterns develop.

We are very excited to let you know that as part of our new round of data collection we will soon be calling you to collect information about the home environment. The interview is a one-off phone call, which takes around 30 minutes to complete

Why are we calling you?
Well, you may remember being interviewed over the telephone about your home when your twins were 4 years old. We asked lots of questions about the food in your home, the opportunities for physical activity and about electronic devices in the home. Thanks to your incredible support and time spent helping us, we were able to collect valuable information about how aspects of the home influence development during childhood.

A lot of changes happen in the home as children grow up. With your support we are about to launch a new and exciting telephone interview study. The aim of this new study is to collect information about your home now yours twins are 12 years old.

Before we contact you, we would like to ask if you would be happy to participate in this part of the study?

If you are happy to take part, please follow the link to book a time and date that would be best for you:
https://calendly.com/geminihomeenvironment/home-environment-interview

If the available options do not fit your schedule, please do get in contact via email (gemini@ucl.ac.uk) and we will do our best to find a suitable time to call you.

Contact information
If you have any queries about the study, please contact the lead researcher on this project Alice Kininmonth [a.kininmonth@ucl.ac.uk].

Kind regards,
The Gemini Team
Alice, Clare, Ali, Andrea and Silvia.

Approved by the UCL Research Ethics Committee – Project ID number 1624/004.
All data will be collected and stored in accordance with GDPR.

A.10 Contact letter and online survey for expert panel

Dear Dr/Professor (surname),

I hope this email finds you well. My name is Alice Kininmonth, I am a PhD student at the University of Leeds. My research involves investigation of the role of the home environment in the risk of weight gain in school-aged children. This research aims to identify potentially modifiable 'risk factors' in the home environment thereby providing new insights to develop useful guidelines for parents to engage in healthy home policies. This project is undertaken under supervision of Dr Alison Fildes, Dr Andrea Smith and Dr Clare Llewellyn. Using a modified version of an existing psychometric measure, we will be collecting home environment data via telephone interviews from families with twins aged 12-13.

The individual item selection from the psychometric tool which will be used to calculate an overall composite 'Home Environment score' was based on peer-reviewed published literature but the published evidence is not always strong, I would like to reinforce these choices with an estimate of expert agreement using the Delphi method (a consensus-based systematic technique that provides a method of aggregating informed judgments from a group of experts).

As an expert in the field of health behaviour research, I would very much appreciate your contribution. If you are willing to contribute your opinion to this expert consensus, then I would please ask that you indicate for each of the listed home environment variables whether you believe it to be related to an increased or decreased risk for weight gain in childhood. There is also an option to select 'not sure'.

Any further comments are also welcome, with a comments box at the bottom of each page. Please use the link below to submit your responses. The entire form should take roughly < 5 minutes to complete.

https://tinyurl.com/home-environment

Responses will be anonymised and there will not be any follow-up on your individual answers; though I will circulate the consensus conclusions upon project completion. Due to the time-sensitive nature of our research, we would be grateful if you provide us with responses to the survey within one month (12th April 2020).

Please feel free to contact me, Alice Kininmonth [a.r.kininmonth@leeds.ac.uk] if you have any further queries.

Thank you very much for your time.
Kind regards,

Alice Kininmonth

PhD Student
University of Leeds
Email: a.r.kininmonth@leeds.ac.uk

Q1. For each home environment variable, please indicate whether you think it is related to increased or decreased risk for weight gain in childhood

	Probably/definitely INCREASED risk	Probably/definitely DECREASED risk	Not sure
Outdoor recreaction area close to home	○	○	○
Garden/yard that the child can play in	○	○	○
Indoor recreation centres close to home	○	○	○
Play equipment in the garden/yard	○	○	○
Greater frequency that the child is allowed to play actively in the garden/yard	○	○	○
Greater frequency that the child is allowed to play actively inside the home	○	○	○
Larger garden/yard that child can play in vs. smaller garden/yard	○	○	○
Child has usable bike, scooter, rollerblades, or skateboard	○	○	○
Parental support of physical activity	○	○	○
Parental modelling of physical activity	○	○	○
Greater amount of media equipment in child's bedroom (e.g. TV, computer, games consoles, laptops, tablets, phones)	○	○	○
Greater amount of media equipment in the home (e.g. TVs, DVD players, games consoles, laptops, tablets, mobile phones)	○	○	○
Greater maternal time engaged in screen-based viewing	○	○	○
Greater paternal time engaged in screen-based viewing	○	○	○
Greater maternal time playing video games (I.e. games console, phone, tablet, computer)	○	○	○

Greater paternal time playing video games (i.e. games console, phone, tablet, computer)	◯	◯	◯
Parental rules around use of media equipment	◯	◯	◯
Parental use of electronic device time (e.g. phone, TV, computer, games console) as a reward	◯	◯	◯
Parental limits on media equipment time (e.g. phone, TV, computer) if the child misbehaves	◯	◯	◯
Child eats whilst watching TV or using an electronic device	◯	◯	◯
Greater frequency of eating whilst watching TV or using an electronic device	◯	◯	◯
Child has access to and use of social media	◯	◯	◯
Parental rules around child's online activities and social media use	◯	◯	◯

Q2. Any comments

Q3. For each home environment variable, please indicate whether you think it is related to increased or decreased risk for weight gain in childhood

	Probably/definitely INCREASED risk	Probably/definitely DECREASED risk	Not sure
More types of fruit in the home	○	○	○
Fruit on display (visible)	○	○	○
Child is allowed to help themselves to fruit	○	○	○
More types of vegetables in the home	○	○	○
Ready-to-eat vegetables in the fridge or on the kitchen counter	○	○	○
Child allowed to help themselves to vegetables	○	○	○
More types of energy-dense snack in the home	○	○	○
Child allowed to help themselves to energy-dense snack	○	○	○
Energy-dense snacks on display (visible)	○	○	○
Greater frequency of eating fast food/takeaways	○	○	○
Greater frequency of convenience foods (e.g. microwave meals, oven chips) as main meal	○	○	○
Fruit juice or smoothies in the home	○	○	○
Fruit juice or smoothies on display (visible)	○	○	○
Full-fat milk in the home	○	○	○
Skimmed milk in the home	○	○	○
Semi-skimmed milk in the home	○	○	○
Child is allowed to help themselves to milk	○	○	○
Child is allowed to help themselves to fruit juice or smoothies	○	○	○
Sugar-sweetened drinks in the home	○	○	○

Sugar-sweetened drinks on display (visible)	○	○	○
Child is allowed to help themselves to sugar-sweetened drinks	○	○	○
Family meals at the table	○	○	○
Sugar-free drinks in the home (excluding water)	○	○	○
Sugar-free drinks (excluding water) on display (visible)	○	○	○
Child is allowed to help themselves to sugar-free drinks (excluding water)	○	○	○
Caffeinated energy drinks in the home	○	○	○
Caffeinated energy drinks on display (visible)	○	○	○
Child is allowed to help themselves to caffeinated energy drinks in the home	○	○	○
Greater frequency of meals eaten together at the table as a family	○	○	○
Parental rules around family mealtimes	○	○	○
Parental restriction of unhealthy foods	○	○	○
Parental use of food to make child feel better	○	○	○
Parental use of food as a reward	○	○	○
Parental encouragement for the child to eat fruit and vegetables	○	○	○
Parental monitoring of the child's unhealthy food intake	○	○	○
Parental control of child's food intake	○	○	○
Parental pressure for the child to eat	○	○	○
Parental covert restriction of child's unhealthy food intake	○	○	○

A.11 Recruitment poster for piloting

A.12 Cognitive interviews participant information and informed consent

UCL

UNIVERSITY OF LEEDS

PARTICIPANT INFORMATION SHEET AND CONSENT FORM

Study of the measurement of the home environment in UK Families

We would like to invite you to take part in a short one-to-one feedback session. Before you decide whether you wish to take part, you need to understand why the research is being done and what it would involve. Please take some time to read this information sheet carefully and discuss it with others if you wish.

All proposals for research using people are reviewed by an ethics committee before they can proceed. This study has been approved by the UCL Research Ethics Committee – Project ID number 1624/004.

What is the purpose of this study?
The purpose of this study is to gain a better understanding of how to measure the environment within the family home. We are trying to understand what different households look like in terms of the types of electronic devices (e.g. phones, TVs, computers and more), foods and drinks, and activity equipment (e.g. bikes, scooters) available. We are also interested in how you and your family spend your time in the home. In order to do this, we need to speak to parents of children aged 11-13 about their understanding of some questions.

Do I have to take part?
No, you are free to not give consent to take part in the feedback session. You are also allowed to withdraw your data from the study up to one month after completing the session. If you wish to withdraw your data please contact one of the research team, whose contact details are at the end of this letter.

When will I take part?
If you express interest in the study, a member of the research team will contact you to arrange a suitable date/time for the one-to-one feedback session and will ask whether you are happy to complete this over the telephone or in person.

What will the study involve?
At the beginning of the session, the researcher will explain what the study is about and confirm that you want to take part. It will be made clear that there are no consequences if you decide that you do not want to take part. The researcher will then read through a list of questions and will ask you your thoughts about these questions, for example "What do you think they were they asking in that question?" and "Was there anything you found confusing or hard to understand?". We will ask to audio-record the discussion to ensure accuracy. You may request that the recording be paused at any time. The recording of the discussion will later be transcribed (written up) with your permission and analysed. All information that you give us, whether in the recording or paper form, will remain confidential and will not be shared in any

way that can lead to your identification. The discussion will be transcribed and wiped cleaned of identifiers. The session should take no longer than 30 minutes.

Will my information be kept confidential?
Yes. During the one-to-one interview you will be referred to by a pseudonym to ensure your comments remain confidential. All audio recordings will be stored on a password protected computer which only the research team have access to.

Will my participation in this study be kept confidential?
Yes. All the information that we collect will be kept strictly confidential. The information you provide will be stored in a pseudoanonymised format using your participant ID numbers (separate from your name and contact details), in a secure password protected database. It will not be possible to identify any individual from the data, or in any ensuing reports or publications. Confidentiality will be respected subject to legal constraints and professional guidelines. Please also note that this research is not aimed at assessing individual children's diet, health, parenting or home environment.

What are the benefits of taking part?
Research has found that the home environment that children grow up in has an influence on their health and development. The feedback that you provide during this study will be used to help us improve how the home environment is measured in UK households. It is hoped that this tool will help us gain a clearer understanding of the environment within the family home.

What if I have any questions?
If you have any questions, please contact a member of the research team (listed below) and we will discuss it with you straight away.

Many thanks,

Alice Kininmonth (University of Leeds & University College London)

If you require any further information about the study or have any questions, please contact

Contact for further information

Lead Investigator Contact Details:

Alice Kininmonth Email: ps16ark@leeds.ac.uk or a.kininmonth@ucl.ac.uk
School of Psychology
University of Leeds
Woodhouse Lane
Leeds, LS2 9JT

UCL UNIVERSITY OF LEEDS

INFORMED CONSENT FORM

Title of Project: Study of the measurement of the home environment in UK Families

Please complete this form after you have read the Information Sheet and return it to the researcher team.

This study has been approved by the UCL Research Ethics Committee – Project ID number 1624/004.

Participant ID number: ______________

Name of Researcher: Alice Kininmonth

Thank you for your interest in taking part in this research.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Participant's Statement

Please read the following statements carefully and put an **'X'** in the box if you agree. If you have any questions, please do not hesitate to ask.

I confirm that:

- I have read the notes written above and the Participant Information Sheet and understand what the study involves. ☐
- I have been given the opportunity to ask questions and if I have asked questions, I have received satisfactory answers. ☐
- I understand that I have the right to withdraw at any time, without having to give a reason and that I can request to remove my data from the study. ☐
- I understand that all information will be treated in strict confidence and will be kept anonymous and confidential. ☐
- I understand that my participation will be audio-recorded and I consent to use of this material as part of the project. ☐
- I agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study. ☐

Participant signature ______________________________________ Date: ___/___/___

Printed name (BLOCK CAPITALS): ____

Researcher signature: ____________________________________ Date: ___/___/___

A.13 Recruitment poster for test-retest reliability data collection

A.14 Consent form for test-retest reliability data collection

PARTICIPANT INFORMATION SHEET

Study of the measurement of the home environment in UK Families

We would like to invite you to take part in **two 45 minute telephone interviews** (total 1 hour 30 minutes), **over a two week period.** Before you decide whether you wish to take part, you need to understand why the research is being done and what it would involve. Please take some time to read this information sheet carefully and discuss it with others if you wish.

All proposals for research using people are reviewed by an ethics committee before they can proceed. This study has been approved by the UCL Research Ethics Committee – Project ID number 1624/004.

What is the purpose of this study?
The purpose of this study is to gain a better understanding of the environment within the family home. We are trying to understand what different households look like in terms of the types of electronic devices (e.g. phones, TVs, computers and more), foods and drinks, and activity equipment (e.g. bikes, scooters) available. We are also interested in how you and your family spend your time in the home. In order to do this, we need to speak to parents of children aged 11-13 to ask them questions about the environment within the family home.

Do I have to take part?
No, you are free to not give consent to take part in this study. You are also free to withdraw your data from the study up to one month after completing the session. If you wish to withdraw your data, please contact the primary researcher, whose contact details are at the end of this letter.

When will I take part?
If you express interest in the study, a member of the research team will contact you to arrange a suitable date/time for the two telephone interviews.

What will the study involve?
The study will consist of **two 45 minute telephone interviews**, which will be completed over a **2 week period**. At the beginning of the interview, the researcher will explain what the study is about and confirm that you want to take part. You will be asked questions about the environment within the family home, in terms of the types of electronic devices, foods and drinks, activity equipment available. We will also ask you questions about how you and your family spend your time in the home. After completing the first telephone interview, we will ask you to book a time/date to complete the second telephone interview. The second interview will need to be completed 7-14 days after the initial interview.

Will my information be kept confidential?
Yes. All the information you provide is for research purposes only, and will be kept strictly confidential. The results of the study will be published in peer-reviewed scientific journals

Will my participation in this study be kept confidential?
Yes. All the information that we collect will be kept strictly confidential. The information you provide will be stored in a pseudoanonymised format using your participant ID numbers (separate from your name and contact details), in a secure password protected database. It will not be possible to identify any individual from the data, or in any ensuing reports or publications. Confidentiality will be respected subject to legal constraints and professional guidelines. Please also note that this research is not aimed at assessing individual children's diet, health, parenting or home environment.

What are the benefits of taking part?
Research has found that the home environment that children grow up in has an influence on their health and development. The information that you provide during this study will be used to help us improve how the home environment is measured in UK households. It is hoped that this tool will help us gain a clearer understanding of the environment within the family home.

Rewards
To say thank you for taking part, we will send you (by email) a **£20 love2shop voucher**, which can be used at a wide range of websites. This reward is only available if you complete both interviews.

What if I have any questions?
If you have any questions, please contact a member of the research team (listed below) and we will discuss it with you straight away.

Many thanks,

Alice Kininmonth
If you require any further information about the study or have any questions, please contact:

Lead Investigator Contact Details:

Alice Kininmonth
Email: a.r.kininmonth@leeds.ac.uk
School of Psychology
University of Leeds
Woodhouse Lane
Leeds, LS2 9JT

PARTICIPANT INFORMED CONSENT

Please complete this form after you have read the Information Sheet.

This study has been approved by the UCL Research Ethics Committee – Project ID number 1624/004.

Name of Researcher: Alice Kininmonth

Thank you for your interest in taking part in this research.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Participant's Statement
Please read the following statements carefully and put a tick in the box if you agree. If you have any questions, please do not hesitate to ask.

I confirm that:

- ☐ I have read the notes written above and the Participant Information Sheet and understand what the study involves.
- ☐ I have been given the opportunity to ask questions and if I have asked questions, I have received satisfactory answers.
- ☐ I understand that I have the right to withdraw at any time, without having to give a reason and that I can request to remove my data from the study.
- ☐ I understand that all information will be treated in strict confidence and will be kept anonymous and confidential.
- ☐ I agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study.

Please enter your full name

____

Please enter the first name of your child

____

Please enter your child's date of birth (dd/mm/yyyy)

Please provide an email address for contact purposes

A.15 Example of training material developed for training individuals to deliver the HEI[1]

gemini
health and development in twins

Interviewer add relevant Gemini family details before starting the phone call.

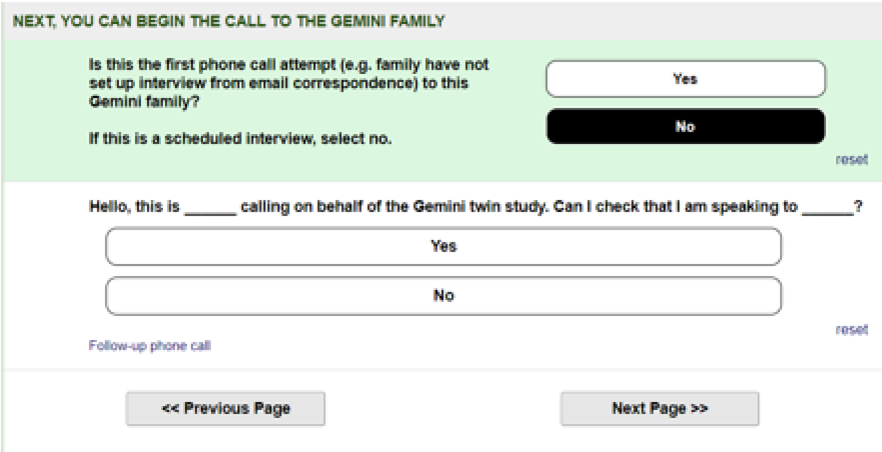
Today's date	Today D-M-Y
Enter the first name of mother or primary caregiver	
Enter the last name of the mother or primary caregiver	
Enter first name for twin registered as twin 1	
Enter first name for twin registered as twin 2	
Enter the twins DOB from our records	Today D-M-Y
Enter first line of address	
Enter 2nd line of address on record	
Enter address 3 line	
Enter the postcode on record for this family	
Researcher name:	
<< Previous Page	Next Page >>

Once you have entered the information click '**Next page >>**'. You will be taken to the next page that asks you to state whether the family has been contacted previously or if this is the first-time family is being contacted.

[1] I delivered the training session with two MSc students to train them to be able to deliver the HEI, however, due to the Covid-19 pandemic, data collection ceased before they were able to administer interviews. As a result all interviews were completed by myself.

There are **two different 'introductory text'** that can be read out to families at the beginning of the call. You will need to state on the computer form whether this is the 'first phone call attempt' to this family.

If the family has been contacted previously or you are conducting a scheduled[3] interview, select **'No'** and read from the text for 'If FOLLOW-UP phone call'


NEXT, YOU CAN BEGIN THE CALL TO THE GEMINI FAMILY

Is this the first phone call attempt (e.g. family have not set up interview from email correspondence) to this Gemini family?

If this is a scheduled interview, select no.

Yes

No

reset

Hello, this is ______ calling on behalf of the Gemini twin study. Can I check that I am speaking to ______?

Yes

No

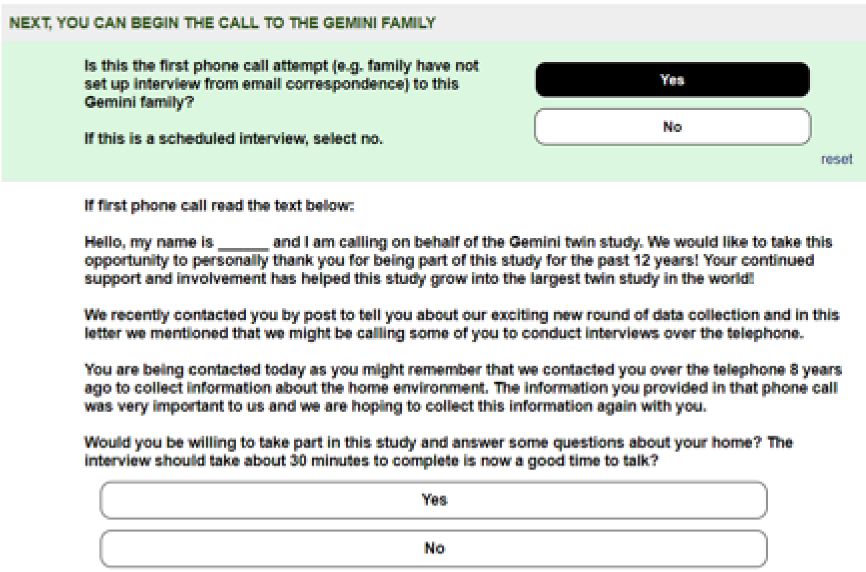
reset

Follow-up phone call

<< Previous Page

Next Page >>

If not previously contacted select 'Yes' and read from the "If first phone call" instructions:


NEXT, YOU CAN BEGIN THE CALL TO THE GEMINI FAMILY

Is this the first phone call attempt (e.g. family have not set up interview from email correspondence) to this Gemini family?

If this is a scheduled interview, select no.

Yes

No

reset

If first phone call read the text below:

Hello, my name is ______ and I am calling on behalf of the Gemini twin study. We would like to take this opportunity to personally thank you for being part of this study for the past 12 years! Your continued support and involvement has helped this study grow into the largest twin study in the world!

We recently contacted you by post to tell you about our exciting new round of data collection and in this letter we mentioned that we might be calling some of you to conduct interviews over the telephone.

You are being contacted today as you might remember that we contacted you over the telephone 8 years ago to collect information about the home environment. The information you provided in that phone call was very important to us and we are hoping to collect this information again with you.

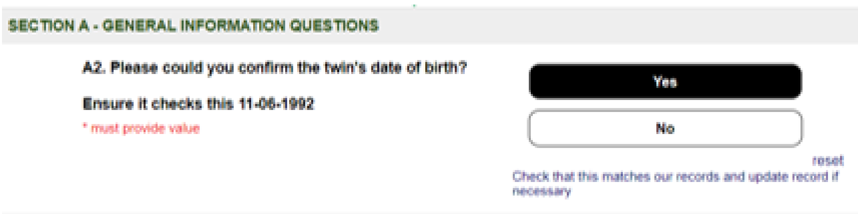
Would you be willing to take part in this study and answer some questions about your home? The interview should take about 30 minutes to complete is now a good time to talk?

Yes

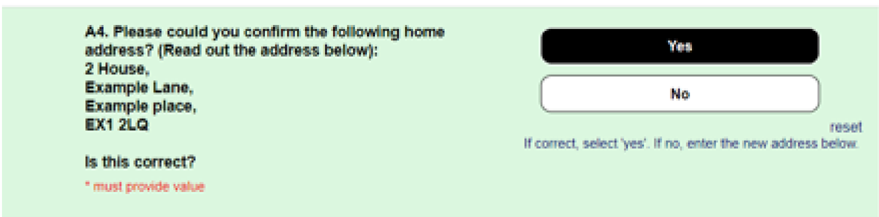
No

[3] Scheduled interviews are those where the family have been invited to take part via email. These families were sent a link to various time slots that have been made available and the family booked a time/date that was convenient to them.

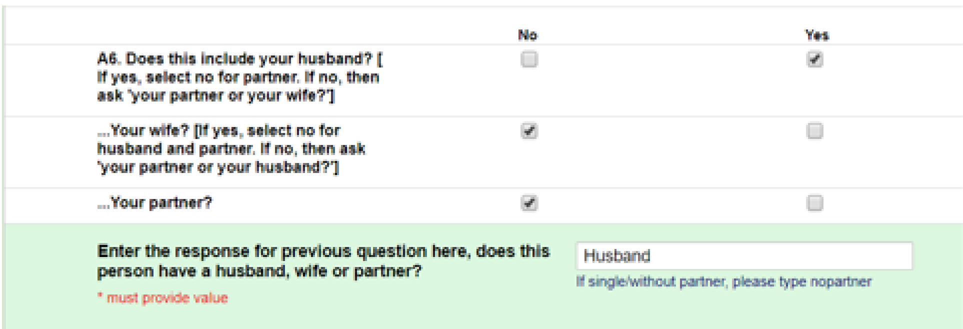
In the first section of the interview ('Section A – General Information Questions'), you will check that we have the correct information for the family. For question **A2.** you confirm the twins date of birth. The date here is pulled in from the information that you entered on the first page so you must ensure that you have entered the correct information here. (For the screenshot below I have used my birthday as an example of how it will look)



For question **A4**. you must confirm that we have the correct current home address on system. The address in this space is pulled in from the information that you entered in the first part of the data entry system so you must ensure you enter the correct information. If we do not have the families current address, select 'No' and a free text box will appear. Enter the correct/new address for the family here.



For question **A6.** you should confirm whether the parent/caregiver has a husband/partner/wife or is single. Use the 'yes' 'no' tick boxes to do this. Then enter their response in the open text box.



If the parent is single, without partner then enter 'nopartner' in this box. Typically, the parent has a partner/wife/husband but if they do not – the questions for the partner will still appear, but you need to ignore these questions and simply ask about the parent themselves.

Appendix B

Additional tables and figures for Chapter Three

B.1 PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title page
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	

Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	

B.2 Search strategy used for Medline Based on the PICOS framework.

1	exp family/
2	exp child/
3	exp PARENTS/px
4	(child* or toddler* or infant*).mp
5	(boy* or girl* or youth*).mp
6	(schoolchild* or school child* or school-child*).mp
7	(pediatr* or paediatr*).mp.
8	(preschool* or pre-school*).mp.
9	12 year old*.mp.
10	age 12.mp.
11	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
12	home environment.mp.
13	(home media or home media environment or tv viewing).mp
14	(obesogenic environment or obesogenic home or unhealthy home).mp
15	(home food environment or food environment or family meal* or family mealtime* or family meal-times or food availability or home food or available food or food access* or food in home or parental monitoring).mp
16	(home activity or physical activity home or home physical activity or sedentary behaviour or parental activity or family physical activity or physical activity social environment or parent physical activity modelling or physical activity or physical home environment).mp
17	(screen time or media physical environment or screen-time or media social environment or sedentary behaviour).mp
18	(parental policies or parental role model or parental modelling).mp
19	(snacking or eating behaviour or food intake).mp.
20	12 or 13 or 14 or 15 or 16 or 17 or 18 or 19
21	(weight or bmi or body mass index).mp
22	(growth charts or Anthropometr*).mp.
23	(BMI z-scores or BMI-for-age or weight-for-length percentiles or weight-for-height percentiles or waist circumference).mp.
24	(adipos* or weight status).mp.
25	exp child development/
26	exp body weight/
27	exp obesity/
28	exp childhood obesity/
29	exp body mass index/
30	21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29
31	11 and 20 and 30
32	limit 31 to (english language and humans and ("all infant (birth to 23 months)" or "newborn infant (birth to 1 month)" or "infant (1 to 23 months)" or "preschool child (2 to 5 years)" or "child (6 to 12 years)") and journal article)

*The syntax used in this search strategy was adjusted where necessary according to the requirements of each database.

B.3 Risk of bias assessment using the Newcastle Ottawa scale (NOS) for cohort studies included in home environment systematic review (Adapted for the assessment of observational, cohort studies (Modesti et al 2016).

	Selection				Comparability		Outcome		Total Score
	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of exposure	Controls for most important confounder	Controls for additional confounders	Assessment of outcome	Statistical test	
Adachi-Mejia et al. 2007	A*	A*	C	B*	A*	A*	D	A*	6
Anderson & Whitaker, 2010	A*	A*	C	B*	A*	A*	A**	A*	8
Atkin et al. 2013	A*	B	B	A**	A*	A*	A**	A*	8
Borghese et al. 2015	B*	A*	B	A**/B*[1]	A*	A*	A**	A*	9/8
Cameron et al. 2013	B*	A*	B	A**	A*	A*	A**	A*	9
Cassimos et al. 2011	C	B	C	B*	B	B	A**	B	3
Chahal et al. 2013	B*	B	B	A**	A*	A*	A**	A*	8
Chaput et al., 2014	B*	A*	B	A**	A*	A*	A**	A*	9
Chen et al. 2018	B*	B	C	A**	A*	A*	A**	A*	8
Chivers et al. 2012	C	A*	B	B*	B	B	A**	A*	5
Couch et al. 2014	B*	B	B	A**	A*	A*	A**	A*	8
Crawford et al. 2012	B*	B	B	B*	A*	A*	A**	A*	7
Downs et al. 2009	B*	B	B	B*	B	B	A**	B[2]	4
Dube et al. 2017	A*	B	B	B*	A*	A*	A**	A*	7
Farajian, P., et al. 2014	A*	A*	B	A**/B*[1]	A*	A*	A**	A*	9/8
Ferrari et al. 2015	B*	A*	B	B*	A*	A*	A**	A*	8
Ferrari et al. 2017	B*	A*	B	A**	A*	A*	A**	A*	9
Gable and Lutz, 2000	C	B	A*	B*	B	B	A**	A*	5
Gomes, T.N., et al. 2015	B*	A*	B	B*	A*	A*	A**	A*	8
Gubbels et al 2011	B*	B	A*	B*	A*	A*	A**/D[3]	A*	8/6
Hales, D., et al. 2013	B*	B	A*	B*	B	B	A**	A*	6
Hardy, L.L., et al. 2012	A*	A*	B	A**	A*	A*	A**	A*	9
Heilmann, A., et al. 2017	A*	B	B	B*	A*	A*	A**	A*	7
Humenikova & Gates, 2008	B*	B	B	B*	A*	A*	A**	A*	7
Huynh, D.T., et al. 2011	A*	A*	A*	B*	A*	A*	A**	A*	9
Ihmels et al. 2009	B*	B	B	B*	B	B	A**	A*	5
Jones et al. 2009	B*	B	B	A**	B	B	A**	A*	6

Keihner et al. 2009	A*	B	B	B*	A*	A*	D	A*	5
Kim et al. 2014	B*	A*	A*	B*	B	B	A**	B	6
Lane et al. 2014	A*	A*[5]	B	B*	A*	A*	A**	A*	8
Lehto, R., et al. 2011	B*	B	B	B*	A*	A*	A**	A*	7
Li et al. 2014	B*	B	B	A**/B*	A*	A*	A**	A*	8/7
Liszewska et al. 2018	D	B	A*	A**	A*	A*	A**	A*	8
Lopez-Barron et al. 2015	B*	B	B	B*	B	B	A**	A*	5
MacFarlane et al. 2009	A*	B	A*	B*	A*	A*	A**	A*	8
Mathialagan et al. 2018	B*	A*	B	B*	B	B	A**	A*	6
Mihrshahi et al. 2017	A*	A*	B	B*	A*	A*	A**	A*	8
Moreno et al. 2011	B*	B	B	B*	B	B	A**	A*	5
Palfreyman et al. 2014	B*	B	B	B*	B	B	D	B[2]	2
Rodenburg et al. 2013	A*	B	A*	A**	A*	A*	A**	A*	9
Rosenberg et al. 2010	B*	B	C	B*	A*	A*	D	A*	5
Rutherford et al. 2015	A*	A*	B	B*	A*	A*	A**	A*	8
Schalkwijk et al. 2018	B*	B	B	B*	B	B	A**	A*	5
Schrempft, S., et al. 2015	B*	B	A*	A**	A*	A*	D	A*	7
Serene et al. 2011	A*	A*	B	A**/B*[1]	B	B	A**	A*	7/6
Serrano et al. 2014	B*	A*	B	A**	B	B	A**	A*	7
Sijtsma et al. 2015	A*	A*	B	B*	A*	A*	A**	A*	8
Sijtsma et al. 2015	A*	A*	A*	A**	B	B	A**	A*	8
Sirikulchayanonta et al. 2011	B*	A*	C	B*	A*	A*	A**	A*	8
Sleddens et al. 2017	B*	B	A*	A**/B*[1]	A*	A*	D	A*	7/6
Taylor et al. 2011	B*	B	B	A**	A*	A*	A**	A*	8
Terry, K. and Beck, S. 1985	C	B	C	B*	B	B	A**	A*	4
Tiberio, S.S., et al. 2014	B*	B	A*	B*	A*	A*	A**/D[4]	A*	8
Torres, R., et al. 2014	B*	A*	B	B*	B	B	A**	A*	6
Umstattd Meyer et al. 2013	B*	B	C	B*	B	B	D	A*	3
Van Lippevelde et al. 2013	A*	A*	B	A**	A*	A*	A**	A*	9
Vaughn, A.E., et al. 2017	C	A*	B	B*	B	B	A**	B[2]	4

[1]Used a combination of validated and non-validated tools (adapted from existing measures) for measurement of the exposure.
[2]Did not present data for weight, only stated that there was no significant association with weight.
[3]At time 1 weight was measured via standardized measure and at time 2 weight was parent-reported.
[4]A combination of standardized measurement by researcher and rest parent-reported
[5]Available elsewhere **https://www.growingup.ie/pubs/BKMNEXT255.pdf**

B.4 Cross-sectional association between physical and social aspects in the home media domain and child adiposity outcomes.

Author, year	Country	Age	Greater availability of & access to electronic devices	Parental rules & limit setting around media	Parental modelling of media use
Adachi-Mejia et al. 2007 (16)	USA	9-12 y			
Atkin et al. 2013 (39)	UK	9-11 y			
Borghese et al. 2015 (40)	USA, Canada	10 y	*		
Cameron et al. 2013 (41)	7 European countries	10-12 y			
Chahal et al. 2013. (42)	Canada	10-11 y			
Chaput et al. 2014 (43)	Canada	9-11 y			
Dube et al. 2017 (44)	Canada	10-11 y			
Farajian et al. 2014 (45)	Greece	10-12 y			
Ferrari et al. 2015 (46)	Brazil	9-11 y			
Ferrari et al. 2017 (47)	Brazil	9-11 y			
Heilmann et al. 2017 (48)	UK	7-11 y			
Gomes et al. 2015 (49)	Portugal	9-11 y			
Lane et al. 2014 (50)	Ireland	9 y			
Li et al. 2014 (51)	China	8-10 y			
Lehto et al. 2011 (52)	Finland	9-11 y			
Sijtsma et al. 2015 (23)	Netherlands	3-4 y			
Anderson et al., 2010 (22)	USA	4 y			
Tiberio et al. 2014 (53)	USA	5-9 y			
Hardy et al. 2012 (27)	Australia	5-12 y			
Rutherford et al. 2015 (28)	Australia	4-9 y			
Hales et al. 2013 (33)	USA	3–12 y			
Jones, et al. 2009 (34)	Australia	2-6 y			
Sleddens et al. 2017 (15)	Netherlands	5-7 y			
Taylor et al. 2011 (65)	Australia	7-12 y			
Mathialagan et al. 2018 (66)	Malaysia	10-12 y			
Rosenberg et al. 2010 (67)	USA	5-11 y			
Mihrshahi et al. 2017 (68)	Australia	6-10 y			
Keihner et al. 2009 (69)	USA	9-11 y			
Huynh, et al. 2011 (26)	Vietnam	4-5 y			
Crawford et al. 2012 (36)	Australia	5-12 y			
Rodenburg et al. 2013 (37)	Netherlands	8–12 y			
Ihmels et al. 2009 (35)	USA	6-7 y			
Kim et al. 2014 (24)	South Korea	2-5 y			
Gubbels et al 2011 (75)	Netherlands	5- 7 y			

Key: Green = negative association (lower adiposity); Red = positive association (higher adiposity); Light grey = null; White = Not measured/no data.

Author, year	Country	Age	Greater availability of & access to electronic devices	Parental rules & limit setting around media	Parental modelling of media use

*****This study examined two samples, US sample and Canadian sample, differences were observed in the results. In the American sample TV in bedroom only associated with higher BF% in boys. In Canadian sample TV in bedroom associated with higher BF% in both boys and girls.

B.5 Cross-sectional association between physical and social aspects in the home food domain and child adiposity outcomes.

Author, year	Age	Greater availability of & access to energy dense foods	More fruits and vegetables available and accessible in home	Parental modelling of eating	Parental rules & limit setting around food
Cassimos et al. 2011 (54)	9-12 y	Red			
Chen et al. 2018 (30)	3-6 y	Red			
Couch et al. 2014 (13)	6-11 y	Light grey	Light grey	Green	Light grey
Downs et al. 2009 (55)	9-12 y	Light grey	Light grey		
Humenikova 2008 (56)	10-11 y		Green		
Gable 2000 (9)	6-10 y	Light grey	Light grey		
Lopez-Barron et al. 2015 (57)	10-11 y	* Green	* Red		
MacFarlane et al. 2009 (38)	5-6 & 10-12 y	Light grey			Light grey
Terry 1985 (58)	8-12 y	Light grey	Light grey		
Palfreyman et al. 2014 (59)	1-8 y			Light grey	
Van Lippevelde et al. 2013 (60)	10-12-y		Light grey		
Vaughn et al. 2017 (31)	3-12 y	Light grey	Light grey	Light grey	Light grey
Mihrshahi et al. 2017 (68)	6-10 y	Red			Light grey
Keihner et al. 2009 (69)	9-11 y			Light grey	
Huynh et al. 2011 (26)	4-5 y		Green		
Serene et al. 2011 (70)	9-12 y	Light grey	Light grey	Light grey	
Serrano et al. 2014 (71)	12 y			Light grey	
Torres et al. 2014 (74)	12 y	Red	Light grey		
Crawford et al. 2012 (36)	5-12 y			Green	
Ihmels et al. 2009 (35)	6-7 y			Green	
Kim et al. 2014 (24)	2-5 y			Red	
Gubbels et al 2011 (29)	5- 7 y			Green	

Key: Green = negative association (lower adiposity); Red = positive association (higher adiposity); Light grey = null; White = Not measured/no data.

* OW/OB associated with lower availability of Energy Dense Foods (EDF) at home (OR 0.56, p<.001). OW/OB associated with increased odds of availability of fruits and vegetables (OR = 1.10, p = 0.035).

B.6 Cross-sectional association between physical and social aspects in the home PA domain and child adiposity outcomes.

Author, year	Country	Age	Greater access to and availability of PA	Parental modelling & support of PA
Chivers et al., 2012 (61)	Australia	1-10 y		
Sijtsma et al. 2015 (62)	Netherlands	3-4 y		*
Liszewskaet al. 2018 (63)	Poland	6-11 y		
Schalkwijk et al. 2018 (32)	UK	3-7 y		
Umstattd Meyer et al. 2013 (64)	US/Mexico border	6-11 y		
Hales et al. 2013 (33)	USA	3–12 y		
Jones, et al. 2009 (34)	Australia	2-6 y		
Sleddens et al. 2017 (15)	Netherlands	5-7 y		
Taylor et al. 2011 (65)	Australia	7-12 y		
Mathialagan et al. 2018 (66)	Malaysia	10-12 y		
Rosenberg et al. 2010 (67)	USA	5-11 y		
Serene et al. 2011 (70)	Kuala Lumpur	9-12 y		
Serrano et al. 2014 (71)	Puerto Rico	12 y		
Torres et al. 2014 (74)	Puerto Rico	12 y		
Crawford et al. 2012 (36)	Australia	5-12 y		
Ihmels et al. 2009 (35)	USA	6-7 y		
Kim et al. 2014 (24)	South Korea	2-5 y		
Gubbels et al 2011 (29)	Netherlands	5- 7 y		

Key: Green = Negative association (lower adiposity); Red = Positive association (higher adiposity); Light grey = null; White = Not measured/no data.

*This study examined parental modelling of PA; differences were observed between the types of activities modelling. No association between parental modelling of PA and BMI or waist circumference. Parental modelling of commuting to school/work by bike or walking associated with lower BMI Z-score (r = −0.062).

Appendix C

Additional tables for Chapter Four

C.1 Experts' categorisation of the home food, activity and media environment variables (% (n)).

	Probably/definitely INCREASED risk	Probably/definitely DECREASED risk	Not sure
Home Food Environment Variables			
More types of fruit in the home	0.0 (0)	**80.9 (17)**	19.1 (4)
Fruit on display (visible)	0.0 (0)	**85.7 (18)**	14.3 (3)
Child is allowed to help themselves to fruit	0.0 (0)	**71.4 (15)**	28.6 (6)
More types of vegetables in the home	0.0 (0)	**90.5 (19)**	9.5 (2)
Ready-to-eat vegetables in the fridge or on the kitchen counter	0.0 (0)	**85.7 (18)**	14.3 (3)
Child allowed to help themselves to vegetables	0.0 (0)	**76.2 (16)**	23.8 (5)
More types of energy-dense snack in the home	**90.5 (19)**	0.0 (0)	9.5 (2)
Child allowed to help themselves to energy-dense snack	**95.3 (20)**	0.0 (0)	4.8 (1)
Energy-dense snacks on display (visible)	**90.5 (19)**	0.0 (0)	9.5 (2)
Fruit juice or smoothies in the home	33.3 (7)	0.0 (0)	66.7 (14)
Fruit juice or smoothies on display (visible)	38.1 (8)	0.0 (0)	61.9 (13)
Full-fat milk in the home	19.1 (4)	14.3 (3)	66.7 (14)
Skimmed milk in the home	0.0 (0)	38.1 (8)	61.9 (13)
Semi-skimmed milk in the home	0.0 (0)	33.3 (7)	66.7 (14)
Child is allowed to help themselves to milk	14.3 (3)	23.8 (5)	61.9 (13)
Child is allowed to help themselves to fruit juice or smoothies	57.1 (12)	0.0 (0)	42.86 (9)
Sugar-sweetened drinks in the home	**95.2 (20)**	0.0 (0)	4.76 (1)
Sugar-sweetened drinks on display (visible)	**90.5 (19)**	0.0 (0)	9.52 (2)
Child is allowed to help themselves to sugar-sweetened drinks	**100.0 (21)**	0.0 (0)	0.00 (0)
Family meals at the table	0.0 (0)	**90.48 (19)**	9.52 (2)
Sugar-free drinks in the home (excluding water)	9.5 (2)	28.57 (6)	61.90 (13)
Sugar-free drinks (excluding water) on display (visible)	9.5 (2)	28.57 (6)	61.90 (13)

	Probably/definitely INCREASED risk	Probably/definitely DECREASED risk	Not sure
Child is allowed to help themselves to sugar-free drinks (excluding water)	9.5 (2)	23.81 (5)	66.67(14)
Caffeinated energy drinks in the home	45.0 (9)	0.00 (0)	55.00 (11)
Caffeinated energy drinks on display (visible)	42.9 (9)	0.00 (0)	57.14 (12)
Child is allowed to help themselves to caffeinated energy drinks in the home	52.4 (11)	0.00 (0)	47.62 (10)
Greater frequency of meals eaten together at the table as a family	0.0 (0)	**90.48 (19)**	9.52 (2)
Parental rules around family mealtimes	0.0 (0)	**71.43 (15)**	28.57 (6)
Parental restriction of unhealthy foods	4.8 (1)	**76.19 (16)**	19.05 (4)
Parental use of food to make child feel better	**76.2 (16)**	4.76 (1)	19.05 (4)
Parental use of food as a reward	**90.5 (19)**	0.00 (0)	9.52 (2)
Parental encouragement for the child to eat fruit and vegetables	0.0 (0)	**85.00 (17)**	15.00 (3)
Parental monitoring of the child's unhealthy food intake	0.0 (0)	**85.71 (18)**	14.29 (3)
Parental control of child's food intake	28.6 (6)	38.10 (8)	33.33 (7)
Parental pressure for the child to eat	**71.4 (15)**	0.00 (0)	28.57 (6)
Parental covert restriction of child's unhealthy food intake	0.0 (0)	**66.67 (14)**	33.33 (7)
Home Media Environment Variables			
Greater amount of media equipment in child's bedroom (e.g. TV, computer, games consoles, laptops, tablets, phones)	**95.2 (20)**	0.0 (0)	4.8 (1)
Greater amount of media equipment in the home (e.g. TVs, DVD players, games consoles, laptops, tablets, mobile phones)	**76.2 (16)**	0.0 (0)	23.8 (5)
Greater maternal time engaged in screen-based viewing	**76.2 (16)**	0.0 (0)	23.8 (5)
Greater paternal time engaged in screen-based viewing	**76.2 (16)**	0.0 (0)	23.8 (5)
Parental rules around use of media equipment	4.8 (1)	**76.2 (16)**	19.0 (4)
Greater maternal time playing video games	57.1 (12)	0.0 (0)	42.9 (9)
Greater paternal time playing video games	57.1 (12)	0.0 (0)	42.9 (9)

	Probably/definitely INCREASED risk	Probably/definitely DECREASED risk	Not sure
Parental use of electronic device time (e.g. phone, TV, computer, games console) as a reward	42.9 (9)	9.5	47.6 (10)
Parental limits on media equipment time (e.g. phone, TV, computer) if the child misbehaves	0.0 (0)	28.6	71.4 (15)
Child eats whilst watching TV or using an electronic device	**85.0 (17)**	5.0	10.0 (2)
Greater frequency of eating whilst watching TV or using an electronic device	**80.9 (17)**	4.8	14.3 (3)
Child has access to and use of social media	33.3 (7)	9.5 (2)	57.1 (12)
Parental rules around child's online activities and social media use	0.0 (0)	57.1 (12)	42.9 (9)
Home Physical Activity Variables			
Greater frequency that the child is allowed to be physically active in the garden/yard.	0.0 (0)	**95.2 (20)**	4.8 (1)
Greater frequency that the child is allowed to be physically active inside the home.	0.0 (0)	**80.9 (17)**	19.1 (4)
Play equipment in the garden/yard.	0.0 (0)	**85.7 (17)**	14.3 (3)
Garden/yard that the child can play in	0.0 (0)	**80.9 (18)**	19.1 (4)
Outdoor recreation area close to home	0.0 (0)	57.1 (12)	42.9 (9)
Larger garden/yard that the child can be active in vs smaller garden/yard	0.0 (0)	52.4 (11)	47.6 (10)
Indoor recreation centres close to home	0.0 (0)	45.0 (9)	55.0 (11)
Child has a usable bike, scooter, rollerblades or skateboard.	0.0 (0)	**61.9 (13)**	38.1 (8)
Parental modelling of physical activity	0.0 (0)	**100.0 (21)**	0.0 (0)
Parental support of physical activity	0.0 (0)	**100.0 (20)**	0.0 (0)

C.2 Constructs included in the home environment composite score. (Items coloured red are those added to the original composite score during the update)

Version 1: HE Composite 2012	Version 2: Updated HE Composite
Food-related constructs (21)	**Food-related constructs (21)**
Availability	***Availability***
Number of fruit types[1]	Number of fruit types[1]
Number of vegetable types[1]	Number of vegetable types[1]
Number of energy-dense snack types	Number of energy-dense snack types
Presence of sugar-sweetened drinks	Number of sugar-sweetened drinks
Accessibility (visibility)	***Accessibility (visibility)***
Fruit on display[1]	Fruit on display[1]
Vegetables ready-to-eat[1]	Vegetables ready-to-eat[1]
Energy-dense snacks on display	Energy-dense snacks on display
Sugar-sweetened drinks on display	Sugar-sweetened drinks on display
Accessibility (child can help him/herself)	***Accessibility (child can help him/herself)***
Fruit[1]	Fruit[1]
Vegetables[1]	Vegetables[1]
Energy-dense snacks	Energy-dense snacks
Sugar-sweetened drinks	Sugar-sweetened drinks
Parental feeding practices	***Parental feeding practices***
Emotional feeding	Emotional feeding
Instrumental feeding	Instrumental feeding
Encouragement[1]	Encouragement[1]
Modelling[1]	Modelling[1]
Monitoring[1]	Monitoring[1]
Covert restriction[1]	Covert restriction[1]
Restriction[1]	Restriction[1]
Family meal frequency at the table	Family meal frequency at the table
Frequency child eats while watching TV	Frequency child eats while watching TV and/or using a device
Physical activity-related constructs (6)	**Physical activity-related constructs (6)**
Garden/outdoor space[1]	Garden/outdoor space[1]
Garden play equipment[1]	Garden play equipment[1]
Allowed to play indoors[1]	Allowed to play indoors[1]
Allowed to play outdoors[1]	Allowed to play outdoors[1]
Caregiver modelling of physical activity[1]	Caregiver modelling of physical activity[1]
Caregiver support of physical activity[1]	Caregiver support of physical activity[1]
Media-related constructs (5)	**Media-related constructs (5)**
Number of media equipment in home	Number of media equipment in home
TV in the child's bedroom	Number of media equipment in child's bedroom
Household rules around media use[1]	Caregiver rules around use of media equipment[1]
TV viewing of primary caregiver (hrs. per week)	Primary caregiver time engaged in screen-based viewing (hrs. per week)
TV viewing of partner (hrs. per week)	Partner time engaged in screen-based viewing (hrs. per week)

[1] Variable was identified as being associated with decreased risk for weight gain.

Appendix D

Additional tables for Chapter Five

D.1 Means (±SD) or % (N) for the home environment constructs included in the composite scores at age 4 and age 12 and significance of differences between time points (Paired samples t-test or McNemar's test).

Home food environment	Age 4	Age 12	Significance of 4-12 years difference
Availability			
Number of fruit types[1]	8.48 (2.98)	9.65 (4.25)	t=-5.57, p<0.001
Number of vegetable types[1]	11.57 (4.11)	13.58 (4.63)	t=-7.38, p<0.001
Number of energy-dense snack types	4.97 (2.14)	6.96 (3.22)	t=-10.49, p<0.001
Number of sugar-sweetened drink types	0.51 (0.78)	1.44 (1.05)	t=-14.04, p<0.001
Accessibility (visibility)			
Fruit on display[1]	94.6 (282)	95.3 (284)	χ^2=3.29, p=0.070
Vegetables ready-to-eat[1]	50.3 (150)	43 (128)	χ^2=0.04, p=0.845
Energy-dense snacks on display	15.4 (46)	4.0 (12)	χ^2=21.78, p<0.001
Sugar-sweetened drinks on display	8.7 (26)	6.0 (18)	χ^2=1.75, p=0.186
Accessibility (child can help him/herself)			
Fruit[1]	77.9 (232)	92.6 (276)	χ^2=214.00, p<0.001
Vegetables[1]	51.7 (154)	94.6 (282)	χ^2=109.26, p<0.001
Energy-dense snacks	8.1 (24)	55.4 (165)	χ^2=131.54, p<0.001
Sugar-sweetened drinks	2.7 (8)	41.6 (124)	χ^2=103.32, p<0.001
Parental feeding practices			
Emotional feeding[2]	1.68 (0.55)	1.45 (0.47)	t=7.64, p<0.001
Instrumental feeding[2]	2.32 (0.64)	1.81 (0.53)	t=15.52, p<0.001
Encouragement[1, 2]	1.93 (0.52)	2.28 (0.59)	t=-11.43, p<0.001
Modelling[1,2]	2.29 (0.64)	3.65 (0.68)	t=-21.45, p<0.001
Monitoring[1,2]	2.32 (0.93)	2.44 (0.98)	t=-2.26, p=0.025
Covert restriction[1, 2]	2.90 (0.84)	3.23 (0.89)	t=-6.68, p<0.001
Restriction[1, 3]	2.71 (1.07)	3.52 (1.16)	t=-11.70, p<0.001
Family meal frequency at the table (days per /week)	4.00 (1.60)	3.43 (1.22)	t=5.40, p<0.01
Frequency child eats while watching TV and/or using a device (days per /week)	1.03 (1.38)	1.24 (1.19)	t=-2.52, p=0.012
Home activity environment			
Garden/outdoor space[1]	99.3 (296)	98.7 (294)	X^2 = NA[7], p=0.687
Garden play equipment[1, 4]	81.9 (244)	65.8 (196)	χ^2=23.01, p<0.001
Allowed to be physically active indoors[1, 4, 5]	4.70 (0.70)	4.30 (1.07)	t=6.86, p<0.001
Allowed to be physically active outdoors[1, 4, 5]	4.31 (0.83)	4.76 (0.56)	t=-5.82, p<0.001
Parental modelling of physical activity[1]	3.95 (0.77)	3.97 (0.96)	t=-0.24, p=0.813

Home food environment *Availability*	**Age 4**	**Age 12**	**Significance of 4-12 years difference**
Parental support of physical activity[1]	4.04 (0.59)	3.53 (0.77)	t=-13.75, p<0.001
Home media environment			
Number of media equipment items in home	4.98 (2.30)	15.48 (4.20)	t=-50.30, p<0.001
Number of media equipment in child's bedroom	0.07 (0.29)	1.70 (1.37)	t=-21.13, p<0.001
Caregiver rules around use of media equipment[1,6]	0.71 (0.45)	2.38 (0.78)	t=-33.50, p<0.001
Maternal time engaged in screen-based viewing (hours/week)	14.73 (8.78)	14.26 (8.55)	t=1.00, p=0.319
Partner time engaged in screen-based viewing (hours/week)	15.24 (9.53)	14.94 (9.61)	t=0.43, p=0.667

[1]Variables identified as being associated with decreased risk for weight gain were reverse scored. However, in this table the scores are not reversed for comparison purposes. The only scores presented as reversed in this table are the Parental feeding practices: Encouragement, Modelling, Monitoring, Covert restriction and Restriction.
[2] Measured using a five-point Likert scale (1= never, 5= always).
[3] Measured using a seven-point Likert scale (1= not at all, 7= strictly).
[4]n= 294 as four children did not have access to a garden or outdoor space.
[5]Measured using a five-point Likert scale (1=never; 5=all the time)
[6](0 = no rules, 1=rules around one device, 2 = rules around two devices, 3 = rules around 3 or more devices)
[7] The number of discordant pairs was <25 therefore no chi-square value is provided and the exact test is used to represent the significance.

Appendix E

Additional tables and figures for Chapter Six

E.1 Systematic search strategy

Search strategy used in Ovid Medline based on PICO framework	
1	exp CHILD/ or exp ADOLESCENT/ or exp CHILD, PRESCHOOL/ or CHILD/ or exp INFANT/
2	(child* or adolescen* or infant*).mp
3	(teenage* or young people or young person or young adult*).mp.
4	(schoolchildren or school children).mp.
5	(pediatr* or paediatr*).mp
6	(boys or girls or youth or youths).mp.
7	1 or 2 or 3 or 4 or 5 or 6
8	(Child* Eating Behavio?r Questionnaire or CEBQ).mp or appet* traits.mp or eating behaviours.mp or food fussiness.mp or food responsiveness.mp
9	(Emotional over-eating or emotional overeating or emotional eating or emotional over eating).mp
10	(enjoyment of food or desire to drink or satiety responsiveness or slowness in eating).mp
11	(Emotional under-eating or emotional undereating or emotional under eating)).mp.
12	8 or 9 or 10 or 11
13	(adipos* or (weight or weight status)).mp. or exp obesity/ or exp overweight/
14	BMI z-scores.mp. or BMI-for-age.mp. or weight-for-length percentiles.mp.
15	((weight-for-height percentiles or waist circumference) adj2 growth charts).mp. or skinfold thickness.mp. or Anthropometr*.mp. or
16	((weight or bmi or body mass index) adj2 (gain or loss or change or reduc*)).mp.
17	13 or 14 or 15 or 16
18	7 and 12 and 17
19	limit 18 to yr="2001 -Current"

**The syntax used in this search strategy was adjusted where necessary according to the requirements of each database.*

E.2 Newcastle-Ottawa quality assessment scale for all included studies.

	Selection				Comparability		Outcome		
Cross-sectional CEBQ studies (n=43)	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of exposure	Controls for most important confounder	Controls for additional confounders	Assessment of outcome	Statistical test	**Total Score**
Carnell & Wardle, 2008[§]	B*	A*	A*	B*	A*	A*	A**/D[‡]	A*	7/9[#]
Cao, 2012	C	B	A*	A*	A*	A*	A**	B	6
Bergmeier, 2014	B*	B	A*	B*	A*	A*	A**/D[‖]	A*	6/8[#]
Boswell, 2018[§]	A*	A*	A*	B*	A*	A*	D	A*	7
Braden, 2014†	C	B	B	B*	A*	A*	A**	A*	6
Brown, 2012	B*	B	A*	B*	A*	A*	D	B	5
Cross, 2014[§†]	C	B	A*	B*	A*	A*	A**	A*	7
Demir, 2017	A*	A*	C	B*	B	A*	D	A*	5
Domoff, 2015[§†]	C	B	B	A*	B	B	A**	A*	4
Emond, 2017[§†]	C	B	B	B*	A*	A*	A**	A*	6
Escobar, 2014[§†]	A*	B	C	B*	A*	A*	A**	A*	7
Frankel, 2014[§]	C	B	C	B*	A*	A*	A**	A*	6
Fuemmeler, 2013[§†]	C	B	B	B*	A*	A*	A**	A*	6
Gregory, 2010[§]	B*	B	A*	A*	A*	A*	D	A*	6
Hankey, 2016[§]	B*	A*	A*	B*	A*	A*	A**	A*	9
Hardman, 2016[§†]	B*	B	C	B*	B	A*	D	A*	4
Haycraft, 2011[§†]	B*	B	B	B*	A*	A*	D	A*	5
Hayes, 2016[§]	C	B	A*	B*	B	B	A**	A*	5
Jansen, 2012[§]	A*	B	B	A*	A*	A*	A**	A*	7
Koch, 2014[§]	A*	A*	A*	B*	B	B	A**	A*	7
Larsen, 2017[§]	B*	B	C	B*	A*	A*	A**	A*	7
Lipowska, 2018	A*	A*	A*	B*	A*	A*	A**	A*	9
Loh, 2013[§]	B*	A*	A*	A*	A*	A*	A**	A*	9
Lora, 2016[†]	B*	B	A*	A*	A*	A*	A**	A*	8
Mallan, 2013	B*	B	B	B*	A*	A*	A**/B[¶]	A*	7/5[#]
McCarthy, 2015[†]	A*	A*	A*	B*	A*	A*	A**	A*	9
McPhie, 2011[§]	B*	A*	B	B*	A*	A*	D	A*	6
Parkinson, 2010	A*	A*	A*	B*	A*	A*	A**	A*	9

Pesch, 2018	C	A*	A*	B*	A*	A*	A**	A*	8
Quah, 2017[§†]	A*	A*	A*	B*	A*	A*	A**	A*	9
Roach, 2017	C	A*	B	B*	A*	A*	A**	A*	7
Rudy, 2016[§]	C	A*	B	A*	A*	A*	A**	C	6
Sanchez, 2016[§†]	A*	A*	A*	B*	A*	A*	A**	A*	9
Sanlier, 2016	C	B	C	B*	A*	A*	A**	A*	6
Silva Garcia, 2016[§†]	C	B	B	B*	A*	A*	A**	A*	6
Sleddens, 2008[§]	B*	B	A*	B*	A*	A*	D	A*	7
Somaraki, 2018	C	A*	B	B*	A*	A*	D	A*	5
Soussignan, 2012[§†]	B	A*	A*	B*	A*	A*	D	A*	6
Svensson, 2011	B	A*	B	B*	A*	A*	B*	A*	6
Tay, 2016[§†]	A*	A*	A*	B*	A*	A*	A**	A*	9
Viana, 2008[§]	B*	B	C	B*	A*	A*	D	A*	5
Vollmer, 2015[§†]	B	A*	C	B*	A*	A*	A**	A*	7
Webber, 2009[§†]	B	A*	A*	B*	A*	A*	A**	A	7

	Selection				**Comparability**		**Outcome**		
Longitudinal CEBQ studies (n=12)	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of exposure	Controls for most important confounder	Controls for additional confounders	Assessment of outcome	Statistical test	Total Score
Mallan, 2016	B*	B	B	B*	A*	A*	A**	A*	7
Mallan, 2014	C	B	A*	B*	A*	A*	A**	A*	7
McPhie, 2012	B*	B	C	B*	B	B	D	A*	3
Quah, 2015 [†]	B*	A*	B	B*	A*	A*	A**	A*	8
Steinsbekk, 2015	A*	A*	A*	B*	A*	A*	A**	A*	9
Steinsbekk, 2016	A*	A*	A*	B*	A*	A*	A**	A*	9
Derks, 2018	A*	A*	A*	B*	A*	A*	A**	A*	9
Steinsbekk, 2017	A*	A*	A*	B*	A*	A*	A**	A*	9
Bjorklund, 2018	A*	A*	A*	B*	A*	A*	A**	A*	9
Bergmeier, 2014	A*	A*	A*	B*	A*	A*	D	A*	7
Escobar, 2014 [†]	A*	A*	A*	B*	A*	A*	A**	A*	9
Parkinson, 2010	A*	A*	A*	B*	A*	A*	A**	A*	9
van Deutekom, 2016 [†]	A*	A*	A*	B*	A*	A*	B**	A*	9

	Selection				**Comparability**		**Outcome**		

BEBQ Studies (n=5)	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of exposure	Controls for most important confounder	Controls for additional confounders	Assessment of outcome	Statistical test	Total Score
Mallan, 2014	B*	A*	A*	B*	B	B	B**	A*	7
Quah, 2015	B*	A*	B	B*	A*	A*	A**	A*	8
Shepard, 2015	B*	B	A*	B*	B	B	A**	A*	6
van Jaarsveld, 2015	B*	A*	A*	B*	A*	A*	D	A*	7
Patel, 2018	C	A*	A*	B*	A*	A*	A**	A*	8

† Indicates studies for which authors provided additional data.

‡ Weight outcome measured differently in sub cohorts. TEDS is parent reported BMI, and community sample is researcher-measured BMI.

§ Indicates studies included in the meta-analysis.

‖ Weight outcome measured differently in sub cohorts. Half the cohort provided parent reported BMI, and half via standardised weight measurement during home visit.

¶Weight outcome measured differently in sub cohorts. Sample 1 provided researcher-measured weight, and Sample 2 & 3 provided mother-reported weight.

\# Different values for Total Score indicate studies where quality of outcome assessment differed across sub cohorts, resulting in sub cohort specific total NOS scores.

E.3 Results table for all CEBQ studies examining cross-sectional associations between each CEBQ scale and adiposity (n = 40), prospective associations from CEBQ scales to later adiposity (n=11), and prospective associations from adiposity to later CEBQ scales (n=5).

Cross-sectional associations of each CEBQ scale with adiposity (n = 40)

Study ID	FR	EF	EOE	DD	SR	SE	FF	EUE	SR/SE
Carnell & Wardle, 2008*									
Cao, 2012									
Bergmeier, 2014									
Boswell, 2018*									
Braden, 2014†									
Brown, 2012									
Cross, 2014*†									
Demir, 2017									
Domoff, 2015*†									
Emond, 2017*†									
Escobar, 2014†									
Frankel, 2014*									
Fuemmeler, 2013*†									
Gregory, 2010*									
Hankey, 2016*									
Hardman, 2016*†									
Haycraft, 2011*†									
Hayes, 2016*									
Jansen, 2012*									
Koch, 2014*									
Larsen, 2017*									
Loh, 2013*									
Lora, 2016†									
Mallan, 2013									
McPhie, 2011*									
Parkinson, 2010									
Pesch, 2018									
Quah, 2017*†									
Roach, 2017									
Rudy, 2016*									
Sanchez, 2016*†									
Silva Garcia, 2016*†									
Sleddens, 2008*									
Soussigan, 2012*†									
Svensson, 2011									
Tay, 2016*†									
Viana, 2008*									
Vollmer, 2015*†									

Webber, 2009*†									

Prospective studies: association of each CEBQ scale with later adiposity (CEBQ → adiposity) (n =11)

Study ID	FR	EF	EOE	DD	SR	SE	FF	EUE	SR/SE
Mallan, 2016									
Mallan, 2014									
McPhie, 2012									
Quah, 2015 ‡									
Steinsbekk, 2015									
Derks, 2018									
Steinsbekk, 2017 ‡									
Bjorklund, 2018 ‡									
Bergmeier, 2014									
Escobar, 2014 †‡									
Parkinson, 2010									

Prospective studies: association of adiposity with later CEBQ scale (adiposity → CEBQ scale) (n=5)

Study ID	FR	EF	EOE	DD	SR	SE	FF	EUE	SR/SE
Steinsbekk, 2015									
Steinsbekk, 2016									
Derks, 2018									
Steinsbekk, 2017 ‡									
van Deutekom, 2016 †									

Cross-sectional associations of each BEBQ scale with adiposity (n = 5)

Study ID	FR	EF	SR	SE	GA	SR/SE
Mallan, 2017						
Quah, 2015						
Shepard, 2015						
van Jaarsveld, 2015						
Patel, 2018						

Key: Green = positive association; Red = negative; Light grey = null; White = not measured/no data

* Indicates studies included in the meta-analysis
† Indicates studies for which authors provided additional data.
‡ When multiple time points of data are presented in the original study, the longest eligible association has been included in the table

Lipowska et al. (2018), McCartney et al. (2015) and Sanlier et al (2016) presented estimates stratified by weight status and/or gender, and therefore have not been included in this table.

Patel (2018) reported cross-sectional data exclusively
When multiple timepoints of data are presented in the original study, the longest eligible association has been included in the table above.

E.4 Testing for linearity across weight categories (n=19).

Study ID	Test for linearity	FR	EF	EOE	DD	SR	SE	FF	EUE	SR/SE	Weight categories used	Additional observations
Carnell & Wardle, 2008	x										Low-normal, mid-norm, high, very high	
Croker et al., 2011	x							NS	NS		UW, NW, OW, OB, Clinically OB	
de Groot et al., 2017											NW, OW	FR scores were higher for OB compared to NW (p<.001). No significant difference between NW and OB for SR, EF, DD.
dos Passos et al., 2015	x							NS	NS		NW, OW, OB, Severe OB	
Gardner et al., 2015	x		NS								NW, OB	
Ho-Urriola et al., 2014	x				NS			NS	NS		NW, OB	
Jahnke et al., 2008	x										UW, NW, OW, OB	
McCarthy et al., 2015											UW, NW, OW/OB	FR and EF were significantly higher for OW/OB children compared to UW and NW (p<.001). SR, SE and FF were significantly lower for OW/OB children compared with UW and NW (p<.001). No significant difference between weight status categories for EOE, DD and EUE.
Mosli et al. 2015											NW (<85th), OW/OB (85th>)	SR and FF were significantly lower for OW/OB children compared to NW.
Obregon et al., 2017											NW, OW, OB	FR, EOE, EF were significantly higher for OB children compared to OW and NW (p<.001). DD was significantly higher for OB children compared to NW (p<.001) but not OW. SR and SE were significantly lower for OW/OB compared to NW (p<.001).
Parkinson et al., 2010	x										BMI centile lowest, middle, highest	

Study ID	Test for linearity	FR	EF	EOE	DD	SR	SE	FF	EUE	SR/SE	Weight categories used	Additional observations
Powers et al., 2006											UW, NW, at-risk for OW, OW	No significant difference between weight status categories for DD and FR.
Sanchez et al., 2016	x								NS		NW, OW, OB	
Soussignan et al., 2012											NW, OW	FR, EOE, DD were significantly higher for OB children compared to NW (p<.05). SR was significantly lower for OB children compared to NW (p<.05). No significant difference between weight status categories for EF, SE, EUE and FF.
Spence et al., 2011	x										UW, NW, at-risk for OW, OW	
Webber et al., 2009	x x								NS		Thinness grade 1/2, low NW 50th centile or less, mid normal weight >50th but not OW, OW/OB	
Sandvik et al., 2018											Thinness, NW, OW, OB	Analysis showed that eating behaviours differed between the weight status groups.
Sanlier et al., 2018											UW, NW, OW, OB	FR, EOE, EF were significantly higher for OB children compared to OW, NW and UW (p<.001). SR and SE were significantly lower for OB compared to OW, NW and UW (p<.001). No significant difference between weight status categories for DD.
Boswell et al., 2018	x						NS				UW, NW, OW, OB	

Key: Green = positive association; Red = negative; Yellow = none; White = not measured/no data.

Appendix F

Additional table for Chapter Seven

F.1 Comparison of the study sample and the total HEI sample on the study variables.

	Study sample, % of families (No.) (n= 770)	Total HEI sample, % of Families (No.) (n=1113)	P difference
	Mean (SD) or % (n)	**Mean (SD) or % (n)**	
Age of child at HEI (years)	4.12 (0.40)	4.17 (0.40)	0.19
Gestation (weeks)	36.32 (2.44)	36.2 (2.54)	0.43
Sex of child			
Male	34.0 (262)	33.7 (375)	0.90
Female	35.7 (275)	35.0 (389)	
Opposite	30.3 (233)	31.4 (349)	
Zygosity			
MZ	33.80 (260)	33.7 (375)	0.30
DZ	66.20 (510)	65.2 (726)	
Unknown	-	1.1 (12)	
Maternal age at twin's birth (years)	34.14 (4.49)	33.9 (4.75)	0.02
Overall home environment			
Lower risk	57.5 (438)	54.2 (603)	0.02
Higher risk	42.5 (324)	45.8 (510)	
Home food environment			
Lower risk	52.90 (403)	52.0 (579)	0.12
Higher risk	47.10 (359)	48.0 (534)	
Home activity environment			
Lower risk	55.5 (423)	57.2 (637)	0.23
Higher risk	44.5 (339)	42.8 (476)	
Home media environment			
Lower risk	60.9 (464)	56.0 (623)	<0.01*
Higher risk	39.1 (298)	44.0 (490)	

HEI = Home Environment Interview (HEI); MZ = monozygotic; DZ = dizygotic; SD = standard deviation.