Understanding inequalities in child development and the impact on adolescent health

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Abstract

Introduction

Optimal development in childhood is important for future health. Evidence on the relationship between components of child development and adolescent health, and the influence of socioeconomic conditions, is poorly understood. This research aimed to identify aspects of development most associated with adolescent health and understand trajectories of development, in mid-childhood, in terms of socioeconomic and adolescent health impacts.

Methods

A participatory systematic review was undertaken to synthesise evidence on the relationship between child development (3-7 years) and health in adolescence (8 -15 years); and to identify factors which shape the relationship. Then, longitudinal analysis progressed in three steps. First, group-based trajectory models (GBTM) to identify trajectories of; socioemotional, cognitive and concurrent socioemotional and cognitive problems, from age 3 to 14 years. Second, multinomial regression to assess associations between socioeconomic, parental and school level predictors and the derived trajectories. Finally logistic regression to assess associations between trajectory groups and adolescent health at age 14 and 17.

Results

Poor socioemotional development at school starting age was the aspect of child development most strongly associated with overweight and mental ill health in adolescence, followed by cognitive development. In each model four mid-childhood development trajectories were found. These were trajectories of early, late, and persistent and no problems. In each analysis, those in the problem trajectories were more socioeconomically disadvantaged. Trajectories of persistent cognitive and socioemotional problems and all adverse trajectories of socioemotional problems were strongly associated with overweight and mental ill health in adolescence.

Conclusion

There are socioeconomic inequalities in children's socioemotional and cognitive development. This inequality will have a negative impact on weight and mental health in adolescence, driven mainly by adverse socioemotional development. Child and adolescent health policy with a central focus on social and emotional wellbeing using prevention and mitigation approaches is needed to improve health and reduce health inequalities in adolescents.

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Abbreviations

BAS	British Ability Scales
BMI	Body Mass Index
CI	Confidence Interval
DAG	Directed Acyclic Graph
DRF	Doctoral Research Fellowship
ECD	Early Child Development
GBTM	Group Based Trajectory Modelling
GLD	Good Level of Development
HLE	Home Learning Environment
LQAT	Liverpool Quality Assessment Tool
MCS	Millennium Cohort Study
NIHR	National Institute for Health Research
OFSTED	Office for Standards in Education, Children's Services and Skills
OR	Odds Ratio
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PRISMA-P	Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols
RRR	Relative Risk Ratio
SDH	Social Determinants of Health
SDQ	Strengths and Difficulties Questionnaire
SES	Socioeconomic Status
SEC	Socioeconomic Circumstances
SMFQ	Short Moods and Feelings Questionnaire
STATA	Statistics and Data
SWiM	Synthesis Without Meta-analysis
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organisation

Declaration

I, Michelle Nora Black, confirm that the Thesis is my own work. I am aware of the University's Guidance on the Use of Unfair Means (www.sheffield.ac.uk/ssid/unfair-means). This work has not been previously been presented for an award at this, or any other, university.

Publications and Dissemination

Peer-reviewed journal publications:

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Oral Conference Presentations:

Black, M. Impact of childhood social and emotional development on adolescent health: Longitudinal Analysis from the UK Millennium Cohort Study. Plenary abstract presentation. Royal College of Paediatric and Child Health Conference, Glasgow, UK. 23rd May 2023.

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Other presentations to disseminate research:

Sheffield city council lunch and learn: 15th December 2022

Child of the North Workshop: 19th January 2023

University of Sheffield Public Health Society: 7th March 2023

ScHARR webinar series: 21st March 2023

Chapter 1: Introduction – The Importance of the Adolescent Years

This chapter provides an overview of the justification and rationale for the research. It describes the evidence and evidence gap on the relationship between child development and adolescent health. It describes why it is important to fill this gap in relation to informing policy to address rising inequalities in adolescent health. It culminates with the research question and an overview of the structure of the thesis.

1.1. Relevance of the Issue – socioeconomic inequalities in adolescent health

Across the globe inequalities in adolescent health are increasing due to changing demographics and living conditions (1). For example, inequalities in obesity and mental ill health are increasing, in part, because of unequal social and economic conditions between population groups (2). Addressing health and socioeconomic inequalities in health across the world's 1.6 billion adolescents (16% of the world population) is imperative for their future health and life opportunities, and for those of the next generation.

Adolescence represents the transition from childhood to adulthood and is typically defined as the period from age 10 to 19 years (3). It represents a period of considerable development (4, 5), in which good health provides both the foundation for later health (6) and the foundation to benefit from education (7), at a prime time for educational opportunity. Education is one of the strongest determinants of health (8) and one of the key enablers for improving life chances and reducing socioeconomic inequalities in health within and between generations (9). Thus, maximising health and reducing health inequalities at this crucial life stage, is an opportunity for improved future health and wellbeing at an individual and population level.

Addressing adolescent health inequalities requires an understanding of the 'causes' of inequalities, which may be different in different countries. In high income countries, inequalities in adolescent overweight and mental ill health are stark, and are known to be driven, in part, by differences in socioeconomic circumstances and socioeconomic status (SES) between groups (10, 11). Reducing inequalities in these outcomes, at population level, requires an understanding of how they emerge over time from socioeconomic inequality: from differential exposure and susceptibility to the socioeconomic 'causes' of adverse health (12, 13). Indeed, the 'causes' of inequalities in health are, in part, because of differences in material living circumstances (such as living in a neighbourhood with a high obesogenic environment, leading to greater exposure to innutritious foods) and to linked psychosocial factors (including stress and anxiety, leading to greater susceptibility to overweight

because of mental ill health in the home) which are experienced differentially across the population (14).

Adolescent health is preceded by health and socioeconomic circumstances earlier in the life course and thus by inequalities in child health and development in the early years. Child health inequalities in the early years are increasing, with children in the most deprived parts of the UK having some health outcomes amongst the worst in Europe (15). There is a strong association between socioeconomic status (SES) and child health in most western countries (16). Children born to families of lower SES are more likely to be obese (17), have behavioural and mental health problems (18), poor diet (19) and lower levels of physical activity (20) than children in families of higher SES. The root of some of this inequality is thought to be in early childhood with inequalities in child development (21) (cognitive, emotional and social) persisting across the life course, negatively impacting on future health wellbeing and life chances, perpetuating health inequalities in adulthood (22).

Evidence shows that early child development impacts adolescent academic outcomes, presenting an opportunity for onward social mobility throughout adolescence and into adulthood. Child development encompasses a child's; cognitive, social and emotional, physical, and language and communication development. There are socioeconomic inequalities in early child development as measured when starting primary school with children from more deprived backgrounds at lower levels of development than their more affluent peers (21). For example, adverse material living circumstances are associated with worse cognitive outcomes and adverse family psychosocial factors are associated with poor behavioural outcomes in early childhood (23). Evidence shows that socioeconomic inequality in early child development is detrimental for later academic success as good development on starting school is associated with greater academic achievements in adolescence (24, 25). Further, a recent study highlighted that 1 in 5 children in the UK do not pass academic tests (GCSEs) in English and Maths at age 16. The study found that those children ('the forgotten fifth') were more likely to not be 'school ready' at age 3 or have reached expected standards at age 5 (26). In essence their early educational development trajectory set them towards a path of poor educational attainment as adolescents. This is detrimental for future education (27) and employment opportunities (28).

Evidence on the links between early child development and academic attainment in adolescence supports policy emphasis on education attainment. However there is less of a policy focus on health in the adolescent period. This is a missed opportunity. First, because of the evidence for health selection during the adolescent part of the life course, and second, because it represents a

significant period of development. Health selection (also known as reverse causation) refers to differences in health status leading to differences in social status. It argues that it is health which determines someone's SES rather than SES determining health. There is causal evidence that health in adolescence causes better SES because it enables selection into education (29). This contributes to social causation arguments as a cause of health inequalities across the life course (30). Therefore focusing on health in adolescence is critical to enable them to get the most out of their later educational experiences for wellbeing and employment opportunities. In relation to development, with the onset of puberty in mid-childhood (age 6-12), a new stage of brain development begins. In this phase a child's interactions with the social, cultural, and educational environment shapes the brain development involved in processing and regulating emotions and cognitive control, which are essential for functioning in society (31). This development is informed by earlier child development and will subsequently determine future development in adulthood.

It is recognised that there is a need for research to better connect early life experiences with continued growth in childhood and adolescence (32). The evidence for the positive effect of early child development (cognitive and non-cognitive skills) on health and economic outcomes in adulthood is clear; early skills development improves human capital (33) which strongly influences wellbeing, obesity, mental health, heart disease, literacy and numeracy, criminality and economic productivity in adulthood (34). There is less evidence on the relationship between early child development and health outcomes in adolescence, although there is some evidence for the effect of early child development programmes on obesity reduction, greater social competence, improved mental health and crime prevention (35). This limited evidence on the impact of early child development on adolescent health, may limit interventions in childhood to improve adolescent health and reduce inequalities in health.

In summary, adolescent health, health inequalities and academic outcomes are influenced by early childhood development and socioeconomic circumstances. The evidence on the relationship between early child development and academic outcomes in adolescence is relatively clear. Also, the evidence for early skills development on adult health and economic outcomes is clear. However there is less evidence on the relationship between early child development and adolescent health at a critical time in the life course for health itself and for later academic success. Thus, better understanding the relationship between child development and adolescent health, in the context of socioeconomic circumstances, may identify how and when to intervene to improve health, and reduce socioeconomic inequalities in health, in adolescence.

1.2. Previous research and gaps in the literature

1.2.1. Evidence on, and the impact of, inequalities in child development and health

Inequalities in child development and health tend to tack forward and increase over time to influence inequalities in later health outcomes (36). Therefore, reducing inequalities in child and adolescent health and development is a global health priority. Evidence suggests that optimal development of knowledge, skills and attributes in early childhood could reduce health risks from childhood through to adulthood (37). Recognising the interconnected nature of health and development in childhood, and the importance of socioeconomic circumstance in determining outcomes, many programmes are in place across the UK which seek to address health and development across the wider determinants of child health, such as; quality early years education (38), universal services such as welfare and health visiting (39), parenting programmes (40) and community support through children's centres (41, 42). Whilst improvements for children as a whole are being seen for some health outcomes (asthma, epilepsy, diabetes) (15), socioeconomic inequalities persist (15), and for some outcomes inequalities are increasing (43). This is particularly the case for obesity and mental ill health in early adolescence (44) with negative consequences for weight (45) and wellbeing (46) in adulthood.

Obesity in adolescent girls has a negative impact on their future health and education with evidence that they are less likely than their non-obese peers to go to college as a result of increasing anxiety (47). In the area of mental health there is evidence of 'missing years' in adolescence (48). Currie highlights that a lack of research in this period is critical as it is when many mental health conditions are diagnosed and there is limited knowledge on how and when to intervene (48).

The public health burden of these health outcomes, obesity and mental ill health, is great and increasing. Globally the prevalence of anxiety and depression has doubled from pre- to post-pandemic years and currently affects around 1 in 4 of those under the age of 18 years (49) with stark inequalities in high income settings. Children and adolescents in families with a lower socioeconomic status (SES) are two to three times more likely to develop mental health problems than their peers living in families with a higher SES (10). Prevalence of, and inequalities in childhood obesity is also increasing. For example, in the UK, 1 in 4 children are obese when they leave primary school at age 10-11 years (11), the start of their adolescent journey.

1.2.2. Why study the relationship between child development and adolescent health

The importance of the early years

The early years is a critical period in the development of cognitive, non-cognitive and social and emotional skills with life-long effects (50). From birth to 3, 'the first 1000 days', is a period of significant brain development and heightened plasticity (51). In addition to neurodevelopment, immune and endocrine responses are also sensitive during this period (52). Childhood experiences, environment and genetics all lay the foundations for how well this significant physiological development happens and shapes future health. Biological embedding is the term used to describe how systematic differences in experiences and environments in early childhood can lead to biological and physiological disruptions which have consequences on health, wellbeing, learning and behaviours into adulthood (53). Genetics, have a key role in driving embedding through epigenetics. This is the interaction between genes, the environment and early childhood experience which alter gene expression to influence physical and mental health later in life (54). Exposure to toxic stress such as poverty, abuse or severe maternal depression in childhood can have lasting effects on health through biological embedding via neural, immunological and endocrine development and epigenetics (55).

The evidence for the early years as a critical period of development together with the health economics research in this field make the early years a prime area for public policy and public health investment. The health economics research by Heckman elucidated the cost-benefit impact of investing in early childhood development programmes in disadvantaged children compared to investing in later life (56). This work was based on human capital theory which infers that cognitive and non-cognitive skills formation, acquired through education and training increase the productivity of the workforce leading to greater economic output for society and a higher income for the individual. He found that investing in disadvantaged children to optimise development in the early years (age 0-3 years) brings about wide ranging human capital development in later life which strongly influences wellbeing, obesity, mental health, heart disease, literacy and numeracy, criminality and economic productivity (34). So investing in the early years, particularly for disadvantaged children, matters because it lays foundational skills which later education can build upon.

The relationship between education, health and health inequality

As educational attainment increases so too does life expectancy and years in better health in adulthood (57, 58). There are three explanations proposed for this association; causation, selection and confounding (29). Causation infers that education causes better health through schooling,

leading to employment and higher social status which in turn affect health (59). Selection or reverse causality surmises that health causally affects amount of schooling (poor health affecting educational attainment through absence). Confounding means that both education and health are affected by another factor such as time preferences or childhood experience (58). Time preference relates to the likelihood of engaging with current effort for future benefit, both education and positive health behaviours involve doing something now for future benefit and thus can be affected by a person's time preferences confounding the relationship between education and health. The relationship between education and health is bi-directional and this has important policy implications. Do we invest in education to improve health or invest in health to improve education? Or do we need to understand the relationship better to inform policy in both?

Whilst causality in either direction is much researched and disputed there is evidence of a causal effect between education (when measured as compulsory schooling) and outcomes in adulthood such as reduced mortality, smoking and obesity (60). Other research provides evidence that selection and confounding have a greater effect than causation, with more educated adults having better health (self-reported health and healthy weight) because adolescents with good health select into education and because adult education and health are both affected by similar earlier life experiences (29, 61). Thus, there is evidence for all three explanations for the relationship between education and health. Research has been criticised for attempting to assign one explanation (62), rather than conceptualising the education-health relationship as a developmental life course process grounded in the broader social context and trying to understand how that process leads to health (63).

How education affects health from a life course perspective

Within a life course perspective education is considered both a *product* and a *process*, within a social context (63). The current understanding on how education affects adult health is through the acquisition of a range of cognitive and non-cognitive skills which result in 'educational attainment', a measurable educational *product* (57). Educational attainment improves health directly and also indirectly by improving access to resources via employment, a greater sense of control and healthier behaviour (64). There is also evidence for education as a *process* to imbue knowledge, skills and personal control. Ross and Mirowsky provide evidence that it is these skills that mediate the relationship between education and health rather than 'products' such as a diploma or a degree (65).

So, whilst the evidence is clear that education, in terms of years of schooling and development of knowledge and skills causes better health in adults we have much less understanding about when

and how childhood education and development may start to translate into health in adolescence. Understanding what is known about the relationship between development at the start of primary school and adolescent health is the starting point to unpick the development and health relationship in childhood.

1.2.3. Evidence on the relationship between child development and adolescent health

In the UK 'school readiness' is the term used to measure child development at the end of a child's first year of primary school. In essence this is the first educational 'product' in childhood and is a composite measure of personal, social and emotional, physical, communication and language development, assessed as a binary outcome with a child either meeting a good level of development or not. Continued educational development in primary schools is measured in Standard Assessment Tests (SATs) tests.

School readiness is a policy lever in many developed countries, with governments using it to prescribe the curriculum, which, for the early years, is intended to develop school ready children: *'the broad range of knowledge and skills that provide the right foundation for good future progress through school and life*' (66). Many local and national policies in the UK strive to reduce the early years attainment gap using school readiness as the measure, as it is seen as an important marker of whether a child has been given the 'best start' in life which in turn will lead to better health and wellbeing in adulthood.

The idea of school readiness, however, is not universally accepted as it is a construct which can be defined and interpreted differently; for example, with a narrow focus on cognitive education or with a broader focus on life skills, such as confidence and social skills (67). The use of the term highlights an ideological view that there is a need to start setting children towards measurable outcomes for future economic success and is criticised for not recognising childhood education as a developmental process with children starting the process of learning from birth (68). Education as a developmental process that builds children's capabilities is an alternative view, but is arguably much more difficult to measure.

In summarising the evidence for school readiness it is necessary to look at early childhood programmes which are in essence about health and skills development in the early years. There is evidence from the US, UK and Canada that early childhood programmes improve later academic success (69), cardiovascular health outcomes in adulthood (70) and reduce delinquency and crime in adolescence (71). Programmes which encompass parenting support and early learning opportunities in or out of the home enhance child development in readiness for school improving

cognitive and non-cognitive skills in children (72). Positive cognitive development on starting school is associated with academic achievement by age 13 years (24) and socioemotional development by age 10 years (73). Non-cognitive skills such as social skills and self-regulation on starting school also improve academic success and psychosocial outcomes in subsequent years (74). A systematic review on school readiness and later school related outcomes found that language and math skills at preschool age, higher SES, and socioemotional skills were the most significant factors in the promotion of positive development in school age children in high income settings (75).

There is less evidence of the effect of early child development programmes on health outcomes in later childhood or adolescence other than limited evidence for obesity reduction, greater social competence, improved mental health and crime prevention (35) and on reducing childhood hospitalisations for infections and injury (76). There is evidence that measures of cognitive development at primary school starting age, as a component part of a model incorporating routinely collected data, predict socioemotional behaviour and obesity at age 11 years (77). To move beyond the predictive value of measures, evidence is needed on 'how' early child development may affect later health outcomes. In particular if we are to improve adolescent health there is a need to understand the associations and pathways between child development and adolescent health and the socioeconomic factors which shape this relationship (78).

1.2.4. Evidence Gap

There is a considerable gap in understanding the relationship between child development at school starting age and key health outcomes, such as weight and mental health in early adolescence. Specifically there is little evidence on associations between different aspects of development and adolescent health, as highlighted above; many studies evidence development as a composite measure such as 'school readiness' or look at a specific aspect of development such as cognitive or non-cognitive skills. Evidence is lacking in terms of component parts of child development and which components are most associated with later health. Evidence is needed on the relationship in terms of associations and mechanisms, that is, which aspects of development (cognitive, social and emotional, communication and language and physical) are most associated with adolescent weight and mental health and how.

Understanding the relationship between development and health in the child to adolescent life course provides an opportunity to learn about the social contexts which shape the relationship. The SES a child is born into affects their health and life opportunities which from a social causation perspective is because of material, psychosocial and behavioural factors and this leads to inequalities in health. However, there is no evidence on if and how a child's socioeconomic

circumstance affects the development-health relationship in childhood to adolescence. Similarly expanding the evidence base on the role of a child's own agency in how health behaviours develop from foundational knowledge and skills recognises education not only as a route to resource (human capital) but as a developmental process, throughout the life course, developing values and choice.

Additionally, there is little literature on whether trajectories of development, during the school years in mid-childhood, impacts on adolescent health. Whilst existing research has studied some elements of developmental domains separately over time (79-82) little is known about population level trajectories of concurrent development in mid-childhood nor the impact of trajectory of development on adolescent weight and mental health. Acquiring knowledge in this regard may illuminate how and when to intervene in mid-childhood to improve adolescent health and identify how to build upon 'best start' policies, and inform policy in mid-childhood and adolescence. For example, if children are behind when they start school, and many are with gaps in level of development on starting school linked to deprivation, do they remain on a poor development trajectory or do they improve. What characteristics are associated with improvements or declines? Are there groups of children following distinct trajectories of development and what impact do those trajectories have on adolescent health. Increasing knowledge on whether and how development impacts on later health may improve cross sector collaboration to improve health and reduce inequalities in adolescent health, and determine the balance between interventions on socioeconomic circumstances and those on development.

1.2.5. Policy Gap

The above sections have highlighted the evidence gap with regard to relationships between aspects of child development, trajectories of child development and adolescent health. There is also a significant policy gap in this area – both globally and nationally in the UK with existing policy focused on 'best start in life' initiatives, rather than in later childhood and adolescence. Indeed, in the UK there has been tremendous focus on early years, with investments made in children's' centres, early years education and access to health visitors prioritised. Despite this approach, which incorporates actions across education, health, and access to social support, a review of policy approaches across UK countries since 1999 (83) found that poverty and resourcing were the key influences on child health outcomes, suggesting more fundamental action is needed.

Indeed, there is an argument that current policy on health and development has substantially neglected and underserved children from primary school starting age to adolescence, and that research and action on child health and development should evolve from a narrow emphasis on the first 1,000 days to a holistic approach over the first 8,000 days in order to embrace the needs across

the life cycle (4). This strong policy focus on the first 1000 days has led to significant investment in the early years. This mirrors the volume of health literature in the under 5's compared to older age groups (age 5-19). However there is increasing emphasis being placed on the need for research in mid-childhood to adolescence because of neuro development/plasticity and physical growth during mid-childhood to adolescence (5).

As suggested by the evidence presented above about people's life course, there is scope for future action to embed this kind of life course approach and to build upon 'best start' initiatives, because the impact of poverty or adverse socio-economic circumstances does not stop at a certain age. Yet evidence is needed to help bridge this policy gap between early childhood and adolescent health; and specifically on understanding the impact of development, at this critical juncture (and during the school years), on adolescent health.

There are intergenerational benefits of policy actions in later childhood and adolescence (4), particularly in relation to education and this has implications for health inequalities policy. The direct effect of education on wellbeing is greater than the direct effect of social origins on wellbeing, with education mediating most of the relationship between social origins and wellbeing via its impact on economic and work resources (84). This research also showed that education has a greater effect on health in those born to poorly educated parents than on those born to better educated parents. This highlights the opportunity of education to improve health to those born in lower SES and an opportunity to break intergenerational transmission of health inequality by ensuring children born to poorly educated parents have access to educational opportunities (9). This emphasises both the opportunity and role of health and education sectors in creating child-adolescent life course policy to reduce inequalities, if they can better understand and maximise the impact of one on the other at critical stages of the life course.

Inter-sectoral action is a key factor in achieving policy coherence on health inequalities (85), and this can be achieved by shared understanding of information between sectors (86). Action and policy coherence is limited (87) by the lack of evidence and understanding about the relationship between education and health outcomes in the context of socioeconomic circumstances (78) and how interactions between education, health and social factors shape outcomes. This is pertinent learning for improving health in adolescence because it is the interactions between prenatal and early childhood development and the biological and social changes during mid-childhood, shaped by socioeconomic circumstances and risk and protective factors that influence health-related behaviours (6).

Better understanding the relationship between child development and key health outcomes in early adolescence may inform public health policy and action across the child-life course to improve adolescent health and reduce health inequality. In addition it may improve understanding and coherence between agencies and help cross sector decision-making in tackling health inequalities.

Therefore the aim of this research was to explore how development, in children of primary school age, affects health (specifically weight and mental health) in adolescence in the context of socioeconomic circumstances to inform interventions to improve health and reduce inequalities in these outcomes in adolescence.

1.3. Research Aim and Questions

The overall aim of this research was to better understand the development-health relationship in the child-adolescent life course, in the context of socioeconomic circumstances, to inform interventions to improve health and reduce health inequalities in early adolescence. To achieve this aim, the following questions were addressed:

RQ1: What are the associations between measures of child development recorded at primary school starting age (3-7 years) and subsequent weight and mental health in adolescence (8 - 15 years)?

RQ2: How does development in children of primary school starting age affect health outcomes in adolescence, in the context of socioeconomic inequality?

Specifically what is reported in the literature in relation to:

- What are the effect modifiers (socioeconomic and environmental factors) of this relationship? (This will identify variables which alter the strength of the observed associations.)
- What are the mediators of this relationship? (This will identify variables or pathways which explain the observed associations.)

RQ3: Are there distinct trajectories of development in mid childhood and are these characterised by socio-economic, school and parental factors? What are the associations between any identified developmental trajectories and adolescent weight and mental health?

As will be explained in Chapter 5, the answers to RQ1 and RQ2 were used to refine RQ3, in terms of which aspects of development to analyse.

1.4. Thesis structure and layout

This thesis is presented as an alternate format thesis, comprising three published papers together with more 'traditional' introduction and discussion chapters. The thesis started with, a systematic review (Phase 1 of the research), which focused on understanding the relationship between child development on starting school and adolescent weight and mental health and what factors might shape or explain that relationship (RQ1 and RQ2). The findings of the review illustrated evidence on the relationship between each aspect of development (cognitive, physical, social and emotional, language and communication) and health. These findings were used to refine RQ3. Subsequent longitudinal analysis, phase 2 of the research, answered the more refined RQ3 (outlined in Chapter

5) to improve understanding of the relationship between trajectories of socio-emotional and cognitive development in mid childhood and adolescent weight and mental health at age 14 and 17 years and how these trajectories of development are influenced by socio-economic and other factors.

Theoretical insights that underpin the thesis, the quantitative analysis and the interpretation of results, are articulated in Chapter 2, which begins with a brief overview of the theory and policy discourse of health inequalities. It then presents what is known about pathways to inequalities in child health stemming from socioeconomic circumstances and development. It culminates with the conceptual model for the research. Chapter 3 outlines the refined research questions and methodology for phases 1 and 2. Chapter 4 presents the first two papers, a protocol paper and a systematic review. This review was the means of refining the research question for the subsequent longitudinal analysis phase of the PhD.

The research question for the longitudinal analysis was based on the findings from the systematic review. Chapter 5 presents the findings of the longitudinal analysis and the third paper. The paper reports the findings of the multi trajectory analysis of socioemotional and cognitive development concurrently. Chapter 5 also presents two other pieces of analysis; trajectories of socioemotional problems, and trajectories of cognitive problems. Chapter 6 presents the discussion of the findings and contributions to research, practice and policy.

The published articles (papers 1 and 2 in Chapter 4 and paper 3 in Chapter 5) present the main findings of my PhD at the University of Sheffield. As first author of the published articles, I was responsible overall for the design, method, analysis, interpretation and drafting of the manuscripts for submission. Author agreement forms were signed for each submission and author contributions are printed in the published articles. Contributions for all authors, together with my contribution, is summarised in appendix 1. The publishing license for each paper includes permission to publish them in this thesis, confirmation of the permissions are available in appendix 2. There is some duplication between the protocol paper (paper 1) and the systematic review (paper 2). However, this is unavoidable given the nature of a protocol paper. Deviations from protocol to review are specifically highlighted after the protocol paper. The complete set of supplementary materials for each paper are available in appendices 3 to 5.

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1.5. Chapter Summary

Reducing child and adolescent health inequalities is a global health priority. Evidence suggests that early child development is crucial for future wellbeing. Adolescent health is an important life course transition for future health and for providing the foundation to benefit from education. The benefit of early child development on later academic success in adolescence is clear. However the relationship between early child development and adolescent health outcomes, in the context of socioeconomic inequality, remain poorly understood. This limits interventions and coherent cross-sector policy in mid-childhood to address increasing child and adolescent health inequality. Increasing knowledge of the relationship between child development and adolescent health could inform interventions in later childhood. This knowledge could provide an opportunity to improve health at a key point in the life course, enabling access to educational opportunities and future employment. From a public health perspective improving adolescent health and reducing health inequalities provides an opportunity to break cycles of intergenerational inequality.

Chapter 2: Setting the Scene - What determines your future?

This chapter provides a brief review of theories of what 'causes' health inequalities and the pathways through which the 'causes' lead to inequalities in health and development in children. It describes the key contributions of these theories to this research and how they inform a conceptual model. It concludes by summarising the key points to be taken forward in this research.

2.1. Conceptualising Health Inequalities

There are different ways of understanding and conceptualising the causes of differences, or inequalities, in children's development and health. In this thesis I am embedding a social determinants life course perspective, with a focus on capabilities and human capital, to inform the conceptual model which underpins my research. Here I describe how these theories informed the conceptual model.

2.1.1. Defining Health Inequalities and Health Inequities

The World Health Organisation (WHO) define health inequity as the systematic difference in health status of different population groups (88). From this perspective they are considered unfair and avoidable as they could be reduced by government policy (88). The definition stems from our understanding of the impact of social conditions on health which is largely influenced by Mckeown's research which attributed increases in life expectancy in the 19th century to living conditions such as nutrition, sanitation and clean water rather than medical advancements such as antibiotics and improved hospitals (89). However, the improvements in health conferred by improved social and living conditions, hereafter referred to as socioeconomic circumstance (SEC), are not seen uniformly across society. Differences in life expectancy persist between people depending on their SEC, with more affluent people living longer than those less affluent. Income matters but so too does social status. The British Whitehall studies highlighted the importance of social status for health and wellbeing. In these studies of civil servant workers, a relatively affluent population, a gradient in health relative to socioeconomic position was observed (90). Those workers in higher socioeconomic positions had better health and life expectancy than those in lower socioeconomic positions. This social gradient in health, seen across whole populations (91), evidences the *systematic difference in health status of different population groups* or health inequity.

Health inequalities is the term most used in UK public health research and practice but it is important to make a distinction between health inequality and health inequity at the outset. Health inequality refers generically to a difference in the health of individuals or populations (92). From this definition, some health inequalities are unavoidable because of genetics or free choice and it is

considered ethically and ideologically impossible and/or unacceptable to reduce them e.g. health differences based on age or individual decisions taken after screening for downs syndrome. However, some health inequalities are deemed avoidable as they are a result of the uneven distribution of social conditions and are a result of, or changeable through, political choices that are made: for example, less employment opportunities in some areas can result in financial insecurity, poverty and inequalities in mental health. It is these avoidable inequalities which lead to systematic differences in health or health inequity. The term "inequalities" is used throughout this thesis with reference to health inequities as a result of avoidable health inequalities.

2.1.2. The Social Determinants of Health

The WHO definition of health inequality is rooted in the concept that it is social conditions which largely determine health and health inequalities. Our health and wellbeing is affected by a complex range of factors which occur at both the individual and societal level. Individual factors include biology, genetics, our personality and behaviours. At a societal level, our health is determined by factors such as education, housing, access to healthcare, employment, income, food, social cohesion and social status (93). These societal factors are largely determined by social and public policy at local, national and international levels and in public health the term social determinants of heath (SDH) is used to describe them. It is considered that it is these wider determinants which collectively shape health by '*creating the conditions in which people are born, grow, live, work and age'* (93). This framing of health as socially, politically and economically determined accentuates it as an issue of social justice and human rights, with the pursuit of health for all or health equity a moral imperative for public health action (94). The SDH narrative, in recognising that it is both individual and societal factors which shape health, has led to calls for 'health in all policies', which emphasises that the health implications of policy actions in any sector should be considered to improve public health and reduce health inequality (95). This emphasis on the SDH as both the cause and solution to ill health distinguishes the field of 'public health' from traditional biomedical models of healthcare which emphasise biological (e.g. genetic) and lifestyle factors, such as smoking and diet, as the causes of ill health (96).

2.1.3. The theory of how Socioeconomic Status causes Health Inequalities

Thus far we can see that there are differences in health among populations and some of these differences are considered inequalities, avoidable differences in health. Health inequalities are driven by differences in the social position or status of groups, herein referred to as socioeconomic status (SES). The inequality, from an SDH perspective, is rooted in social conditions as determined by SES. How can we explain how SES leads to health inequality via differing social conditions?

Social Causation

The social causation hypothesis provides a theory on how SES causes health inequality via access to different social conditions. It stems from the seminal work of Link and Phelan who first described the "Fundamental Causes" theory (FCT) to explain the association between SES and health inequalities (97). This theory surmises that inequalities have persisted over time, despite the fact that diseases and conditions previously thought to cause morbidity and mortality among low SES individuals have resolved (e.g. poor sanitation), because SES determines social conditions which affect access to resources (knowledge, prestige, money, power and positive social connections) which in turn determines ability to avoid risk and disease, through various mechanisms. SES is conceived as a meta-mechanism, having effect through multiple intervening risk-factor mechanisms, which vary over time. FCT argues that interventions which focus on these intervening mechanisms (e.g. action on alcohol or tobacco policy) defer attention away from the distal social or structural causes of disease (e.g. income inequality).

Critics of FCT argue that the theory is under-theorised and does little to explain the mechanisms between SES, which is depicted as a multifaceted but static separate entity, and health (98). That is, SES can be depicted in many ways but research usually selects a static marker of SES such as education, poverty or income for example and which measure is used may make a difference to findings. Therefore due consideration should be given to how SES is conceptualised and thus measured as different measures may well produce different results with different policy implications.

Additionally it is argued that the dynamic nature of the relationship between SES and health, is not depicted by FCT. Therefore it is important to move beyond SES as a static cause, and health inequalities as an outcome, to specific theory about aspects of SES and their relationship with health. This requires considering the relationship between measures of SES , resources, agency and health as emergent properties over the life course as a result of complex interactions across determinants within a population (98). Conceptualising research in this way may help to unpick the complexity of the mechanisms and pathways between SES and health.

It is also argued that social causation hypothesis overlooks the role of human agency by focusing entirely on structural causes (the social and economic policies shaping social determinants which generate inequalities). A narrative which strongly downplays the roles of individuals can result in a disempowered 'puppets on a string' world view (99). It ignores that human practices are embedded in social structure. The limits of this narrative are exposed when viewed through Giddens structuration theory. This theory proposes that rather than ascribing the constraints on human

capacity to structural determinants or to agency, that there is a dynamic relationship between all these factors. By focusing on structure as the determinant or cause of health it disregards that health inequalities could be created by the interaction between individual action and social structure rather than ascribing dominance to either (100).

Adding to the structural determinants versus agency debate a further consideration is institutions as reproducers of inequality, that is, it is not the policy itself but also the everyday actions and institutional processes which result in inequality between groups. Young argues that structural inequality is a result of reproduced social processes by institutions and practices (101). She argues that these reinforcing social processes may explain patterns or inequalities between groups.

In summary, from an SDH perspective, SES results in unequal social, material and political conditions between population groups throughout life (93). However, from this perspective, conditions can be changed by policy and therefore it is possible to reduce inequality. Rethinking systematic institutional processes may also illuminate ways to reduce inequality. Incorporating agency into the dynamic relationship between SES, social conditions and health, and designing research to consider the interactions between these factors over time, may help to unpick the complexities of the causes of health inequalities.

2.2. How social conditions shape Children's Health/Health inequalities

Children are born into conditions which can undermine or enhance their health and development. The social status of their parents inform the social conditions in which they live which in turn informs their access to rights, capabilities and resources, shaping experiences in childhood; opportunities to access play, recreation and learning; access to decent work, housing and services (such as transport, health and social care); and thus lifelong health and wellbeing (102, 103). So, how do inequalities in health and development emerge from unequal social, material and political conditions? Several pathways have been developed to explain this. From the child health inequalities literature these are material, psychosocial and behavioural. I explain each in turn here.

2.2.1. Material Pathway

The material pathway relates to the effect of financial resource on the physical environment through parents ability to pay for goods such as books, trips, food and housing quality. These resources are needed for children to develop. For example housing quality affects health, playing a causal role in conditions such as asthma and lead poisoning (104). Inadequate nutrition can lead to weight problems from malnourishment to obesity.

This theory predicts that as parents' financial resources increase they can invest more in their children, as they are able to buy more goods, in particular learning materials. Better development is then mediated through these pathways and can lead to positive opportunities for learning in the home. For example, one of these mechanisms is termed the home learning environment. There is evidence that the home learning environment has a greater association with positive early child development than socioeconomic status (38).

The neo-material pathway further refines the material pathway to reflect that political and economic processes lead to systemic underinvestment in a range of infrastructure and this generates inequality by influencing both individual resources and public resources such as schooling, health care, social welfare, and working conditions (105). Differential access to and quality of services, including health care and education clearly affects children's health and development. For example, despite universal coverage of healthcare and a state education system significant difference by socioeconomic status exists in the UK (15, 106).

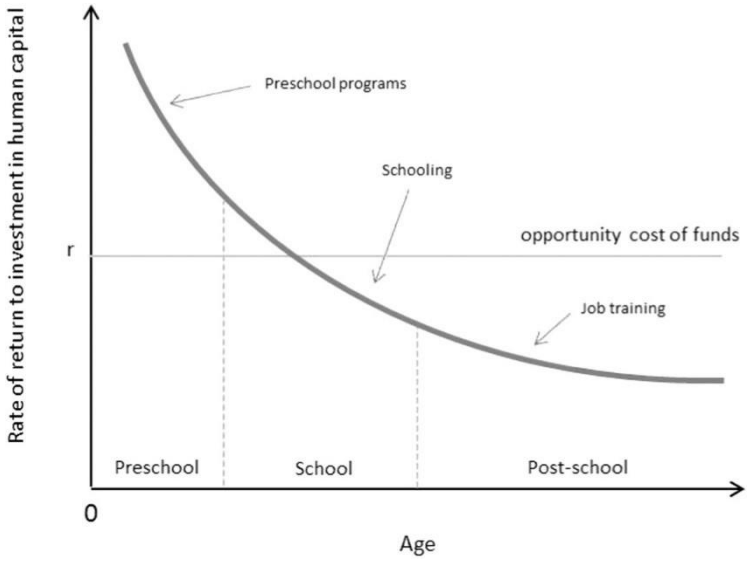
Human Capital Theory

Human capital theory provides the rationale for state or government level material investment in children to boost economic growth. Thus it is included here under the material pathway. Health economics research by Heckman elucidated the cost-benefit impact of investing in early childhood development programmes in disadvantaged children compared to investing in later life (56). This work was based on human capital theory which infers that cognitive and non-cognitive skills formation, acquired through education and training increase the productivity of the workforce leading to greater economic output for society and a higher income for the individual. Heckman produced a summary of the empirical evidence on the rate of returns of interventions in: early childhood education, schooling, adolescent programs, tertiary education, and active labour market, on human capital in later life. Heckman argues that disadvantaged families may invest less in their children leading to a deficit of skills which becomes entrenched and difficult to redress later in life due to the cumulative nature of human capital formation. His work showed that the returns for investing in younger disadvantaged children were higher than investing in later years. The resulting Heckman curve (figure 1) depicts that from a public policy expenditure viewpoint there is a better return for investing early as it addresses equity and efficiency with no trade-off between the two. What is meant by this is that investing in disadvantaged children to address equity is economically efficient as the returns in terms of human capital are high. However if we wait until later in life the cost of the investment to produce the same skill level in adulthood will be economically inefficient,

i.e. it costs more to redress the inequity in skills in adulthood to achieve the same benefits from investing earlier.

The Heckman curve is not without criticism, some of which is related to how it has been interpreted as meaning that the average return on investment of programs differs by the age of recipients, and indeed this is how it has been interpreted by some policy makers (107). However, it does not mean that the average cost benefit of interventions reduces with age or that interventions in later life are not cost effective. Rather, that without the skills formation in early childhood, interventions will be less cost effective because building skills at a young age provides a foundation to build upon, thereby providing greater marginal returns for investments made at an earlier age compared to later years (108). A recent review of the cost benefit of a wide range of programmes provided by the Washington State Institute of Public Policy conclude that rather than generalising on age or disadvantage their review supports assessment of programmes on a case by case basis using rigorous methods to ascertain cost-effectiveness in relation to age and universal/targeting e.g. targeting interventions in young offenders may be more cost effective than early preventative measures if the latter requires a large investment in those not at risk (107, 109).

Figure 1: Rates of Return to Human Capital Investment in Disadvantaged Children
Source: (56)



Note: The opportunity cost is the return from funds if they were invested for purposes unrelated to disadvantaged children.

Notwithstanding recent criticisms about its interpretation, and perhaps in part because of it, the Heckman curve has had significant policy influence and led to a plethora of early child development interventions and programmes (based on the Perry pre-school programme for disadvantaged children in the U.S.) It provided the economics and theory for how quality early child development

brings about human capital development in later life which in turn strongly influences wellbeing, obesity, mental health, heart disease, literacy and numeracy, criminality and economic productivity (34).

2.2.2 Psychosocial Pathway

Although material living circumstances play an important role in driving inequality in children's health and development, psychosocial factors are also important (14). The Family Stress/Psychosocial pathway relates to the impact of stress on parenting ability because of socioeconomic hardship. The pathways through which stress impacts on child development include parental mental health, parenting style and parent behaviours. Children born to depressed mothers have poorer social and emotional development and are more vulnerable to developing depression or anxiety themselves (110). There is also evidence of poorer physical health and development, including poorer foetal growth (111), and effects on mother-child interaction in relation to breastfeeding rates and bonding among the children of mothers with post-natal depression (112).

In addition the psychosocial hypothesis infers that feeling poor in comparison to others elicits psychological stress, erodes social resources that help people to cope with stress, and thus contributes to stress-related illness (113). In adolescents there is evidence of the effect of socioeconomic position with relative level of affluence being more closely associated with psychosomatic symptoms than absolute material affluence (114).

2.2.3. Behavioural Pathway

The Behaviour Pathway theorises that negative health behaviours are more prevalent among socially disadvantaged groups (115). Firstly, because healthy behaviours can be expensive, for example a healthy diet can be more expensive than an unhealthy one. Secondly, because people may use some unhealthy behaviours such as smoking or drinking alcohol as a way of coping with difficult situations. This pathway has been criticised for its simplistic focus, since health behaviours are structurally determined and heavily influenced by psychosocial and material pathways and the wider determinants of health (14).

2.2.4 Summary of the pathways

Evidence suggests that, whilst the pathways are not mutually exclusive (92), the material pathway is more important for cognitive outcomes and the psychosocial pathway for behavioural outcomes, with parental mental health and parenting behaviours the strongest factors (23). It is recognised that further evidence is needed with regard to the mechanisms and pathways to inequalities in child health and development outcomes, particularly in the later child life course pathway (14, 23). Understanding the relative effect of these pathways and their respective mechanisms as children

age would help identify how to intervene to improve child health and development and this requires a life course perspective.

2.3. Life-course perspective incorporating health selection and capabilities

2.3.1. Life course

Social causation, via the pathways described, and health selection as a cause of health inequalities are important in considering the emergence of health inequalities over time. Life course epidemiology enables the study of health status at any given age in the context of changing conditions over time. Theory of life course epidemiology allows the examination of health inequalities as an emergent property of the interaction between development and exposure to social conditions and experiences over time. Health selection is of particular importance and relevance in the adolescent life course.

2.3.2. Health Selection – direct and indirect

Health selection refers to differences in health status leading to differences in social status. The health selection hypothesis is also known as reverse causation. It argues that it is health which determines someone's SES rather than SES determining health. It infers that people with poor health have less social mobility and thereby do not achieve or maintain higher socioeconomic positions and 'drift' down the social ladder (116). It is difficult to separate out health in isolation as a cause of health inequalities when other factors such as education predict both health and social position. Considering other factors such as education or early life experiences on the SES-health gradient is known as indirect selection. Whether or not indirect selection is a hypothesis in its own right is disputed in the academic literature with a view that only direct links between SES and health are causal (117). However whether something is causal or not has policy implications, for example, if it is education and early life factors which cause health inequalities by enabling healthy children to select into education and subsequently better socioeconomic positions in adulthood it suggests great potential for improved childhood conditions on intergenerational health (91).

Health selection is different from Darwin's natural selection as it moves beyond considering just innate characteristics as the cause of health inequalities to recognising how society values particular health attributes such as chronic illness or disability and how these may affect occupational opportunities and subsequent health (118) e.g. is it as easy for a person with a disability to gain employment or can employers better protect those with disabilities so that it is easier for them to gain and remain in employment? These employment factors will affect how easy it is for people's health to enable them to select into employment and a better socioeconomic position.

Importance of health selection in the adolescent life course

The general consensus in research is that the evidence favours social causation over health selection as a cause of health inequalities (30). However the variable used to measure SES and the stage of life course are essential considerations in determining which hypothesis is strongest (117, 119). Where employment is the SES variable the evidence favours health selection. This is explained by employers favouring healthier employees. Where education and income are the SES variables used to examine the causes of health inequalities the evidence is stronger for social causation. In terms of education this can be explained by the fact that education completes at a certain age, usually young adulthood and therefore differences in SES as measured by education cannot be further influenced by health. However health selection is of particular importance for children in the transition to adolescence and young adulthood because of the potential for health to have a big impact at this critical juncture between education and educational opportunity as a platform to employment and social mobility (118). Indeed, evidence shows that adolescence is an important transition point in relation to health enabling 'selection' into education and consequently improved SES (29). A recent systematic review highlights findings in relation to the stage of life course with health selection and social causation being of equal importance between childhood and adulthood, whereas the evidence for social causation is stronger in older age (119). So from a life course perspective adolescence is a key point for maximising health to enable selection into education.

2.3.3. Capabilities

Sen's perspective on health inequalities accentuates the nuance in these causal hypotheses in that health and social conditions throughout life are interdependent and affected by a person's capabilities (120). Sen's theory (121) infers that capabilities are the 'freedoms' people need to live the lives they want to lead and it is this which is intrinsic to development rather than access to material resources. Within this health is seen as a higher order capability through which other freedoms (political freedom, economic facilities and social opportunities) can be achieved (122). Therefore determinants of capability is an important consideration. For example, a level of health is needed to enjoy economic success and these then become symbiotic but if the freedom to achieve good health and development can be influenced by other factors such as age, gender, social roles or the environmental context, then these factors become important considerations. A focus on agency (someone's decision making or choices) may help to illuminate determinants of capability in certain contexts.

Integrating human capital with capabilities theory

There is an argument for integrating human capital with capabilities theory in order to combine economics with the development of capabilities to better understand how health inequalities

emerge over the life course. As described earlier, the development of skills in early childhood to maximise later output (human capital theory) particularly for disadvantaged children, matters because it lays foundational skills which later education can build upon. However critics of human capital theory highlight that it provides a narrow view of education, valued only in terms of economic output and of no value in terms of developing capabilities, thereby ignoring education's contribution to agency and choice (123, 124), which may well have an impact on employment choices. Additionally cost benefit analyses, such as those provided by Heckman, provide little detail on the societal and contextual factors which may lead to individual benefit from an intervention (125). These limitations of human capital theory provide a rationale for integrating it within Sen's human capabilities approach which recognises the links between development/education (skills), choice and economic productivity and the interplay between these factors (126, 127). Development via education settings is both a functioning (e.g. education as an accessible service for all) and a capability (opportunity to maximise education and reach economic and social success) with the social context enabling or restricting the conversion of the functioning to a capability. This is important even in childhood with a recognition that children's valued capabilities and the barriers they experience can provide schools and policy makers a perspective on the social and contextual factors that can promote or limit children's development and wellbeing (126).

The pathways between development and health/health inequality in childhood

Capabilities theory as applied to children may help to illuminate how and if children translate development as a functioning into health capabilities, in the context of socioeconomic circumstances which may enhance or hinder that translation. Socioeconomic circumstances are likely to determine capabilities. For example, the negative effect of socioeconomic disadvantage on cognitive skills increases between the ages of 3 and 9 (128). Indeed, by age 7 children born with high cognitive ability but from poorer backgrounds are surpassed by children born with lower cognitive ability but from richer backgrounds (22). This is congruent with health inequalities theory on the cumulative effect (129) of exposure to socioeconomic disadvantage, early and persistent exposure damages development outcomes. This widening gap in development represents a loss of opportunity at individual and population level.

To try to redress this there is a need to better understand how socioeconomic factors shape the developmental-health relationship in childhood. This is a complex picture but necessary to unpick because markers of early child development such as school readiness are not a product to simply predict later health and attainment but a developmental process whereby social and cognitive

capabilities start to emerge in children which can be impeded or enhanced by socioeconomic circumstances.

In addition to pathways which stem from socioeconomic circumstance, described earlier (material, psychosocial and behavioural pathways) there are also direct pathways between the skills developed in early childhood and subsequent adolescent health.

Knowledge/Health Literacy Pathways

Health Literacy is linked to understanding and entails "people's knowledge, motivation and competencies to access, understand, appraise and apply health information in order to make judgments and take decisions in everyday life concerning healthcare, disease prevention and health promotion to maintain or improve quality of life during the life course" (130). A recent systematic review of health literacy in children and young people (131) describe the attributes which comprise health literacy in children as:

- Cognitive attributes: having knowledge, functional literacy, comprehension and understanding, critical thinking
- Behavioural attributes: seeking and accessing information, communication and interaction, application of information, citizenship
- Socioemotional attributes: self-awareness and self-reflection, self-regulation and self-control, self-efficacy, interest and motivation

It is these attributes which imbue children with the capacity to understand which factors affect health and the empowerment to address them. The evidence for the relationship between health literacy and child health outcomes is complicated by the effect of parental literacy and how this is interwoven with that of the child (132). There is limited evidence that low parental literacy is related to worse child health outcomes (depression (133) and asthma (134)). Low levels of adolescent literacy is related to more risk taking behaviour such as smoking and alcohol consumption (135). Low levels of child health literacy is related to obesity (136). Evidence of the relative contribution of parental and child literacy as children develop is limited. In addition the context and the social practices in which it is performed matter e.g. family and friends can support or deter health literacy actions as well as health promoting lifestyles through their norms, actions, and social support (137).

There is an argument for understanding children as active agents in their health (138), especially as they develop through interactions with their environment and social processes with their peers, family, and teachers (139). Without better engagement and understanding of children as active agents we are limited in our application of health literacy as we do it from an adult perspective.

However it is important to balance any responsibility imbued by health literacy so that it does not become a liability for children whereby responsibility may exceed influence (131). This is especially pertinent perhaps for younger age groups or those in more difficult social circumstances.

Social-Cognitive Pathway

This pathway relates to the influence of individual experiences, the actions of others, and environmental factors which provide the social context for learning to influence health behaviours (140). It also confers conversely that cognitive gains have direct benefits on self-esteem, behaviour and motivation, peer Interactions, ability to sustain attention, social competence and emotional competence, which may lead to positive effects on health (35). There is evidence that social competence in childhood reduces risk taking behaviour and smoking in adolescents (141).

2.3.4. Summary of social causation, health selection and capabilities over the life course

In summary what can we say about the social causes, health selection and the development of capabilities over the life course from a child's viewpoint? Children are born into the social conditions of their parents. Their health will be in part predetermined by their parents and previous generations' health and social conditions. Their experiences in childhood, their health, and the social conditions they live in will shape their future capabilities, health and wellbeing. The complex interactions between these factors result in the emergence of health inequalities over time (142).

2.4. Conceptual model

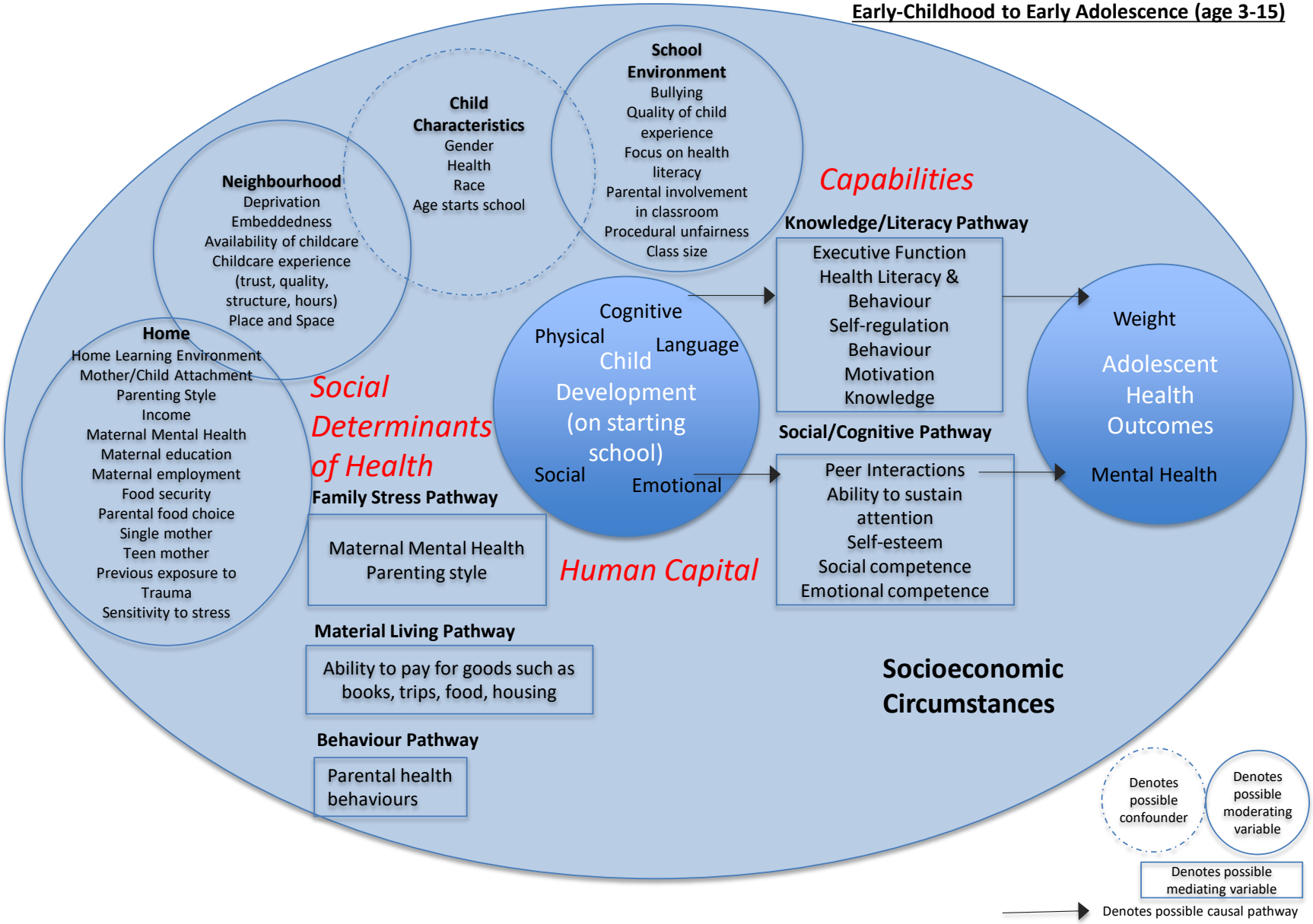
The review of pathways, from social causes and those stemming directly from a child's development, leads to the first output of this thesis - a conceptual model of how children's development may affect health in adolescence in the context of socioeconomic inequality from early - childhood to early adolescence (age 3-15) – see Figure 2. It is underpinned by health inequalities theory. Namely that human capital (skills development for later economic gain) and development of capabilities (freedom/agency) are grounded in the social determinants of health over the life course. Continued development of skills and agency in childhood translates into health in adolescence, which is a higher order capability enabling the development of other capabilities such as educational achievement. This 'translation' can be enhanced or impeded by socioeconomic circumstances.

This conceptual model was the starting point for the participatory systematic review. It was discussed with stakeholders as described in Chapter 4 and formed the underpinning theory and framework for the review.

Figure 2: Conceptual Model

How does development in the early years of primary school age children affect health in adolescence in the context of socioeconomic inequality?

Early-Childhood to Early Adolescence (age 3-15)



2.5. The Politics of Health Inequalities

Political ideology matters for taking policy action on health inequalities. Political ideology shapes whether differences in people's health status are viewed as an issue of social justice (SDH), an economically driven matter (with opportunities to reshape education, training and occupational structures prioritised to improve health (health selection), an issue of capability or freedom (Sen) or perhaps not even a matter for policy if 'Social Darwinistic' ideas of survival of the fittest prevail (the idea that policies that promote weaker groups to higher positions threatens the natural order is used as an argument against egalitarian policies (143)). Political ideas are rooted in societal history, understanding and morality. The framing of how to address health inequalities matters if we are to engage a breadth of decision makers across the political spectrum.

The dominant public health narrative in UK public health practice has moved from lifestyle interventions to social causation via the SDH (144, 145) and the term 'prevention' is used to express the importance of focusing upstream on the wider determinants of health to address health inequalities. 'Upstream' refers to the argument that it is preferable to prevent people from falling in the river than putting all efforts into rescuing those from drowning 'downstream'. It can represent time, for example acting early to give children the best start in life rather than intervening in later life, but has come to be used at the micro and macro level. Downstream or 'micro' can refer to health policy related to individual behaviour and upstream or 'macro' focuses on the general socioeconomic structure of society. The SDH research argument is that research and policy makers should focus upstream on the structural issues or the 'causes of the causes' of inequality (96, 146, 147), rather than on individual behaviours (e.g. in simple terms focus on food policy rather than dietary advice to individuals) because it is these broader factors such as food industry standards, access to education, access to employment and healthy food which provide the circumstances to enable positive health and wellbeing.

Contrary to this 'prevention' discourse there is a greater emphasis on individual level behaviour change than changes to upstream factors in UK public health policy (148) . This may be in part because of a research bias with a dissonance in what is being produced and what is required (149) and also because of the complexities in establishing the evidence for the impact of upstream policy changes on reducing health inequalities (150) . Either way the imbalance in evidence may limit the type and effectiveness of policies introduced to reduce health inequalities.

Leaving aside the inferior evidence base, the persistence of health inequalities has prompted calls for greater public health advocacy and coalitions of support around specific policy goals, alignment

of targets across sectors, commitment and delivery (151). Clarity and specificity of goals is important because researchers and policy makers appear to support improving the wealth of the poorest more than limiting the wealth of the richest (149), an approach which may not reduce inequality. Lack of clear policy goals, the evidence itself and the focus on the poorest rather than health inequalities specifically may be contributing to the persistence of health inequalities through sub-optimal policy.

Another factor considered key for policy success around health inequalities is garnering political will and this requires citizen participation and public support, which can be difficult when potentially advocating for economic or social strategies to reduce inequalities which may not be beneficial for all (152). Political will reflects a society's commitment to support or alter prevention initiatives and is the bridge between evidence and action (153). The pertinent point for research is that the research process is an integral part of garnering political will, from producing evidence to translating and implementing it, and generating a bottom up approach by working with community organisations and social movements (154). This involves acknowledging and understanding different perspectives on the causes of health inequalities.

2.6. Key Points for this Research

The first key point to be taken forward in this research, is the need to continue to unpick the complex relationships between socioeconomic circumstances, agency, and health and development, in childhood to inform action on health inequalities in the child-adolescent life course stage (beyond the 'best start' period). This requires a combination of a life course, social determinants of health and Sen's capabilities approach and it is these theories which form the underpinning theory for my research (as illustrated in the conceptual model).

The second point is the need to focus on health in adolescence as this is a crucial period in terms of enabling selection into education, and thereby providing a platform for better educational outcomes, access to employment and improved life chances, all key to reducing inequality and intergenerational inequality.

Thirdly, devising and implementing a 'health in all policies' life-course approach to reduce inequality, throughout childhood and adolescence, requires that we understand what types of policies may be needed beyond the 'best start' period. To break the cycle of inequality we need to better understand each part of the generative and dynamic (155) relationships between development, health and socioeconomic circumstances and this thesis is focusing on the development and health relationship over the child/adolescent life course from age 3 to 17 years in the context of socioeconomic circumstances. To improve adolescent health and reduce inequalities we can either

intervene early or late or we can do both. If socioeconomic factors are the overriding causes (that is, there is minimal relationship between aspects of development in earlier childhood and adolescent health, once socioeconomic circumstance are accounted for) then we need to intervene early and take a prevention approach building on the first 1000 days, focusing on social causes and the systems and institutions which may reproduce inequality. If there is a relationship between development and health (after accounting for socioeconomic factors) then we can infer that intervening later is still helpful, that is policy which mitigates the effect of earlier social disadvantage. This research hopes to unpick some of this so as to understand better where and how to focus policy to improve adolescent health.

And finally, the need to engage with different political ideologies, communities and coalitions of influence to enable advocacy on clear and specific goals in health inequalities public policy. This has informed the first and final stage of my research which were participatory in nature to address engagement throughout my PhD.

2.7. Chapter summary

In this chapter I have reviewed and explained what is meant by the social determinants of health and health inequality. I have described how inequalities in child development and health are rooted in the SDH and capabilities over the life course and manifest via various pathways over time. I have described how health inequalities theory supports action on the social determinants of health but that there is a dissonance between health inequalities discourse and action in UK public health policy. I have highlighted that in the UK child health policy is primarily focused on the early years. I have argued that there is a need to continue to unpick the complex mechanisms between socioeconomic circumstances, agency and health and development throughout childhood to inform public health policy in the child-adolescent life course.

Chapter 3: Research Question and Methodology

This chapter provides an overview of the research questions and methodologies for each phase of my PhD. Phase 1 incorporated a systematic review and phase 2 incorporated longitudinal analysis.

3.1. Project Aim

The overall aim of this research was to better understand the development-health relationship in the child-adolescent life course, in the context of socioeconomic circumstances, to inform interventions to improve health and reduce health inequalities in early adolescence.

3.2. Research Questions

RQ1: What are the associations between measures of child development recorded at primary school starting age (3-7 years) and subsequent weight and mental health in adolescence (8 - 15 years)?

RQ2: How does development in children of primary school starting age affect health outcomes in adolescence, in the context of socioeconomic inequality?

Specifically what is reported in the literature in relation to:

- What are the effect modifiers (socioeconomic and environmental factors) of this relationship? (This will identify variables which alter the strength of the observed associations.)
- What are the mediators of this relationship? (This will identify variables or pathways which explain the observed associations.)

RQ3: Are there distinct trajectories of development in mid-childhood; are these characterised by socioeconomic, school and parent factors; and what are the associations between any identified developmental trajectories and adolescent weight and mental health.

3.3. Project Plan

Study design

In order to address the research questions this study involved developing and using skills across several methodological areas: including Phase 1) participatory systematic review (to address RQ1 &2) and Phase 2) longitudinal analysis (to address RQ3).

Participatory systematic review adds value over traditional review methods when clarifying underlying theory, ensuring all valued outcomes are captured, adding insight to relationships

between outcomes and understanding how, when and where interventions may work (156) . This process helps to uncover theories of change and assumptions underpinning pathways between cause and effect (157). Producing diagrams, frameworks or logic models are increasingly recognised for their potential to make a contribution to systematic review methodology (158) and particularly in the field of public health (159)

A comprehensive participatory systematic review (involving a series of virtual one-to-one meetings with national and local stakeholders across health and education sectors) was carried out to further develop the initial conceptual model (Chapter 2, Figure 2) of the relationship between child development and education (age 3-7) and health outcomes in early adolescence (age 8-11), in the context of socioeconomic inequality. This model informed the systematic review evidence synthesis.

The findings of the systematic review were used to refine which aspects of development to analyse in the longitudinal analysis, the second phase of this research. Analysis was undertaken on a longitudinal birth cohort, the UK Millennium Cohort Study (MCS). The MCS is an observational, multidisciplinary cohort study that was set up to follow the lives of children born in 2000. The MCS is nationally representative and 18 552 families (18 827 children) were recruited to the cohort in the first sweep. There have been seven main sweeps of data collection; ages 9 months and 3, 5, 7, 11 14 and 17 years. It was designed with sufficient statistical power to explore health inequalities as well as to provide population estimates (160). MCS data was analysed, using group-based trajectory modelling, to; identify trajectories of development (age 3-14 years), assess demographic, socioeconomic, parental and school related predictors, and quantify their associations with weight and mental health at age 14 and 17 years.

The findings were discussed with the initial stakeholder group via second round of participatory engagement with national and local stakeholders, to inform my discussion in particular the section on implications for policy and practice. This is a key component of the research as it is recognised that in public health there is a translation deficit in ensuring knowledge is translated into policy action (161, 162).

Ethics

Ethics approval was not required for this research, as described in NIHR guidance on ethical improvement for involvement activities (163).

Chapter 4: Impact of Child Development at School Entry on Adolescent Health

This chapter presents the systematic review undertaken for my PhD which is presented in the format of two published papers, a protocol paper and a systematic review paper.

4.1. Introduction

Paper 1, published in *Systematic Reviews*, was the first publication to arise from this PhD and presents the systematic review protocol. Paper 2, published in the *International Journal of Environmental Research and Public Health* presents the systematic review which is a synthesis of the evidence on the relationship between child development at school entry and adolescent health. The primary contribution to the design, data collection, data extraction, synthesis, and paper for publication was made by me as the first author. The contribution of the co-authors can be found in Appendix 1 and permission to reproduce in Appendix 2.

The following appendices have been provided to further support the methodology used in this systematic review:

Appendix 3– additional files for the protocol paper

Appendix 4 – additional files for the systematic review paper

4.2. Rationale for undertaking a participatory systematic review

Early childhood programmes delivered in the pre-school years are positive for future health and wellbeing in adulthood, with significant evidence of impact in terms of human capital development. It is widely acknowledged that this period if a critical period for development and provides a policy focus on giving children the 'best start in life'. At the end of this period, termed early child development, a child normally transitions to pre-school and school. In the UK, development at school starting age is measured by an assessment of school readiness, a composite measure of a child's a composite measure of personal, social and emotional, physical, communication and language development. There is evidence on the relationship between school readiness and later academic outcomes but less on its influence on health outcomes in later childhood. There is a gap in understanding if and how childhood development influences health at key time points such as adolescence. This review aims to address this gap by undertaking a participatory systematic review to synthesise the evidence on the relationship between child development at primary school starting age (3-7 years) and subsequent health in adolescence (11 -15 years) and the factors which shape the relationship.

The participatory nature of the review was informed by the desire to engage stakeholders who work in education and public health sectors so that their voices were heard from the outset. Additionally, participatory methods are increasingly recognised for their potential to make a contribution to systematic review methodology (158) and particularly in the field of public health (159). It involved the following activities, included here as additional information to that in the published papers.

Activity 1: Establishing a Stakeholder Network

I established a Stakeholder Network with representation from organisations across health, education, local government and the voluntary sector. The stakeholder Network had a key role throughout the research, particularly in the development and refinement of the conceptual model which underpinned the systematic review and subsequent longitudinal analysis.

Activity 2: Scoping Review

I carried out a scoping review, which mapped, at a high-level, the main pathways linking inequalities in early child development to weight and mental health in adolescence.

Activity 3: Organising initial Stakeholder Meetings

Once I identified the main pathways in published literature in the scoping review, I organised 1:1 meeting with the stakeholders in order to explore their perspectives on these pathway areas; considering, in particular, the following:

- How health outcomes in adolescence are most affected by socioeconomic circumstances in child development at the start of primary school
- General perceptions of what the mediating pathways are, including how pathways are connected and feedback loops
- Where in the system would intervening have most impact on socioeconomic inequality in child development on later health outcomes in adolescence

These meetings were initially meant to be a workshop meeting with plans to use participatory methods and tools, including concept mapping approaches, to refine the conceptual model of pathways linking early child development to health outcomes, and inequalities in, obesity and mental health in adolescence. However due to the COVID-19 pandemic virtual 1:1 meetings were arranged instead. In these meetings I shared the initial conceptual model (Chapter 2, Figure 2), listened to their views and thoughts and subsequently modified the model to capture their insights (Chapter 4, Figure 1a).

Activity 4: Systematic searching of literature and evidence synthesis

I systematically reviewed the literature to produce an evidence synthesis of the relationship between child development and weight and mental health in adolescence, using the conceptual model from the stakeholder meetings as a framework for the review. The model was used to guide the identification of relevant data from published studies.

Activity 5: Ongoing Stakeholder Network Engagement to produce a final diagram of the findings

I organised later and ongoing virtual discussions with stakeholders in order to discuss the emerging findings of the review, identify gaps, sense-check findings and ensure that the final results diagram (Chapter 4, Figure2) made sense to stakeholders. The feedback from the stakeholders was very positive in terms of their experience of being part of the review.

Activity 6: Continued engagement post systematic review

I continued to keep in touch with the stakeholders during the longitudinal analysis ensuring they knew that the findings from the systematic review informed which aspects of development to take forward for further analysis. The findings from the longitudinal analysis were very well received and the stakeholders were keen that the findings were shared, particularly in relation to the role of education in helping children, who are behind when they start school, to catch up. The stakeholders offered continued input with any further research that continues post PhD.

4.3. Paper 1: Impact of child development at primary school entry on adolescent health - protocol for a participatory systematic review

The manuscript presented here is published in Systematic Reviews following peer review and is reproduced with permission from Springer Nature. The version of the record:

Black, M., Barnes, A., Strong, M., & Taylor-Robinson, D. (2021). Impact of child development at primary school entry on adolescent health—protocol for a participatory systematic review. Systematic Reviews, 10(1), 142.

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Abstract

Background

Reducing child health inequalities is a global health priority and evidence suggests that optimal development of knowledge, skills and attributes in early childhood could reduce health risks across the life course. Despite a strong policy rhetoric on giving children the 'best start in life', socioeconomic inequalities in children's development when they start school persist. So too do inequalities in child and adolescent health. These in turn influence health inequalities in adulthood. Understanding how developmental processes affect health in the context of socioeconomic factors as children age could inform a holistic policy approach to health and development from childhood through to adolescence. However the relationship between child development and early adolescent health consequences is poorly understood. Therefore the aim of this review is to summarise evidence on the associations between child development at primary school starting age (3-7 years) and subsequent health in adolescence (8 -15 years) and the factors that mediate or moderate this relationship.

Method

A participatory systematic review method will be used. The search strategy will include; searches of electronic databases (MEDLINE, PsycINFO, ASSIA and ERIC) from November 1990 onwards, grey literature, reference searches and discussions with stakeholders. Articles will be screened using inclusion and exclusion criteria at title and abstract level, and at full article level. Observational, intervention and review studies reporting a measure of child development at the age of starting school and health outcomes in early adolescence, from a member country of the Organisation for

Economic Co-operation and Development, will be included. The primary outcome will be health and wellbeing outcomes (such as weight, mental health, socioemotional behaviour, dietary habits). Secondary outcomes will include educational outcomes. Studies will be assessed for quality using appropriate tools. A conceptual model, produced with stakeholders at the outset of the study, will act as a framework for extracting and analysing evidence. The model will be refined through analysis of the included literature. Narrative synthesis will be used to generate findings and produce a diagram of the relationship between child development and adolescent health.

Discussion

The review will elucidate how children's development at the age of starting school is related to subsequent health outcomes in contexts of socioeconomic inequality. This will inform ways to intervene to improve health and reduce health inequality in adolescents. The findings will generate knowledge of cross-sector relevance for health and education and promote inter-sectoral coherence in addressing health inequalities throughout childhood.

Systematic Review Registration

This systematic review protocol has been registered with PROSPERO CRD42020210011.

Keywords

Child development, Primary School, Adolescent Health, Inequality, Public Health

Background

Reducing child health inequalities is a global health priority and evidence suggests that optimal development of knowledge, skills and attributes in early childhood could reduce health risks from childhood through to adulthood (37). Positive child development in the early years (age 0-3 years) brings about wide ranging human capital development in later life which strongly influences wellbeing, obesity, mental health, heart disease, literacy and numeracy, criminality and economic productivity (34). This evidence for investment in early years on human capital development and the resultant economic gains in later life (56, 164), together with the evidence for the early years as a critical period of development (51), make it a prime area for public policy and public health investment. However, current policy ('best start in life') and research on health and development has neglected children from age 5 years to adolescence, and there is scope for research and action on child health and development in this period to evolve from an emphasis on the first 1,000 days and 'school readiness' to the first 8,000 days in order to support development needs across

children's life cycle (4). Understanding how developmental processes affect health in the context of socioeconomic factors as children age could inform a holistic policy approach to health and development from childhood through to adolescence.

Recognising the interconnected nature of health and development in childhood, and the importance of socioeconomic circumstance in determining outcomes, many programmes are in place across the UK which seek to address health and development across the wider determinants of child health, such as; quality early years education (38), universal services such as welfare and health visiting (39), parenting programmes (40) and community support through children's centres (41, 42). Whilst improvements for children as a whole are being seen for some health outcomes (asthma, epilepsy, diabetes) (15), inequalities in child health are not reducing, with inequalities in outcomes in relation to socioeconomic status (15) and indeed inequalities in some outcomes are widening (43). This is particularly the case for obesity and mental ill health in early adolescence (44) with negative consequences for weight (45) and wellbeing (46) in adulthood. Socioeconomic inequalities in child development are also apparent. Analysis of the Millennium Cohort Study (a nationally representative cohort set to follow the lives of over 18000 children born in the year 2000) found that UK children from low to middle-income families were five months behind children from high-income families in terms of vocabulary skills and had more behavioural problems at age 5 years (21). These inequalities in early child development and health tend to tack forward and increase over time to influence inequalities in later health outcomes (36).

There is evidence that programmes which encompass parenting support and early learning opportunities in or out of the home enhance child development in readiness for school improving cognitive and non-cognitive skills in children (72). Positive cognitive development on starting school is associated with academic achievement by age 13 years (24) and socioemotional development by age 10 years (73). Non-cognitive skills such as social skills and self-regulation on starting school also improve academic success and psychosocial outcomes in subsequent years (74). Whilst the beneficial effects of education on health in adulthood acquired through knowledge, work and social status are clear (57), there is less evidence of the effect of early child development interventions on health outcomes in childhood; other than limited evidence for obesity reduction, greater social competence, improved mental health and crime prevention (35) and on reducing childhood hospitalisations for infections and injury (76). So there is evidence that programmes to enhance child development in readiness for school improve academic success, socioemotional and psychosocial outcomes but the evidence for whether and how measures of child development impact subsequent health in childhood is limited.

Child development on starting school is defined in this study as cognitive or physical or linguistic or socioemotional development at school starting age. There is evidence that measures of cognitive development at primary school starting age, as a component part of a model incorporating routinely collected data, predict socioemotional behaviour and obesity at age 11 years (77). Moving beyond the predictive value of measures to understanding early education as a developmental process in a social context (63) is important if we are to understand how emerging social and cognitive pathways in children interconnect with pathways stemming from socioeconomic circumstances. To improve child health and address inequality, evidence is needed on the mediating pathways between child development on starting school and these later child health outcomes and the socioeconomic and environmental factors which shape this relationship (78).

There is evidence that family stress, material living circumstances and parental behaviours are the main pathways stemming from socioeconomic circumstance which lead to inequalities in child health (14). These factors are potential modifiers of the relationship between child development on starting school and adolescent health. A modifier is a variable which alters the strength of association between an exposure and an outcome. In addition to understanding what might affect the strength of the relationship it is important to understand what variables may explain the relationship. Identifying direct pathways between child development and health (such as knowledge/literacy and cognitive/social pathways) aids understanding of mediators of the relationship. A mediator is a variable which explains the association between an exposure and an outcome.

Increasing understanding of the pathways between child development and health is pertinent learning for improving health because it is the interactions between early childhood development and the biological and social changes during mid-childhood, shaped by socioeconomic factors that influence health-related behaviours in adolescents (6). However the relationship between child development and early adolescent health consequences is poorly understood. Better understanding this relationship could provide knowledge on targeted public health interventions in primary school age children and provide a focus for action and policy coherence across the health and education sectors; and help to mitigate the effect of detrimental socioeconomic factors on child development on later health outcomes and inequalities in those outcomes. Therefore the aim of this review is to summarise evidence on the associations between child development at primary school starting age (3-7 years) and subsequent health in adolescence (11 -15 years) and the factors that mediate or moderate this relationship.

Method

Protocol Registration

The present protocol has been registered within the PROSPERO database (registration number CRD42020210011) and is being reported in accordance with the reporting guidance provided in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) statement (165, 166) (see checklist in Appendix 3, Additional file 1). The planned review will be reported according to the Preferred Reporting Items for Reporting Systematic Reviews and Meta-Analyses (PRISMA) 2020 Statement (167, 168)

Review Questions

The planned review will address the following questions:

- What are the associations between measures of child development recorded at primary school starting age (3-7 years) and subsequent health in adolescence (8 -15 years)?
- What are the effect modifiers (socioeconomic and environmental factors) of this relationship? (This will identify variables which alter the strength of the observed associations.)
- What are the mediators of this relationship? (This will identify variables or pathways which explain the observed associations.)

Study Design

We will undertake a participatory systematic review, involving engagement with national and local stakeholders across health and education sectors. Participation will occur in the following ways: after an initial scoping search and review of papers, discussions with stakeholders will take place to identify any further relevant studies and to further develop an initial conceptual model (as presented in figure 2, Chapter 2). This initial conceptual model will act as a framework for extracting and analysing evidence identified in the systematic review. The model will be revised and refined through analysis of the included literature. Narrative synthesis will be used to generate findings and produce a diagram of the relationship between child development in the early years of primary school and adolescent health outcomes. Where possible we will summarise effect sizes in meta-analysis. This participatory review method adds value over traditional review methods when clarifying underlying theory, ensuring all valued outcomes are captured, adding insight to relationships between outcomes and understanding of how, when and where interventions may work (156). Participatory methods to produce diagrams, maps or models help to uncover theories of

change and assumptions underpinning pathways between cause and effect (157). They are increasingly recognised for their potential to make a contribution to systematic review methodology (158) and particularly in the field of public health (159).

Information Sources and Search Strategy

MEDLINE, PsycINFO, ASSIA and ERIC will be searched for results from November 1990 onwards. The reference lists from all included articles will be searched for eligible articles that may have been missed by the electronic search. Further relevant literature will be identified through stakeholder discussions. Grey literature searching will be undertaken by searching relevant organisations websites and discussions with stakeholders, to find all relevant literature for inclusion. The search terms relate to measures of child development in the early years of primary school and health outcomes in early adolescence. Studies will be limited to those that include children, some or all of whom are aged between 3 and 15 years and those that are in English. A pilot search strategy has been undertaken – Appendix 3, Additional File 2.

Data management

Dates of searches and results will be recorded using Excel. Search results will be downloaded to EndNote desktop software. Studies identified through reference searching, stakeholder discussions and grey literature will be recorded and imported into EndNote

Eligibility Criteria

Definition of terms

In this review child development refers to a measure of cognitive or physical or linguistic or socioemotional development at primary school starting age (3-7 years).

Inclusion Criteria

Observational studies (ecological, case-control, cohort (prospective and retrospective)) randomised control trials (RCTs), quasi experimental, review level studies including theory papers which are:

- Studies of children that include a measure of child development at age 3-7 (the age most children enter pre-school or school) and weight/mental health outcomes between age 8-15 years.
- Studies that explore factors which affect associations between child development and these outcomes

- Studies that explore mechanisms or pathways between child development and these outcomes

Cross-sectional studies, conference abstracts, dissertations, studies reporting neither outcomes data nor mechanism will be excluded.

The population and context, exposure, outcomes and study designs are described below and summarised in relation to inclusion and exclusion criteria in Table 1.

Population and context

Studies must include children, some or all of whom are aged between 3 and 15 years, across socioeconomic strata in high-income country settings, defined as OECD membership.

Exposure

A measure of child development at primary school starting age (3-7 years), defined as: cognitive or physical or linguistic or socioemotional development at school starting age, including:

- School readiness, as measured by scales such as the Bracken Basic Concepts Scale Revised (BBCS-R)(169) and Good Level of Development
- Cognitive development as measured by, for example, non-reading intelligence tests, vocabulary tests, maths tests or parent/teacher ratings.
- Language and literacy (as measured by academic achievement test scores such as pre-reading/reading, vocabulary, oral comprehension, phonological awareness, pre-writing/writing or verbal skills.
- Emotional well-being and social competence (behavioural assessments of social interaction, problem behaviours, social skills and competencies, child-parent relationship/child-teacher relationship), measured using the Child Behaviour Checklist.
- Physical development as measured by amount of physical activity or assessment of gross motor skills.

Primary Outcome(s)

The primary outcomes of interest will be weight and mental health as quantitative data, including measures of wellbeing. The outcomes measures are:

- Weight (Body Mass Index (BMI))
- Mental Health (as measured by standard questionnaires or clinically)

- Socioemotional behaviour (as measured by social competence, emotional competence behavioural problems, self-regulation and executive function)
- Proxy measures such as dietary habits and behaviour and measures of wellbeing will be included.

These outcome measures were highlighted in an initial scoping review of the literature and during discussions with stakeholders.

Secondary Outcome(s)

The secondary outcome of interest is educational outcomes measured as:

- Performance at the end of primary school (age 10-11), measured by standardized tests.

The rationale for this outcome is that it facilitates analysis through consideration of possible temporal dynamics to the relationship under study.

Table 1: Summary of eligibility criteria

	Inclusion	Exclusion
Population and context	Studies must include children, some or all of whom are aged between 3 and 15 years, across socioeconomic strata in high-income country settings, defined as OECD membership.	Studies of children from non-OECD countries. Studies which focus solely on a particular subset of children with a particular health or development need.
Exposure	A measure of child development at primary school starting age (3-7 years), defined as: cognitive or physical or linguistic or socioemotional development at school starting age, measured by any of the following: • School readiness, as measured by scales such as the Bracken Basic Concepts Scale Revised (BBCS-R)(169) • Cognitive development as measured by, for example, non-reading intelligence tests, vocabulary tests, maths tests or parent/teacher ratings. • Language and literacy (as measured by academic achievement test scores such as pre-reading/reading, vocabulary, oral comprehension, phonological awareness, pre-writing/writing or verbal skills. • Emotional well-being and social competence (as measured by behavioural assessments of social interaction, problem behaviours, social skills and competencies, child-parent relationship/child-teacher relationship). • Physical development. Studies that explore socioeconomic and environmental factors which affect associations between child development at primary school starting age and these outcomes. Studies that explore mechanisms or pathways between child development at primary school starting age and these outcomes.	Studies reporting neither data nor mechanism between exposure and outcome will be excluded.
Outcome	**Primary Outcome(s)** The review will incorporate evidence health and wellbeing outcomes, reported between the ages of 8-15 years, specifically: Weight (BMI)Mental Health (as measured by standard questionnaires or clinically)Socioemotional behaviour Proxy measures such as dietary habits and behaviour and measures of wellbeing will be included. **Secondary Outcome(s)** Educational outcomes Performance at the end of primary school (age 10-11), measured by standardized tests.	Studies reporting neither data nor mechanism between exposure and outcome will be excluded.
Study design and sources	Observational studies (ecological, case-control, cohort (prospective and retrospective)) RCTs, Quasi experimental, Review level studies including theory papers	Cross-sectional studies, conference abstracts, books, dissertations, opinion piece

Development of a conceptual model

We have undertaken a scoping review to identify the main factors and pathways between child development at primary school starting age (3-7 years) and subsequent health outcomes at age 8-15 years. Meetings with five stakeholders from local authority, health, education and voluntary sector were held in September 2020 to explore perspectives on these pathway areas; considering in particular, the following:

- How health outcomes in adolescence are most affected by socioeconomic circumstances in child development at the start of primary school
- General perceptions of what the mediating pathways are, including how pathways are connected and feedback loops
- Where in the system would intervening have most impact on socioeconomic inequality in child development on later health outcomes in adolescence

Participatory methods and tools, including concept mapping approaches will continue to be used in stakeholder meetings to finalise a conceptual model of the pathways (see Figure 1a for draft). This initial model forms a framework for the review and provides initial categories for extracting and analysing evidence from published studies. The model will then be revised and refined iteratively through analysis of the included literature to produce a final diagram. This will illustrate where factors in the initial diagram were not reported in the literature and where there may be associations and relationships between factors. The model will be used to formulate a directed acyclic graph (DAG) for further statistical analysis of the associations and pathways in subsequent phase of this study (see figure 1b).

Selection and Data Collection Process

Articles will be screened using the inclusion and exclusion criteria at title and abstract level, and then at full article level by the review team. At each stage a sample will be checked independently by another member of the review team and inter-rater reliability will be recorded. Any queries regarding inclusion will be discussed with at least one other team member. Data extraction using a bespoke form will be undertaken for all studies that meet the inclusion criteria by the lead reviewer and a sample will be checked independently by another team member. A data extraction form has been developed using previous expertise of the team, and has been piloted on a sample of different sources. The following data will be extracted: Study design, Country, Year, Study population, Study characteristics, Child development measure, Health outcomes, Factors affecting associations,

Pathways, Main findings, Strengths & weaknesses. In cases where additional data from studies is required the lead reviewer will contact the study authors.

Quality Assessment

Quality assessment of the included studies will be conducted using the Liverpool University Quality Assessment Tool (LQAT), which allows for a specific tool to be used for each study design (170). This tool has been independently evaluated against other quality assessment tools (171). Quality assessments will be done by the main author and second checked by a member of the review team and any discrepancies will be discussed.

Strategy for Data Synthesis

This review is broad in scope and as such it is anticipated that there will be considerable heterogeneity between studies in terms of design and measurements of the exposures and outcomes. It is anticipated that the data will not allow for a meta-analysis and as such narrative synthesis will be used for each review question, and using the conceptual model referred to above to as a way to synthesise and illustrate the associations, mediators and moderators within the identified body of literature. The Synthesis Without Meta-analysis (SWiM) guidelines will be used to guide reporting of results (172). To describe the associations between exposure and outcomes, studies will be grouped by exposure measure for synthesis. The quality assessment of individual studies will be used to determine the strength of the evidence and greater weight will be given to conclusions drawn from the most methodological sound and reliable studies. Summary tables will be produced for each grouping to describe the exposures, outcomes and effect sizes. Modifiers and mediators of the relationship will be described narratively using structured headings as determined by the participatory element of the review, as illustrated in the initial conceptual model – Figure 1a. This narrative synthesis will be used to generate findings and will inform a final diagram of the relationship between child development at primary school starting age and health outcomes in early adolescence.

Additional Analyses

Analysis by geographical context to capture any differences in the relationship by country, will be considered during the data synthesis and will be identified in the narrative synthesis.

Confidence in cumulative evidence

In addition to assessing the quality of each individual paper the overall strength of the review findings will be assessed drawing on criteria used by Hoogendoom (173) and Baxter (158, 174)

together with principles of GRADE specific to observational studies (175). The review findings by typology of papers, grouped by exposure, will be assessed for relative strength of evidence. The assessment will be based on; volume, quality and consistency in effect sizes, in studies. This will allow each review finding to be graded as either stronger, weaker, inconsistent or limited evidence. Assessment on the strength of evidence in relation to mediators and moderators of the relationship may be more difficult to grade using standard tools. Whereby any findings are based on theory papers or author opinion on proposed mechanisms this will be reflected in the grading of the evidence. Strength of evidence will also be illustrated in the final diagram. Agreement on grading of review findings will be agreed by the whole review team.

Discussion

This review will address an important knowledge gap by increasing our understanding of the associations between measures of development and health in childhood, and the factors which affect these associations. By using participatory methods alongside systematic evidence synthesis the review will elucidate how children's development at the age of starting school is related to subsequent adolescent health outcomes in contexts of socioeconomic inequality. This will inform ways to intervene to improve health and reduce health inequality in adolescents. The findings will generate knowledge of cross-sector relevance for health and education and promote inter-sectoral coherence in addressing health inequalities (85, 86) throughout childhood.

Any amendments made to this protocol when conducting the review will be outlined in PROSPERO and reported in the final manuscript. Results will be disseminated through conference presentations and publication in a peer-reviewed journal.

Strengths and Limitations

This review will provide, for the first time, a systematic overview of the association between child development at primary school entry, and adolescent health and factors that shape this relationship. It will incorporate stakeholder views to add depth and insight to guide the review process. The involvement of a sample of stakeholders raises the potential for biases to be introduced by selection of stakeholders with particular views, opinions or experiences. The risk of bias will be minimised by the use of transparent and replicable systematic review methods. The review may also be limited by primary studies with limited data on the mechanisms between exposure and outcome. Additionally risk of bias in observational primary studies may bias the overall review results. This will be addressed at the quality assessment stage by recording risk of bias and using the assessment scores to decide the weight to assign to the conclusions drawn from each review. At review level the

heterogeneity of the study designs, exposure and outcome measures will need careful consideration in the data synthesis with care taken to group studies to ensure reliable and valid conclusions are drawn.

Figure 1a: Conceptual Model

How does development in the early years of primary school age children affect health in adolescence in the context of socioeconomic inequality?

Early-Childhood to Early Adolescence (age 3-15)

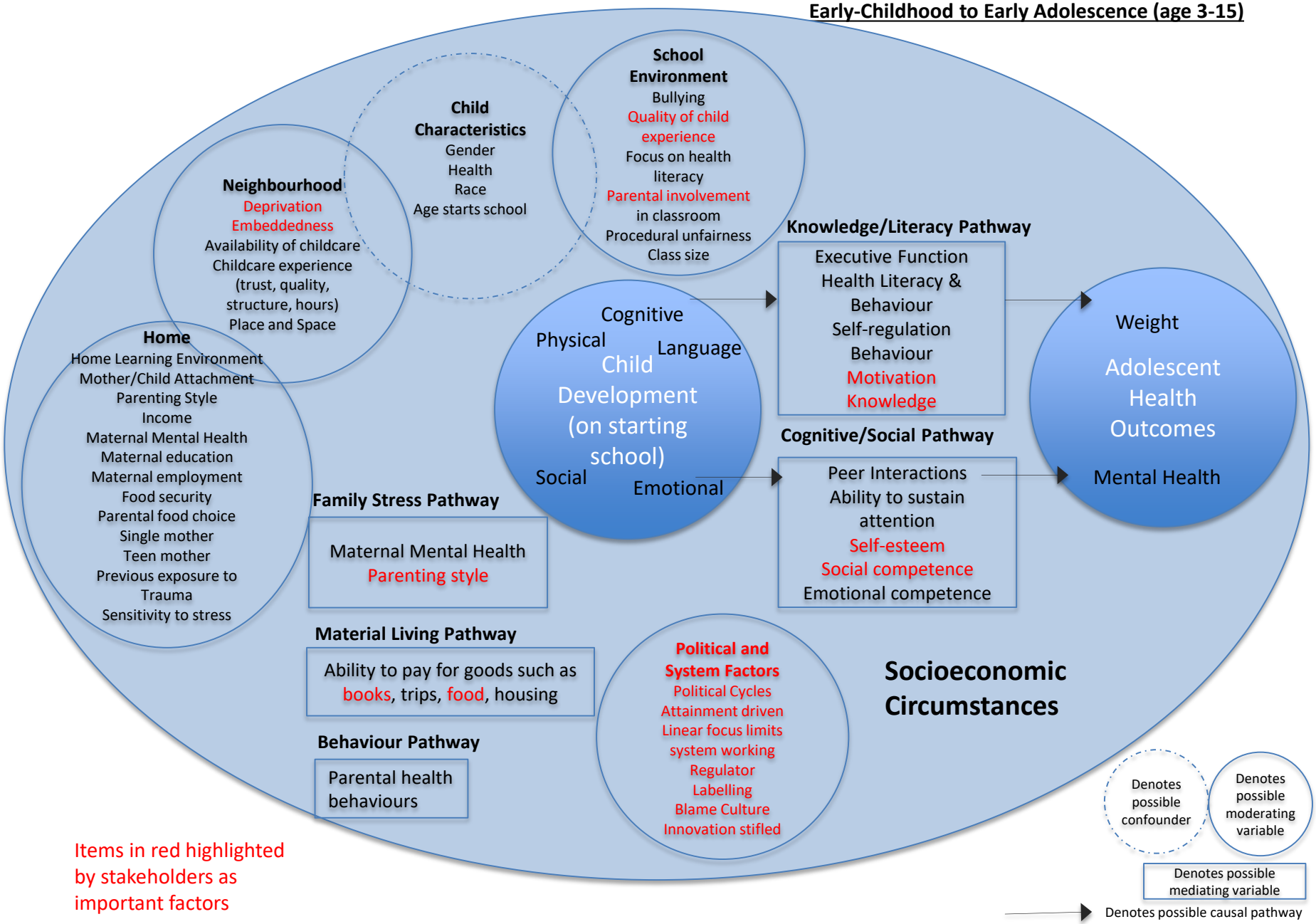
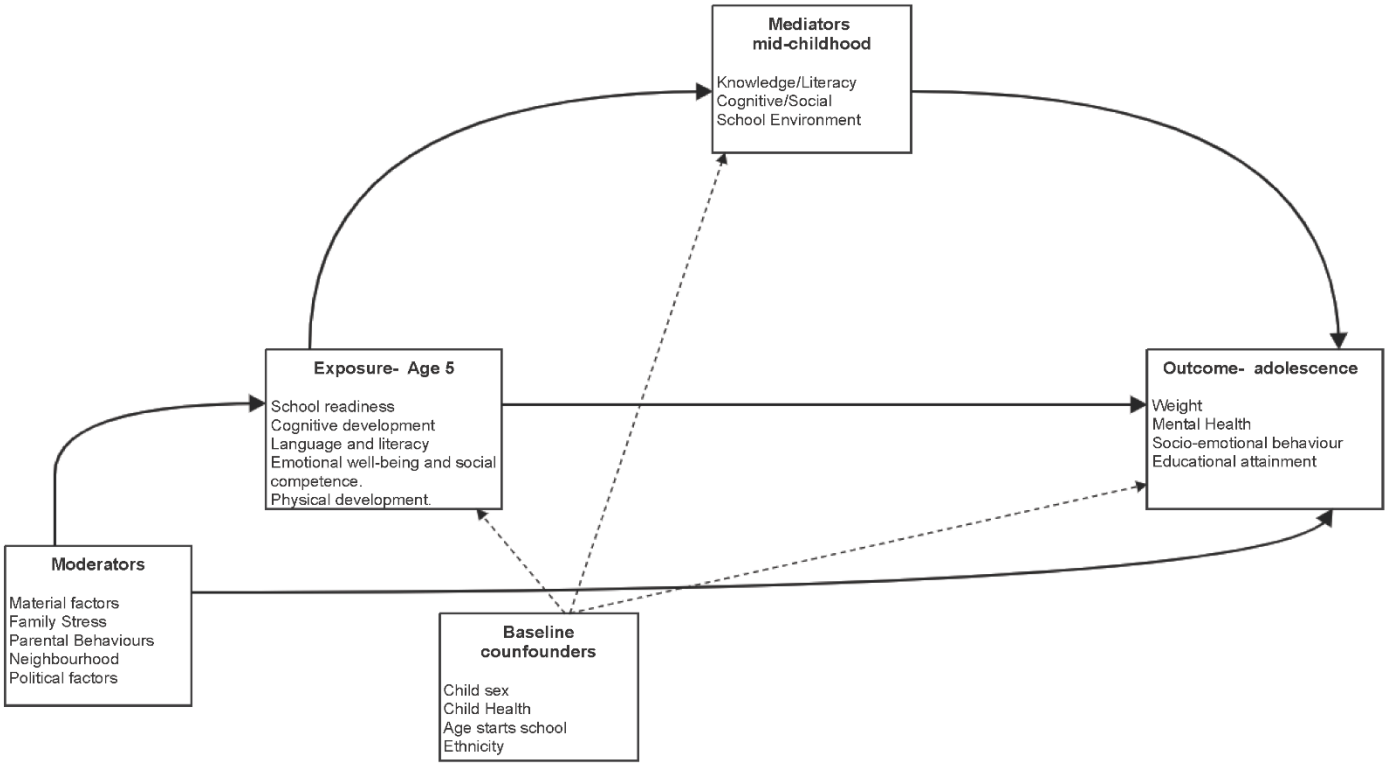


Figure 1b: Illustrative DAG of the Realationship between Child development in the early years of primary school and Adolescent Health



4.3. Paper 2: Relationships between child development at school entry and adolescent health - a participatory systematic review.

The manuscript presented here is a pre-copy-edited, author-produced PDF of an article accepted for publication in the *International Journal of Environmental Research and Public Health* following peer review. The version of the record:

Black, M., Barnes, A., Strong, M., Brook, A., Ray, A., Holden, B., Foster, C., & Taylor-Robinson, D. (2021). Relationships between Child Development at School Entry and Adolescent Health-A Participatory Systematic Review. *International journal of environmental research and public health*, *18*(21), 11613.

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Abstract

The relationship between child development and adolescent health, and how this may be modified by socioeconomic conditions, is poorly understood. This limits cross-sector interventions to address adolescent health inequality. This review summarises evidence on the associations between child development at school starting age and subsequent health in adolescence and identifies factors affecting associations. We undertook a participatory systematic review, searching electronic databases (MEDLINE, PsycINFO, ASSIA and ERIC) for articles published between November 1990 and November 2020. Observational, intervention and review studies reporting a measure of child development and subsequent health outcomes, specifically weight and mental health, were included. Studies were assessed for quality individually and collectively using a comparative rating system of stronger, weaker, inconsistent or limited evidence. Associations between child development and adolescent health outcomes were assessed and reported by four domains of child development (socioemotional, cognitive, language and communication and physical development). A conceptual diagram, produced with stakeholders at the outset of the study, acted as a framework for narrative synthesis of factors that modify or mediate associations. Thirty-four studies were included. Analysis indicated stronger evidence of associations between measures of socioemotional development and subsequent mental health and weight outcomes; in particular, positive associations between early externalising behaviours and later internalising and externalising, and negative associations between emotional wellbeing and later internalising and unhealthy weight. For all other domains of child development, whilst associations with subsequent health were positive, the evidence was either weaker, inconsistent or limited. There was limited evidence on factors which altered associations. Positive socioemotional development at school starting age appears

particularly important for subsequent mental health and weight in adolescence. More collaborative research across health and education is needed on other domains of development and on the mechanisms that link development and later health, and on how any relationship is modified by socioeconomic context.

Keywords: child development; childhood education, school, adolescent health; health inequality, adolescent mental health, adolescent weight

1. Introduction

Inequalities in many child health outcomes are increasing in the UK and the health of those living in its most disadvantaged areas are amongst the worst in the developed world (15). Some of the roots of health inequality are thought to be in early childhood with socioeconomically driven inequalities in child development persisting across the life course; negatively impacting on people's future health, wellbeing and life chances and perpetuating health inequalities into adulthood (22). Evidence that the early years, or the first '1000 days', is a critical period of development (50, 51) (together with health economics research in this field (56)) has meant that the early years have become a prime area for public policy and public health investment in many high-income countries including the UK (176).

All of the countries of the UK provide early childhood programmes, which aim to improve outcomes for children by supporting optimal health and development through access to services such as early education and care; between the ages of 0-4 years or pre-school (159). There is evidence that programmes which support child development in readiness for school can improve cognitive and non-cognitive skills (177). There is also evidence that positive cognitive development on starting school is associated with academic achievement by age 13 years (24) and positive socioemotional development by age 10 years (73). Non-cognitive skills such as social skills and self-regulation on starting school are also associated with later academic success and psychosocial outcomes in subsequent years of childhood and early adolescence (74). There is less evidence for whether and how child development, or interventions to support child development, are related to subsequent health in childhood. For example, there is limited evidence on the effect of early child development programmes (such as attending pre-school, accessing health services and parenting programmes) on adolescent health; with one systematic review finding little to no effect of early childhood programmes on later child health; though with some evidence for obesity reduction, greater social competence, improved mental health and crime prevention(35). A review of Sure Start (a UK early years programme from 1999-2017, for families with children under the age of four years and

targeted in more disadvantaged areas) found that access to Sure Start was associated with fewer childhood hospitalisations for infections and injury (76). Potential mechanisms proposed for this association were: the provision of information to parents and changing parents behaviour, leading to a safer and more nurturing home, and to reducing externalising behaviour in children, leading to less fights or dangerous activities (76).

To better understand whether and how child development at school starting age is associated with subsequent health in childhood, requires a clear understanding of what is meant by 'child development', reliable measures of child development, and also the development and testing of conceptual frameworks or theories regarding the relationships between child development and later adolescent health. In terms of defining what we mean by 'child development', this is contested academic and policy terrain and, as such, is difficult to define. For some, child development is understood through a narrow focus on cognitive education, whilst for others it is about broader life skills, including confidence and social competencies (67). In English health and education policy, child development has tended to be defined in the former, relatively narrow way; with, for example, child development at school starting age understood through a specific composite measure of a child's personal, social and emotional, physical, cognitive and communication and language development, termed 'school readiness' (66). Internationally, school readiness, when considered more broadly, has been seen as a viable strategy to reduce inequalities in learning and development gaps at the start of formal education (178). However, how it is defined and used in England has been criticised as reductionist, with school readiness used as a performance and accountability measure, resulting in a narrowing of the curriculum, marginalisation of children who fail to achieve required levels of development through grouping by ability, and subjugation of teachers and schools to meet targets (179). Moving beyond targets to understanding child development more broadly, as an ongoing developmental process in a social context (63), is important if we are to develop interventions to support equitable health and development. Therefore, we consider 'child development' in this review as any measure of child development which encapsulates a process of change in what a child is capable or able of doing, or in how they are feeling. There is no existing framework for characterising different aspects or measures of child development. Therefore, in this review we use four over-arching domains of child development: socioemotional development, cognitive development, language and communication, and physical development. These domains broadly encompass the areas of learning within the early years curriculum in England (66). We see these categories as potentially useful despite the described shortcomings of England's composite measure 'school readiness'. Conceptualising child development in this way provides a platform for

learning about the relationships between specific domains of child development (using a range of child development measures) and subsequent health.

Understanding whether and how child development and adolescent health outcomes are related presents opportunities for interventions to improve health and reduce health inequalities at an important time in the life-course, adolescence. There is evidence that health in adolescence is on the causal pathway to socioeconomic status (SES) in adulthood by enabling 'selection' into education (29). Therefore, focusing on health in this period is critical to enable children to optimise their subsequent educational outcomes for wellbeing and employment opportunities. Informing interventions requires evidence not just on associations between child development and adolescent health but also on the effect of socioeconomic circumstances on any associations found. In our protocol we outlined pathways by which socioeconomically driven health inequalities may manifest (family stress, material living circumstances and parental health behaviours) and also possible direct pathways (social and cognitive) between child development and subsequent health. This provides a conceptual framework for the review. To inform interventions on any of these pathways there is a need to identify factors which may explain, and the socioeconomic circumstances which may modify, the associations between child development and adolescent health. This requires a public health lens and as far as we are aware no review has analysed the evidence on relationships between different dimensions of child development and adolescent health outcomes or assessed the factors which may shape the relationships.

In summary, there is evidence that aspects of child development at school starting age are associated with later academic success, but less is known about whether and how particular dimensions of child development influence health outcomes in adolescence. This gap in understanding limits cross-sector interventions to improve adolescent health and reduce health inequality. This review addresses this gap by undertaking a participatory systematic review to: 1) synthesise evidence on the relationship between child development at school starting age (3-7 years) and subsequent health in adolescence (8 -15 years) and 2) identify factors which shape the relationship.

2. Materials and Methods

2.1. Protocol Registration

The study protocol was registered with PROSPERO (CRD42020210011) and published (180). The review is reported according to the Preferred Reporting Items for Reporting Systematic Reviews and

Meta-Analyses (PRISMA) 2020 Statement (167, 168), checklist available in additional file 1. Any deviations from protocol are stated and explained in the relevant sections.

2.2. Review Questions

- What are the associations between measures of child development recorded at school starting age (3-7 years) and subsequent health in adolescence (8 -15 years)?
- What are the effect modifiers (socioeconomic factors) of this relationship? (This will identify factors which alter the strength of the observed associations.)
- What are the mediators of this relationship? (This will identify factors or set of factors (pathways) which explain the observed associations.)

2.3. Definition of terms

Child development is defined as a developmental process incorporating measures of development which record changes within a child's cognitive or physical development, or language and communication, or socioemotional development.

2.4. Study Design

The design for this study was a participatory systematic review, involving engagement with national and local stakeholders across health and education sectors.

2.4.1. Stakeholder engagement to design the conceptual diagram

The lead reviewer held discussions with stakeholders to develop a conceptual model of the relationship under study. This process is described in full in the study protocol (180). Their views, together with a scoping review of the evidence, led to an initial conceptual diagram (available in Appendix 4, Additional File 2). This diagram highlights the main pathways by which socioeconomically driven health inequalities manifest; family stress, material living circumstances and parental health behaviours (14), and also illustrates possible direct pathways (knowledge/literacy and social/cognitive) between child development and education and subsequent health. The diagram acted as a framework for the review, providing initial categories for extracting and analysing evidence from published studies.

2.5. Eligibility

Studies needed to include children, some or all of whom were aged between 3 and 15 years, in high-income country settings defined as a member country of the Organisation for Economic and Co-

operation and Development (OECD). Exposures were characteristics of child development at school starting age (3-7 years), defined as: cognitive or physical development, or communication and language, or socioemotional development. Primary outcomes were health and wellbeing outcomes, reported between the ages of 8-15 years: specifically weight, mental health, and proxy measures such as dietary habits and behaviour and measures of wellbeing. Secondary outcomes were academic outcomes of academic tests and proxy measures such as executive function during the outcome age of interest. Secondary outcomes were only included if they were found in a study with a primary outcome of interest. Executive function was included as a secondary outcome of interest because it allows for the regulation, control and management of learning and thus appears an important link between child development and academic outcomes. In addition, executive function is a good predictor of academic achievement (181). Studies which provided data on associations between the exposures and outcomes in the age period of interest, and additionally those that provided evidence on mechanisms, were required. The population and context, exposure, outcomes and study designs are described in full in the published protocol (180) and summarised in relation to inclusion and exclusion criteria in Table 1.

Table 1: Summary of eligibility criteria

	Inclusion	Exclusion
Population and context	Studies must include children, some or all of whom are aged between 3 and 15 years, across socioeconomic strata in high-income country settings, defined as OECD membership.	Studies of children from non-OECD countries. Studies which focus solely on a particular subset of children with a particular health or development need.
Exposure	A measure of child development at school starting age (3-7 years), defined as: cognitive or physical or linguistic or socioemotional development at school starting age, measured by any of the following: • School readiness, as measured by scales such as the Bracken Basic Concepts Scale Revised (BBCS-R) (169). • Cognitive development as measured by, for example, non-reading intelligence tests, vocabulary tests, mathematics tests or parent/teacher ratings. • Language and literacy (as measured by academic achievement test scores such as pre-reading/reading, vocabulary, oral comprehension, phonological awareness, pre-writing/writing or verbal skills. • Emotional well-being and social competence (as measured by behavioural assessments of social interaction, problem behaviours, social skills and competencies, child-parent relationship/child-teacher relationship). • Physical development. Studies that explore socioeconomic factors which affect associations between child development at school starting age and these outcomes. Studies that explore mechanisms or pathways between child development at school starting age and these outcomes.	Studies reporting neither data nor mechanism between exposure and outcome will be excluded.
Outcome	*Primary Outcome(s)* The review will incorporate evidence health and wellbeing outcomes, reported between the ages of 8-15 years, specifically: • Weight (BMI). • Mental Health (as measured by standard questionnaires or clinically). • Socioemotional behaviour. • Proxy measures such as dietary habits and behaviour and measures of wellbeing will be included. *Secondary Outcome(s)* • Performance at the end of primary school (age 10-11), measured by standardized tests. • Proxy measures such as executive function.	Studies reporting neither data nor mechanism between exposure and outcome will be excluded.
Study design and sources	Observational studies (ecological, case-control, cohort (prospective and retrospective)) RCTs, Quasi-experimental, Review level studies including theory papers.	Cross-sectional studies, conference abstracts, books, dissertations, or opinion pieces.

2.6. Search Strategy

We searched four electronic databases for articles published from November 1990 to November 2020: MEDLINE (OVID), PsycINFO (OVID), ASSIA (ProQuest) and ERIC (EBSCO). We also searched the reference lists from all included articles for additional eligible articles. Further relevant literature was identified through stakeholder discussions. Grey literature searching was undertaken by searching relevant organisations' websites. The search strategy was informed by a scoping review of the literature and focused on terms relating to child development, school readiness and adolescent health. The search strategy is available in additional file 3.

2.7. Study Selection and data extraction

Retrieved citations were uploaded to EndNote and duplicates removed. Titles and abstracts were screened by five reviewers against the inclusion and exclusion criteria. A 10% sample of papers were independently checked by two reviewers and inter-rater reliability was 86%. Any disagreements were resolved by discussion between the reviewers, so that a consensus was reached. The full text of papers were read in the second stage of the screening process, by five reviewers, to produce a final list of papers for full text review. The final list of papers included was exported to Excel to be assessed for the data extraction process. The lead reviewer extracted data for those articles that met the inclusion criteria in full. Reasons for exclusion were recorded and a list of excluded papers, together with the reason, is available in Appendix 4, Additional file 4. Data extraction was undertaken solely by the lead reviewer using a bespoke form (Appendix 4, Additional file 5), which had been trialled on a sample of different sources, and a sample of 10% were second checked. The following data were extracted: author and year, study design, analysis method, country and setting, participants, exposure measure and age, exposure measurement instrument, outcome measure and age, outcome measurement instrument, association and effect size, mechanism (studied and proposed), factors which moderate the association, strengths and weaknesses.

2.8. Quality Assessment

Our protocol stipulated the use of Liverpool Quality Assessment Tool (LQAT) (170). However, it was found that LQAT was insufficiently detailed for this review. Therefore, in a deviation from protocol we adapted a tool appropriate for the study designs used in previous systematic reviews (173, 182). The methodological quality of each observational study was assessed for risk of bias and clarity of study description to assign studies to one of three categories of methodological quality: high, moderate or low, using the template in additional file 6. Specifically, studies were assessed against 12 criteria within the following categories: study population, study attrition, data collection and data

analysis with each pertaining to validity, precision or informativeness. In line with Cochrane recommendations (183) studies were not scored, and instead a narrative indication of quality (using +, – and ? against each criteria) was made based on all criteria, with criteria pertaining to validity and precision carrying a greater weight in guiding overall quality. Quality assessments were done by the main author and a 10% sample independently assessed by a member of the review team. In all cases the overall assessments of quality made by the reviewers concurred.

In addition to assessing the quality of each individual paper, the overall strength of evidence for papers grouped by outcome and domain was assessed e.g. mental health outcomes and the socioemotional domain of child development. Within these groupings the overall findings were graded as providing either: stronger evidence (generally consistent findings in higher quality studies); weaker evidence (generally consistent findings in one higher quality study, or in multiple lower quality studies); inconsistent evidence (inconsistent findings across multiple studies) or very limited evidence (a single study). This method draws on techniques used by Hoogendoom (173) and Baxter (158, 174).

2.9. Data Synthesis

As per the protocol, we undertook a narrative synthesis using the SwIM guidelines (172) (Appendix4, Additional File 7) to guide reporting. This was in anticipation of heterogeneity in the variety of exposures, analysis methods and outcomes in the studies. Each study was assessed and associations between exposures and outcomes recorded as either 'positive', 'negative' or 'no association'. Studies were grouped by outcome and, within this, organised by exposure domain and tabulated to illustrate both the associations and assigned quality. The groupings for the outcome measure were done by allocating the measure into either mental health, obesity or academic outcomes. The grouping for exposure measures was an inductive process involving an interpretation of the way child development had been understood and measured in each included paper and then classifying and allocating these into a particular domain of child development; namely, a socioemotional domain, cognitive domain, language and communication domain, physical domain or multiple domains. This was a subjective process because, as indicated in the introduction, there is no existing framework for understanding child development and characterising measures of child development.

An overall rating on the strength of the evidence for each grouping (studies allocated within each domain of child development for each outcome; weight, mental health, academic) was made as described in the quality assessment section. The results for factors which mediate or moderate associations between child development and subsequent health in adolescence (review question 2) was synthesised in relation to the conceptual diagram (Appendix 4, Additional File 2) of the

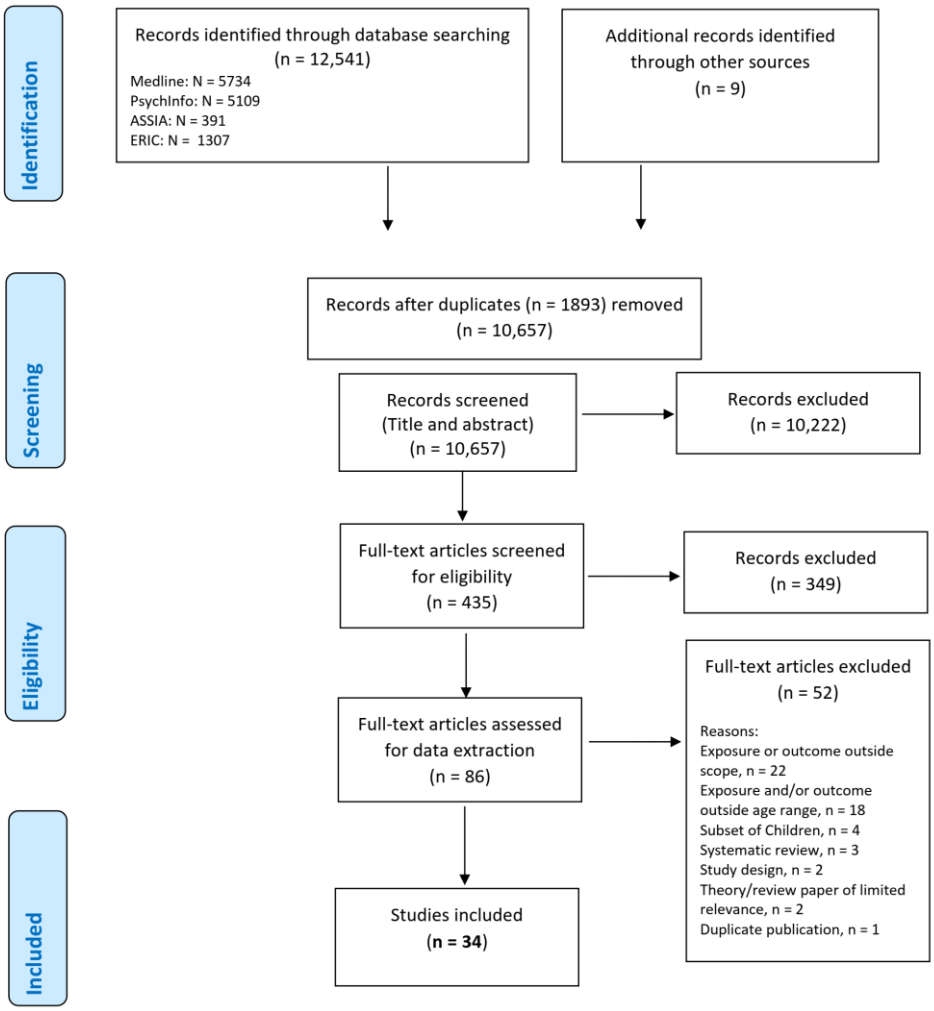
relationship (produced with stakeholders at the outset of the review). Factors were classed as either mediators (those which explain associations) or moderators (those which alter the strength of associations) and assigned to a pathway (grouping of factors); family stress, knowledge/literacy, social/cognitive, material living and parent health behaviours. The overall ratings on the strength of the evidence for each domain and outcome, and stakeholder discussions, were used to inform a final diagram of the relationship between child development and adolescent health.

3. Results

3.1. Literature results

Following screening of 10657 retrieved citations, 34 articles were included in the review. See figure 1 for PRISMA diagram illustrating the study selection process. Fifty-two studies were excluded on full text review, the list of studies excluded, with the reason is available in Appendix 4, Additional File 4.

Figure 1. PRISMA flowchart of study selection process



3.2. Study design and setting

Of the 34 included studies there were 32 prospective longitudinal studies (184-215), one retrospective longitudinal study (216) and one meta-analysis (217). Detailed descriptions of the included studies are available in Appendix 4, Additional file 8. Of the 34 studies, 14 were set in the United States (186, 187, 190, 194, 196, 198, 200-202, 207-210, 215), seven in Canada (189, 197, 203-206, 214), five in Australia (185, 192, 195, 199, 213), three in the UK (191, 193, 212), three in the Netherlands (184, 188, 216), one in Denmark (211) and one in which the countries included in the analysis were not explicitly stated (217).

3.3. Sample size and participant characteristics

The total number of children in included studies in the review was 69,152 (48% female, in those where sex was reported). Participants were recruited from pre-birth (through mother's pregnancy)

to age 12 years, with the majority recruited between the ages of 4-6 years, at pre-school or kindergarten. Across the studies recruitment took place between 1986 and 2009. The majority of the children were enrolled in existing longitudinal studies, were mainly Caucasian and from a mix of socioeconomic backgrounds. Six studies focused on socioeconomic disadvantage; three were of children from socioeconomically disadvantaged families recruited from child care centres (201) or Head Start programmes (early years services to support low-income children and families in the US) (190, 209), two studies oversampled for greater socioeconomic risk (202, 212) and one oversampled for non-marital status (198). A further two studies had children from majority low income (193) and low to middle income families (200). There were three studies in which children from socioeconomic disadvantage were less well represented (185, 189, 203). Children were assessed either in their own homes, pre-school or school apart from in two studies where lab-based assessments were made (197, 202) and two where routinely collected healthcare data was used (212, 216).

3.4. Studies identified across different domains of child development (exposures) and adolescent outcomes

Studies were found which focused on all domains of child development, namely; socioemotional development, cognitive development, language and communication, and physical development. Table 2 illustrates the number of studies within each domain and the related adolescent outcome measure(s). Table 3 provides a summary of the main study characteristics and describes the exposures by domain of child development, outcomes and how they were measured. The main domain of child development studied in included papers was socioemotional development with 24 studies (184-186, 188-190, 193, 195-199, 201, 204, 205, 207-211, 213, 215-217). Exposures included behaviours such as internalising and externalising behaviours, social competence, emotion knowledge, emotional wellbeing, emotional reactivity and peer relations. Exposures within the socioemotional domain were generally measured using the relevant sections of standardized instruments such as the Child Behaviour Checklist (CBCL), the Social Behaviour Questionnaire (SBQ) or the Strengths and Difficulties Questionnaire (SDQ) with a mixture of child report, teacher report and parent report across the studies.

Four studies (191, 202, 203, 214) had an aspect of cognition as the exposure of interest, namely; mathematics skills, executive control, foundational cognitive ability, verbal ability/literacy and Intelligence Quotient (IQ). Executive control refers to a set of cognitive processes necessary for cognitive control of behaviour and was measured by observing tasks. Verbal ability was measured using literacy tests, mathematics skills by number knowledge tests or standardized assessments

relating to the relevant country's curriculum, foundational cognitive ability and IQ by standardized instruments.

Two studies (187, 194) had language and communication as the main exposures and a further study (203) included language as one of multiple exposures. Exposures included receptive and expressive vocabulary. These were measured using the relevant sections of standardised assessments such as the Peabody Picture Vocabulary Test.

Two studies (200, 206) incorporated exposures in the physical domain of child development. Exposures included fundamental movement skills (balance, agility, hand-eye co-ordination) and participation in structured and unstructured physical activity. These were measured by either parent report or assessment of skills by assessors in the child's home.

Two studies (192, 212) measured across all domains of child development and education. One study assessed the component parts of teacher-rated school readiness in relation to the country's early development instrument and one focused on child development in all domains in a health visitor check as a composite measure. In the main, studies analysed the effect of the exposure at a certain time point on an outcome at one later time point. However, two studies repeated measures at subsequent ages to assign children to a trajectory for the exposure of interest (189, 209) and four studies repeated measures to study trends over time (194, 199, 208, 215).

Table 2: Studies by child development domain and adolescent outcomes

Number of studies by exposure domain		**Outcome Measures**		
		Primary		**Secondary**
Domain:	Total studies	Mental Health	Weight	Academic
Socioemotional	24*	18	5	3
Cognitive	4*	3	1	1
Communication and Language	2	2	1^	-
Physical	2	1	1	-
Composite/All domains measured	2*	2	1	-
	34	26	9	4

*Includes one study which measured several outcomes
^ From a study centrally coded to a different domain due to multiple exposures studied

Table 3: Summary of study characteristics

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Ashford et al 2008	Longitudinal	Holland	294 (49.2)	Behaviour internalising and externalising - age 4	Child Behaviour Checklist (CBCL) - parent and teacher rated.	Internalising behaviours - age 11	CBCL – parent and teacher report.
Berthelsen et al 2017	Longitudinal	Australia	4819 (49.1)	Child Behaviour at age 4-5 and early ecological risk factors SEP, MMH, Parenting anger, parenting warmth, parenting consistency.	Child behaviour risk index measured as the sum of scores: sleep (emotional and dysregulation (both parent report) and inattention/hyperactivity symptoms (mother rated).	Executive Function (age 14-15)	A composite score from three computerised tasks for assessing cognition (visual attention, visual working memory and spatial problem solving).
Bornstein et al 2010	Longitudinal	US east coast	118 (42.0)	Social competence at age 4	Social competence as a construct, of: the peer acceptance subscale of the Pictorial Scale of Perceived Competence and Social Acceptance Preschool Form, the Friendship Interview, and the socialization domain of the Vineland Adaptive Behaviour Scales (VABS).	Internalising and externalising behaviours at age 10 and 14	At age 10 years - the CBCL and Teacher Report Form At age 14 years - the CBCL and Youth Self-Report
Bornstein et al 2013	Longitudinal	US east coast	Two studies Study 2 extracted - 139 (39.6)	Language – communication skills - at age 4	Two verbal subtests of the Wechsler Preschool and Primary Scale of Intelligence—Revised and the VABS.	Internalising and externalising behaviours at age 10 and 14	At age 10 years - the CBCL and Teacher Report Form At age 14 years - the CBCL and Youth Self-Report

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Derks et al 2019	Cohort	The Netherlands	One study of three extracted: Generation R study, 3794 (50.4)	Aggressive behaviour - at ages 5-7, 10 and 14	CBCL - mother rated	BMI and body composition (fat mass and fat free mass) - at ages 6 and 10	BMI - the Dutch national reference in the Growth Analyser program. FM and FFM - dual-energy x-ray absorptiometry scanner
Duchesne et al 2010	Longitudinal	Canada	2000 (49.9)	Behaviour - hyperactivity, inattention, aggressiveness and prosociality - age 6 Maternal warmth and maternal control also studied	Social Behaviour Questionnaire (SBQ) - teacher rated	Trajectory of anxiety at age 11-12	Rated annually from kindergarten to Grade 6 using the Anxiety Scale from the SBQ – teacher report Children put into trajectory of anxiety
Fine et al 2003	Longitudinal	US	154 (50.0)	Emotional knowledge, internalising and externalising behaviours age 7	Emotion knowledge – composite score from two tasks: (Emotional labelling & Emotion situation knowledge) Internalising and externalising behaviours – CBCL (teacher report)	Internalising behaviours age 11	Child self-report aggregate of the following measures: Depression - Children's Depression Inventory (CDI) Anxiety - The State-Trait Anxiety Inventory Loneliness. The Loneliness Scale Negative emotions – Differential emotions scale

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Glaser et al 2011	Longitudinal	UK	5250 (50.7)	IQ age 8	Wechsler Intelligence Scale for Children	Depression symptoms - age 11, 13, 14 and 17	Self-reported depressive symptoms were measured with the 13-item Short Mood and Feelings Questionnaire (SMFQ) Moderator: Pubertal stage at 11, 13 and 14 years was measured using a five-point rating scale
Gregory et al 2020	Longitudinal	Australia	3906 (49)	School readiness across 5 domains (physical, social, emotional, language and cognitive, communication and general knowledge) - Age 5	Australian version of the Early Development Instrument – teacher rated. Children scored as vulnerable, at risk or on-track	Age 11: four aspects of student wellbeing (life satisfaction, optimism, sadness and worries)	Middle Years Development Instrument - child self-report
Hay et al 2003	Longitudinal	UK	134 (53)	Co-operation (one form of prosocial behaviour) at age 4	Tester's rating of cooperativeness during the cognitive test (Tester's Rating of Children's Behaviour) & an observational measure of cooperation with the mother during the Etch-A-Sketch task	Internalising and externalising behaviour problems – at age 11	SDQ and CAPA (Child and Adolescent Psychiatric Assessment)

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Hooper et al 2003	Longitudinal	US	74 (52.7)	Language - receptive and expressive language, receptive vocab and working memory - age 5 and 7-8 (kindergarten and second grade)	Receptive and expressive language -The Clinical Evaluation of Language Fundamentals. Receptive vocab (Peabody test) and Working memory (Competing Language Processing Task)	Behaviour problems – externalising problems (conduct and hyperactivity) - kindergarten, first, second, and third grade	Teachers completed assessments of the children's behaviour using a standardized scale of behaviour - Conner's' Teacher Rating Scale-Revised
Howard et al 2018	Cohort	Australia	4983 (49)	Self-regulation - age 4-5 and 6-7	Self-regulation problems were indexed by combining parent-, teacher-, and interviewer-report ratings of children's self-regulatory behaviours	Academic and weight, mental health, substance use, crime, self-harm and suicidal ideation - age 15	Academic achievement - children's total scores on the Year 9 National Assessment Program - Literacy and Numeracy Mental health problems were measured in a private face-to-face interview with the parent/carer who knew the adolescent best Overweight and obesity - BMI

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Howes et al 2000	Longitudinal	US	307 (49.5)	Preschool social—emotional climate, Peer play, Behaviour problems, Teacher-child relationship quality - Age 4	Preschool social—emotional climate - average of children's scores on measures in class. Peer play – peer play scale Behaviour problems – classroom behaviour inventory (CBI) Teacher-child relationship quality - The Pianta Student Teacher Relationship Scale	Social competence - Behaviour with peers at age 8	Teacher reports using the Cassidy and Asher Teacher Assessment of Social behaviour Questionnaire
Jaspers et al 2010	Longitudinal (retrospective)	Holland	2139 (50.9)	Behavioural features at age 4 - 'sleeping, eating, and enuresis problems' and 'emotional and behaviour problems'	Assessed by Preventative Child Healthcare professionals.	Behavioural and emotional problems at age 10 to 12	CBCL - parent completed
Lecompte et al 2014	Longitudinal	Canada	68 (48.5)	Emotional wellbeing - Child-parent attachment at age 3-4	Lab based separation reunion procedure	Anxiety and depressive symptoms and self-esteem (age 11-12)	Dominic Interactive Questionnaire - computerised self-report measure of common mental health disorders in childhood. Self-esteem - self-perception profile for children - self-report
Lee et al 2017	Longitudinal	US	762 (46.3)	Behaviour internalising and externalising - age 5	CBCL - primary caregiver completed	Behaviour internalising and externalising - age 9	CBCL - primary caregiver completed

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Louise at al 2012	Longitudinal	Western Australia	2900 (not stated)	Behaviour - aggressive - age 5, 8, 10 and 14	CBCL, youth self-report at age 14 and teacher report at age 10 and 14	Weight at age 5, 8,10 and 14	Weight - Wedderburn digital chair scale Height was measured using Holtain Stadiometer. BMI was calculated as weight (kg)/height2 (m2)
McKenzie et al 2002	Longitudinal	USA	207 (49.7)	Fundamental movement skills - Balance, agility, eye-hand coordination - age 4,5 and 6	Movement skill tests in the child's home	Physical Activity - age 12	Trained assessors administered the 7-day Physical Activity Recall (PAR) in the child's home on two occasions, approximately 6 months apart
Meagher et al 2009	Longitudinal	USA	56 (55.4)	Socioemotional behaviours observed in pre-school – age 4	Externalising and internalising symptoms from the CBCL – teacher report Observed negative effect by research assistants	Depression symptoms - age 8	Child depression inventory - self-report
Nelson et al 2018	Longitudinal	US	280 (47.9)	Executive control and Foundational Cognitive Abilities at age 5	EC - 9-tasks administered to each child during individual sessions in the laboratory (working memory, inhibitory control, and flexible shifting) FCA - via the Woodcock-Johnson-III Brief Intellectual Assessment	Depression and Anxiety symptoms - Age 9-10.	Child Depression Inventory – child self-report Anxiety symptoms - Revised Child Manifest Anxiety Scale, - child self-report Externalising symptoms - parents completed the ODD and ADHD-

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
							Hyperactivity subscales of the Conners 3rd Edition Parent Ratings Scale
Pedersen et al 2007	Longitudinal	Canada	551 (45.4)	Behaviour - anxiety/social withdrawal and disruptive behaviour - Age 6	Social Behaviour Questionnaire (SBQ) - mother and teacher rated	Peer rejection & Friendedness (at age 8 to 11) Depressive symptoms Loneliness Delinquency - at Age 13	Peer rejection - peer nominations. Friendedness- Children were also asked to nominate up to four best friends Depressive symptoms - CDI - child report Loneliness-self-report measure developed by Asher et al 1984 Delinquency - Self-Reported Delinquency Questionnaire (SRDQ)
Piche et al 2012	Longitudinal	Canada	966 (47.0)	Self-regulatory skills: classroom engagement and behavioural regulation (emotional distress, physical aggression, impulsivity) - Age 6	Classroom engagement (teacher rated) and Behavioural regulation using the SBQ (teacher rated) –	Child Sports Participation and BMI - Age 10	Parents reported on their child's weekly involvement in structured sports outside of school during the past school year BMI was derived from direct height and weight measures made by trained, independent examiners

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Piche et al 2019	Longitudinal	Canada	1516 (51.9)	Participation in structured and unstructured physical activity - Age 7	Parents reported on their children's participation in structured and unstructured physical activity	Age 8 Depressive symptoms,	Depression symptoms assessed through the Social Behaviour Questionnaire
Rudasill et al 2014	Longitudinal	USA	1156 (48.8)	Child temperament (negative emotionality at age 4½ and emotional reactivity at age 7-12) (Student-teacher relationship -teacher perception and child perception tested as mediators)	Negative emotionality: Mothers completed eight subscales from the Children's Behaviour Questionnaire Emotional reactivity: Children's emotional responses to events and environmental stimuli were rated by mothers using a measure designed for use in the NICHD SECCYD	Depressive symptoms in sixth grade (age 11-12)	Mother report of their children's depressive symptoms was measured in 6th grade with the Diagnostic and Statistical Manual of Mental Disorders oriented Affective Problems subscale of the Child Behaviour Checklist
Rudolph et al 2011	Longitudinal	USA	433 (55.0)	Peer Victimization (static and dynamic) (Age 7-12, 2nd to 5th grade)	Children and teachers completed a revised version of the Social Experiences Questionnaire to assess children's exposure to peer victimization.	Depression symptoms and Aggressive behaviour - Age 11-12 (5th grade)	Depression symptoms - Short Mood and Feelings Questionnaire (Child report) Aggressive behaviour - Children's Social Behaviour Scale (teacher report)
Sandstrom et al 2020	Meta-analysis	Any	8836 (51.5)	The mean age at the first BI assessment was 3.61 years	BI: defined as shyness, fear, and avoidance when faced with new stimuli	The mean age at the anxiety assessment was 10.39 years	Anxiety and specific anxiety types searched

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Sasser et al 2017	Longitudinal	USA	356 (54.0)	Intervention targeting social-emotional functioning and language-emergent literacy skills in the first year of pre-school. Executive function measured before and after preschool and each year to third grade (age 8)	Executive function assessment by trained examiners. Children assigned to either low, moderate or high executive function trajectory	Third grade academic outcomes	Reading fluency, language-arts and mathematics (all teacher rated), children self-evaluation of reading ability
Shapero et al 2013	Longitudinal	USA	958 (48.0)	Emotional - emotional reactivity at age 8. (Household income and household chaos also studied. Household Chaos and Household income also studied.)	Emotional reactivity – mother report - 10-item questionnaire about their perceptions of how their child expresses emotions in response to events	Emotional and behavioural problems - Age 15	Adolescent Emotional and Behavioural Problems – Youth Self-Report.
Slemming et al 2010	Longitudinal	Denmark	1336 (49.0)	Behaviour: anxious–fearful, hyperactive–distractible, and hostile– aggressive - Age 3-4	Preschool behaviour questionnaire (PBQ) - parent report	Internalising problems - Age 10-12	Emotional difficulties were measured at age 10–12 years with the parent-administered strength and difficulties questionnaire (SDQ)

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
Straatmann et al 2018	Longitudinal	UK	10262 (not stated)	Five central domains of a health check in England: (1) personal, social and emotional development, (2) communication and language, (3) physical health, (4) learning and cognitive development and (5) physical development and self-care) - at Age 3	Health visitor assessment at routine health check	Language ,weight, socioemotional behaviour - Age 11	Language - British Ability Scale Second Edition (BAS II) Verbal Similarities test Weight was derived from the body mass index (BMI), using the age and sex-International Obesity Task Force cut-offs Socioemotional behaviour - SDQ - mother report
Sutin et al 2017	Longitudinal	Australia	4153 (71.6)	Temperament - sociability, persistence, negative reactivity. Age 4-5	Parents completed a 12-item measure of temperament based on the Childhood Temperament Questionnaire	Weight and weight attitudes and behaviour - Age 14-15	Weight – BMI and waist circumference at all ages Weight attitudes and behaviour. At ages 14–15 years, study children self-reported on several aspects of their attitudes and behaviours.
Weeks et al 2014	Longitudinal	Canada	4405 (50.0)	Verbal ability (age 4-5) and Math skills - age 7-11	Verbal Ability: Peabody Picture Vocabulary Test-Revised (PPVT-R) Math skills - Mathematics Computation Test (MCT)	Internalising symptoms of anxiety and depression - Age 12-13 and 14-15	Questionnaire that included 7 items from the Ontario Child Health Study (OCHS-R), assessing symptoms of anxiety

Author (Year)	Study Design	Country	Participants (% Females)	Exposure (development characteristic) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument
							and depression - self-report.
Yan et al 2018	Longitudinal	USA	695 (49.1)	Emotional Wellbeing - child parent relationship - Age 6	Both fathers and mothers rated their relationships (conflict and closeness) with the child at Grade 1-5 Child-Parent Relationship Scale	Loneliness at grades 1, 3 and 5 (age 10-11)	Loneliness and Social Dissatisfaction Questionnaire - child self-report

3.5. Quality Assessment

Thirty three of the 34 included studies were assessed using the methodological assessment tool for observational studies, available in additional file 6. One study, a meta-analysis, was assessed using AMSTAR (A MeaSurement Tool to Assess systematic Reviews). Results of the quality assessment process for all included studies is available in additional file 9. Ten were rated as low, 16 moderate and eight high in methodological quality. High implies a low risk of bias, moderate implies a moderate risk of bias and low quality implies a high risk of bias.

As outlined in quality assessment section of the methods, confidence in cumulative evidence was assessed within each grouping of papers, grouped by outcome and domain. This is referred to throughout the synthesis of the findings.

3.6. Narrative Synthesis

There was a range of exposures and outcomes reported across the included literature. Studies were organised by outcomes and grouped as follows:

- 'Mental health related symptoms' - this incorporated: internalising symptoms (general, depression, anxiety, loneliness and self-esteem), externalising (general and 'delinquency'), socioemotional behaviour problems, social competence, wellbeing, self-harm and suicidal ideation.
- 'Weight, diet and physical activity' – this incorporated: BMI, overweight/obese, sports participation, unhealthy weight attitudes, and healthy dietary habits.

For secondary outcomes, the group included executive function and outcomes from academic tests.

Within these above groupings, studies were subsequently organised by exposure and by each domain of child development as follows:

- Domain: Social and emotional development. This was further subdivided to aid analysis, as follows:
    - Internalising - internally focused behaviour such as inhibition and withdrawal.
    - Externalising - externally focused behaviour such as aggression, attention problems, hyperactivity and 'delinquent' behaviour.
    - Emotional - internal factors such as social competence, emotion knowledge, pro-social, co-operative and self-regulation skills. External factors such as peer relations, parent-

child relationships, teacher-child relationships, socioemotional climate of school/pre-school setting.
    - Temperament – negative emotionality, emotional reactivity and persistence.
- Domain: Language and communication. This comprised the ability to listen, understand and speak. Exposures included: receptive and expressive vocabulary. Receptive relates to understanding of words and expressive relates to the ability to use words for expression.
- Domain: Cognitive development. This comprised mathematics skills, executive control, foundational cognitive ability, verbal ability/literacy and Intelligence Quotient (IQ)
- Domain: Physical development. This involved fundamental movement skills (balance, agility, hand-eye co-ordination) and participation in structured and unstructured physical activity
- Multiple domains.

A summary of the evidence on associations between exposures (domains of child development) and outcomes are presented in Table 4. Each annotation does not always represent a study in its entirety as many studies analysed multiple exposures and outcomes.

Table 4: Evidence of associations between domains of 'child development' (exposures) and outcomes of mental health symptoms, weight and academic

Domains of Development (Exposures)	Outcomes: Mental Health Symptoms:										Weight, Diet, Physical Activity:					Academic:	
	Internalising	Anxiety	Depression	Loneliness	Poor self-esteem	Externalising	Delinquency	Poor Wellbeing	Socio-emotional problems	Poor Social Competence	Self harm and suicidal ideation	BMI	Overweight	Less Sports Participation	Unhealthy weight attitudes	Unhealthy dietary habits	Worse Executive Function	Worse Academic tests
Socio-emotional																		
Internalising:	0++		0															
Anxious-fearful	+																	
Behavioural Inhibition		+																
Emotion and behaviour problems						0												
Externalising:	+ +		0			+												
Hyperactive	0	+																
Inattention	0	+				+												
Aggression	+											++						
Behaviour problems	0					+				+							+	
Disruptive			+	+			+											
Emotional Wellbeing:																		
Social Competence	-					-												-
Emotional Knowledge		-																
Prosocial		-											+					
Co-operative	0					-												
Self-regulation skills											-	-	-	-				-
Pre-school socio-emotional climate										-								
Child-teacher relationship quality										-								
Mother-child attachment		-	-		-													
Child-parent relationship				-														
Peer Victimization			+			+												
Temperament:																		
Negative emotionality and emotional reactivity	+		+			+							0		+			
Persistence													-		-			
Language and Communication																		
Language skills	-					0												
Receptive and expressive language						-												
Receptive Vocabulary						0										-		
Verbal working memory						0												
Cognitive Skills																		
IQ			-*															
Executive Control			-	-														
Foundational Cognitive ability			0	0														
Verbal ability		-	-															
Maths skills		-*	-*											-				-
Physical Development																		
Participation in activities			- +															
Fundamental movement skills														0				
Multiple Domains																		
Physical, Social and Emotional	-							-										
Language, communication and cognition	-																	
All domains									-				-					

Methodological Quality: Low | Moderate | High

+ indicates a positive assoication (exposure is bad for outcomes)

- indicates a negative association (exposure is good for outcomes)

0 indicates no association found

indicates no evidence found

* these associations changed direction in mid-adolescence

3.7. Primary Outcomes

3.7.1. Mental Health

Summary of associations between child development and mental health

Positive development on starting school is associated with subsequent positive mental health. There is stronger evidence for associations between the socioemotional domain of child development and later mental health, weaker evidence for the cognitive domain, inconsistent evidence for language and communication and limited evidence for physical development.

Summary of associations between socioemotional development and mental health

Eighteen studies analysed associations between a socioemotional exposure of child development and later mental health (184, 186, 189, 190, 193, 195-198, 201, 204, 207, 208, 210, 211, 215-217). All associations highlighted that positive socioemotional development is good for subsequent mental health, apart from five studies where no associations were found for some exposures and outcomes studied (190, 193, 201, 211, 216). The evidence is stronger for exposures of externalising behaviour and emotional wellbeing at school entry, weaker for exposures of internalising behaviour and limited for exposures relating to temperament.

Exposure of internalising behaviours at school entry and subsequent mental health

Eight studies analysed the relationship between early internalising behaviour and later mental health (184, 190, 198, 201, 204, 211, 216, 217), highlighting weaker evidence for positive associations with internalising outcomes and limited evidence for positive associations with externalising outcomes. Of these, six studies analysed the association between early internalising and later internalising behaviours, with two studies of moderate quality showing positive associations (184, 198), one high quality study where no association was found (190) and one low quality study, of 56 children, where no association was found with depression symptoms (201). Specifically anxious-fearful behaviour is associated with later emotional difficulties as reported by parents (211) in a study of moderate quality. Behavioural inhibition is associated with anxiety but this evidence was from a lower quality review (217). Evidence on the relationship between early internalising and later externalising behaviours was scant; providing only limited evidence, with two studies not studying that relationship specifically (198, 204) and one study where no association was found between early emotional and behaviour problems and later externalising (216).

Exposure of externalising behaviours at school entry and subsequent mental health

Nine studies were found on the relationship between externalising behaviours and later mental health (184, 189, 190, 196, 198, 201, 204, 211, 216), highlighting stronger evidence for positive associations with both internalising and externalising outcomes. Of these, seven studies analysed the associations between early externalising and later internalising, with six studies showing positive associations and one study where no association was found. There was evidence of positive associations between general externalising behaviour problems (184, 190) and later internalising symptoms, and specifically aggression (211) was associated with later internalising symptoms. However, whilst two studies showed no association between hyperactive behaviour (211) or inattention (216) and later general internalising symptoms, one high quality study of 2000 children did evidence an association between these behaviours and later anxiety symptoms (189). One study, of lower quality, evidenced that disruptiveness was associated with later depression symptoms and loneliness (204).

Similar to internalising symptoms, whereby the continuity of association was found for early and later symptoms, the same is true for externalising symptoms whereby early problems are associated with externalising at a later age. However, the evidence is stronger with two studies of moderate quality evidencing associations between general externalising (198), inattention and behaviour problems (216) and later general externalising symptoms, with a further study evidencing a relationship between poorer social competence with peers in mid-childhood and earlier behaviour problems (196). Specifically, disruptiveness was associated with delinquency in one low quality study (204).

Exposures of emotional wellbeing at school entry and subsequent mental health

Nine studies were found on the associations between a child's emotional wellbeing and later mental health (186, 189, 190, 193, 195-197, 208, 215) with stronger evidence found for the association with internalising outcomes and weaker evidence for externalising outcomes. A child's emotional wellbeing, in terms of social competence, emotional knowledge (the ability to identify and label emotions), self-regulation and prosociality (behaviour intended to benefit others) appear beneficial to later health in adolescence. Negative associations were found between early social competence and internalising and externalising problems (186). In two high quality studies, associations were found for emotional knowledge (190) and prosocial skills (189) and later anxiety, with increasing emotional knowledge and prosocial skills both associated with less anxiety symptoms. A child's ability to co-operate, a particular prosocial skill, highlighted mixed results in one study (193) with increasing co-operation associated with less externalising but no association found with internalising

problems. Self-regulation problems, in terms of ability to control behaviours, attention, thinking, social interaction and emotions, were subsequently associated, in adolescence, with an increase in the risk of self-harm ideation and behaviour, suicidal ideation, school truancy, mental health problems, smoking and alcohol use and violent and property crime (195). When self-regulation problems reduced, from age 4-5 to 6-7, the association between these adolescent outcomes and earlier self-regulation problems was no longer found (195).

In relation to the child's emotional wellbeing in the context of relationships or setting specific (external factors), studies were found on; mother-child attachment, relationship with parents, teachers, and peers (victimisation), and the socioemotional climate in a pre-school setting and all proved important for positive mental health in adolescence. A small study of 68 children, rated low quality, evidenced that disorganised maternal attachment at pre-school age was associated with greater depression and anxiety symptoms and lower self-esteem in early adolescence (197). A positive relationship with parents, in terms of closeness, was associated with less loneliness, particularly for father-daughter relationships (215). In one low quality study a good quality relationship with teachers and a positive socioemotional climate in a pre-school setting were both associated with improved social competence in mid-childhood (196). With regard to relations with peers, one study evidenced that early and increasing peer victimisation was associated with depression symptoms and aggression (208).

Exposures of temperament at school entry and subsequent mental health

Two studies were found on the association between temperament and later mental health highlighting limited evidence of a negative association, with higher levels of certain traits associated with worse outcomes. These studies investigated child temperament, in terms of negative emotionality and emotional reactivity (the former refers to the propensity to react with negative emotions and the latter relates to the intensity of emotion) (207, 210) and both were of moderate quality. One showed an association between negative emotionality, emotional reactivity and depression symptoms (207) and one between emotional reactivity and internalising and externalising symptoms (210).

Summary of associations between language and communication, cognitive development, physical development, and multiple domains and mental health

Eight studies analysed the associations between exposures relating to either language and communication, cognitive development, physical development or multiple domains of child development and later mental health. All associations highlighted that positive development across

all of the domains of child development are good for subsequent mental health. There was weaker evidence for the effect of cognitive skills and the positive effect of cognitive development appears to alter with age. The evidence for associations between language and communication and later mental health outcomes was inconsistent in relation to internalising and externalising outcomes. There was limited evidence for both physical development and measures incorporating multiple domains.

Exposures within the language and communication domain and subsequent mental health

The results for the effect of language and communication skills on later mental health symptoms was inconsistent with two studies investigating these associations (187, 194). One study of 129 children evidenced that language skills at pre-school age predict internalising but not externalising behaviour problems in adolescence. Conversely, one low quality study of 74 children did find an association between good language skills (receptive and expressive language) and less externalising problems, namely conduct problems but not hyperactivity.

Exposures within the cognitive domain and subsequent mental health

Three studies analysed the effect of cognitive skills on later mental health symptoms, (191, 202, 214) with weaker evidence found. One study found that deficits in executive control predicted depression and anxiety symptoms and clinical level of depression (202). The same study showed that foundational cognitive ability did not predict these outcomes. One high quality study showed an association between cognition, measured as IQ, and depression symptoms with an increased IQ in early childhood associated with less depression symptoms at age 11 (191). However, by age 13-14 the association reversed. The loss of protective effect of cognition was also found in relation to the effect of cognitive skill (measured as mathematics skills and verbal ability) on internalising symptoms whereby a protective effect seen at age 12-13 was reversed or had no associated effect at age 14-15 (214).

Exposures within physical development domain and subsequent mental health

There was limited evidence for the effect of physical development on later mental health related symptoms. One lower quality study, in which time between exposure and outcome was one year, found that structured physical activity was associated with less depression symptoms in boys, whereas unstructured physical activity was associated with more depression in girls. (206)

Exposures incorporating multiple domains and subsequent mental health

Two studies provided evidence across multiple domains (192, 212). One study evidenced that all components of school readiness (as part of a model of early years data), measured by UK health visitors before starting school, predicted socioemotional behaviour problems in early adolescence (212). An Australian study which investigated the relationships between all domains of school readiness and wellbeing at the end of primary school found that all domains were negatively associated with internalising symptoms, whereas only physical and socioemotional development were positively associated with overall wellbeing (192).

3.7.2. Weight, Diet and Physical Activity outcomes

Summary of associations between child development and weight

Positive development on starting school is associated with subsequent healthy weight related outcomes. There is stronger evidence for the socioemotional domain of child development, limited evidence for; language and communication, cognitive and physical domains of child development.

Summary of associations between socioemotional development and weight

Five studies analysed the associations between a socioemotional measure of child development and later weight diet or physical activity outcomes (188, 195, 199, 205, 213). All associations highlighted that positive socioemotional development is good for subsequent weight-related outcomes, apart from one study where mixed associations were found for exposures of certain temperamental traits and later weight related outcomes. The evidence is stronger for exposures within the emotional wellbeing domain, specifically self-regulation skills, with weaker evidence found for exposures of externalising behaviour and no evidence found for internalising behaviour.

Exposures of externalising, emotional wellbeing and temperament and subsequent weight

In relation to externalising, specifically aggressive behaviour, one higher quality study found a positive association with higher BMI (188) and one of moderate quality found an association with higher rate of change in BMI but in girls only (199). In relation to self-regulation, one higher quality study (195) evidenced that early problems in self-regulation (ability to control attention, behaviour and emotion at age 4-5) were associated with being overweight or obese in adolescence but that a change in self-regulation (less problems) at a later age (age 6-7) had no effect on the association. Another study highlighted that increasing self-regulation skills (measured as class room engagement) were associated with lower BMI and increased sports participation (205). Additionally, this study evidenced that emotional distress (a measure of self-regulation) was associated with less sports

participation. In relation to temperament, one higher quality study (213) looked at the associations between the traits of; persistence sociability and negative reactivity, and later BMI and weight attitudes and behaviours and found that persistence decreased the risk of obesity and overweight, sociability increased the risk of overweight but not obesity and negative reactivity wasn't associated with either. In relation to weight attitudes and behaviours, all three traits were associated with restrained eating habits in adolescence, with lower persistence and higher negative reactivity or sociability associated with restrained eating and use of unhealthy weight management strategies.

Summary of associations between domains of: language and communication, cognitive, physical development, multiple domains and weight

There was limited evidence on associations between the domains of; language and communication, cognitive skills, and physical development, and later weight related outcomes. One study, which looked at evidence on a range of school readiness skills and later wellbeing measures, evidenced that receptive vocabulary was associated with healthier dietary habits (203), with increasing receptive vocabulary predicting reduced sweet snack intake and increased dairy intake. The same study (203) evidenced that increasing mathematics skills predicted increasing involvement in physical activity, providing limited evidence for an association between cognitive skills and later weight-related outcomes. There was limited evidence on the association between physical development and weight-related outcomes with one lower quality study finding no association between fundamental movement skills and later involvement in physical activity (200). One study evidenced that all components of school readiness (as part of a model of early years data), as measured by UK health visitors before starting school, predicted overweight and obesity in early adolescence (212).

3.8. Secondary Outcomes

3.8.1. Academic Tests and Executive Function

Summary of associations between child development and academic outcomes

Four studies analysed associations between a domain of child development and later academic outcomes, three in relation to socioemotional development and one in relation to cognitive development. All associations highlighted that positive development is good for subsequent academic outcomes. The evidence is stronger for exposures within the socioemotional domain, specifically self-regulation skills and less behaviour problems with weaker evidence found for exposures within the cognitive domain of child development. There were no studies found looking at

the association between language and communication or physical development and academic outcomes.

Exposures within the socioemotional and cognition domains and subsequent academic outcomes

There were two studies found on associations between socioemotional development and the secondary academic outcomes, both of higher quality (185, 195). One studied the effect of behaviour risk (a composite of poor sleep, emotions and inattention) on adolescent executive function and found that poorer behaviour is associated with lower executive function (185). Another study highlighted that self-regulation problems are associated with reduced scores on numeracy and literacy tests in adolescence (195). An additional study (209) investigated the effect of an intervention targeting socioemotional functioning and language emergent literacy skills in pre-school, through comparing the impact of executive function trajectories on academic test results of children in the intervention group compared to those who were not. This study showed that socioemotional and language programmes improved executive function and academic outcomes for children with the lowest executive function trajectory. There was limited evidence on associations between early cognitive skills and later academic outcomes with one study showing a positive association between kindergarten mathematics skills and later academic outcomes (203).

3.9. Factors affecting relationships

Summary of findings on factors affecting associations (mediation and moderation)

Limited evidence was found on factors affecting associations. Some evidence however was found on factors affecting associations between socioemotional development and subsequent mental health and academic outcomes. The factors are discussed in relation to the pathways identified in the initial conceptual model devised with stakeholders. Factors were found in relation to family stress, knowledge/literacy and social/cognitive pathways. No factors were found which pertained to the material living or parent health behaviour pathways. All of the findings within this section fall into the category of limited evidence as all of the factors described were found in single studies only.

3.9.1. Mediators

Six studies included data on mediating variables, five related to studies focusing on mental health outcomes (186, 187, 197, 204, 207) and one relating to academic outcomes (185). None of the studies which focused on weight as an outcome included data on mediation. Factors mediating associations between socioemotional development and mental health were self-esteem, type of internalising or externalising in mid-childhood and relationships with teachers and friends. Factors

mediating associations between socioemotional development and academic outcomes were approaches to learning and attentional regulation.

3.9.2. Moderators

Seven studies included data on a variables to test for moderation effects on associations between exposure and outcome; five in relation to mental health (189, 191, 198, 210, 215), one in relation to weight (213) and one in relation to academic outcomes (209). Factors moderating associations between socioemotional development and mental health were household chaos and parenting. Household chaos had a negative effect, and aspects of parenting had a positive effect on the associations between the socioemotional domain of child development and mental health outcomes. A factor found to moderate the association between socioemotional development and academic outcomes was trajectory of executive function.

3.9.3. Factors pertaining to the Family Stress Pathway – moderating associations between child development and mental health

This pathway incorporates factors related to stress in the home, which can affect parenting ability, parenting style and consequently child health and development. Household chaos and aspects of parenting were identified as moderators of the relationship between the socioemotional domain of child development and later mental health symptoms. Household chaos was found to disproportionately affect children with higher emotional reactivity resulting in greater internalising problems (210). This effect was not found for household income, that is, level of emotional reactivity made no difference to the impact of income on adolescent emotional and behaviour problems. This implies that the impact of low income on adolescent mental health is pervasive and not amenable to individual interventions promoting self-regulation (in terms of emotional response to events) but that interventions of this type might support how children respond to household chaos. Three studies analysed the moderating role of aspects of parenting on the relationships between socioemotional measures and later mental health related symptoms (189, 198, 215), with all finding positive effects of aspects of child/parent relationships on adolescent outcomes. Two studies found a protective effect of relationships with fathers on continuity of behaviour problems. One found a protective effect for fathers' positive engagement on the continuity of earlier to later internalising and externalising behaviour problems, for those in the greatest poverty fathers' positive engagement was associated with a reduction in the continuity of internalising problems from age 5 to 9 years (198). The authors hypothesize that this is due to development of secure attachment and the development of emotional and behavioural regulation skills. Another looked at the moderating role of parent-child closeness on the continuity of loneliness from age 6-11 years and found that as

parent-child closeness increased, loneliness reduced and this relationship was particularly strong for girls and their fathers (215). Another study looked at the moderating role of maternal parenting practices, warmth and discipline, on the relationship between behavioural characteristics of; inattention, hyperactivity, aggressiveness and low prosociality and trajectory of anxiety in children between the ages of 6-12 years (189). It found that a lack of maternal warmth increased the association between hyperactivity and anxiety. It also found that high level of maternal discipline (rules and controlling child's behaviour) increased the probability of belonging to the high anxiety group.

3.9.4 Factors pertaining to the Knowledge/Literacy Pathway - moderating and mediating associations between child development and academic outcomes

This pathway relates to the way knowledge and literacy can lead to behaviours that can be positive for wellbeing (218). Two studies analysed factors within this category, both on the relationship between the socioemotional domain and later academic outcomes. One highlighted a moderating role of executive function on the relationship between an intervention to improve socioemotional and language emergent skills and later academic outcomes and found that the effect of the intervention was higher in children with low executive function in the intervention group resulting in better academic outcomes compared to controls (209). Another highlighted attentional regulation and approaches to learning as mediators, partially explaining the relationship between child behaviour (composite of sleep, emotional dysregulation and inattention/hyperactivity) and later executive functioning.

3.9.5 Factors pertaining to the Social/Cognitive Pathway - mediating associations between child development and mental health

This pathway relates to the influence of individual experiences, the actions of others, and environmental factors which provide the social context for learning to influence health behaviours (140). Five studies analysed mediators pertaining to this pathway and all in relation to mental health related symptoms, four in relation to the socioemotional domain (186, 197, 204, 207) and one from the language and communication domain (187). In relation to the socioemotional domain of child development and later mental health there is limited evidence that self-esteem, type of internalising or externalising in mid-childhood, relationships with teachers and friends all play a role in explaining the relationship. One study evidenced the role of self-esteem which partially mediated the relationship between emotional wellbeing (measured as parental attachment) and depression but not anxiety (197). Two studies highlighted the role of relationships, one with peers (204) and one with teachers (207). In relation to peers, peer rejection and number of friends in mid-childhood

mediated the relationship between disruptiveness at age 6 and depression at age 13 years, with peer rejection also mediating the relationship between disruptiveness and loneliness. Relationships with teachers (closeness and conflict) also appear important with one study analysing the effect of child-teacher relationships on the relationship between negative emotionality at age 4, emotional reactivity at age 7 and depression symptoms at age 11-12 years (207). This study found that teacher-child conflict mediated the relationship between emotional reactivity and depression symptoms, with children higher in emotional reactivity having more depression symptoms and this was partially explained by conflict with teachers (teacher reported).

3.9.6. Factors pertaining to child characteristics – moderating associations between child development and weight and mental health

Sex moderated the association between socioemotional domain of child development and weight outcomes, with worse outcomes for girls. Age moderated the association between the cognitive domain of child development and subsequent mental health, with a protective role of positive cognitive development on mental health in early adolescence reversing in mid-adolescence.

Two studies analysed the effect of age on the relationship between cognition and later depression symptoms and found that age reversed the protective effect of cognition on early adolescent (age 11) mental health by age 13-15 years (191, 214) but that this reversed again at age 17 for females (191). This study also found that pubertal status mimicked the relationship by age but that this was stronger for females. The loss of the health protective effect of cognition may be due to exam pressures at certain time points or for females, biological hormonal changes. Sex was the only factor studied in relation to weight. One study evidenced that girls with higher aggression cores throughout childhood had a higher rate of change in their BMI (199). Another study highlighted that girls higher in sociability in early childhood had a greater fear of weight gain at age 14-15 years (213).

3.10. Conceptual Model/Diagram Development

A summary of findings and revised conceptual model was discussed with stakeholders and a final diagram of the relationships, as informed by this systematic review were discussed and agreed – see figure 2. Factors which were not found in the review but were deemed important by stakeholders are highlighted on the diagram. These included neighbourhood factors such as, community engagement and community environment, which stakeholder felt could create conditions conducive for optimal health and development. Political and system factors were also identified, such as short political cycles not giving policy sufficient time to embed and effect change, and regulators focusing

narrowly on academic outcomes rather than broader social and emotional wellbeing which dictates the focus of a school. The stakeholder group identified these factors as potential moderators of the relationships between child development and health.

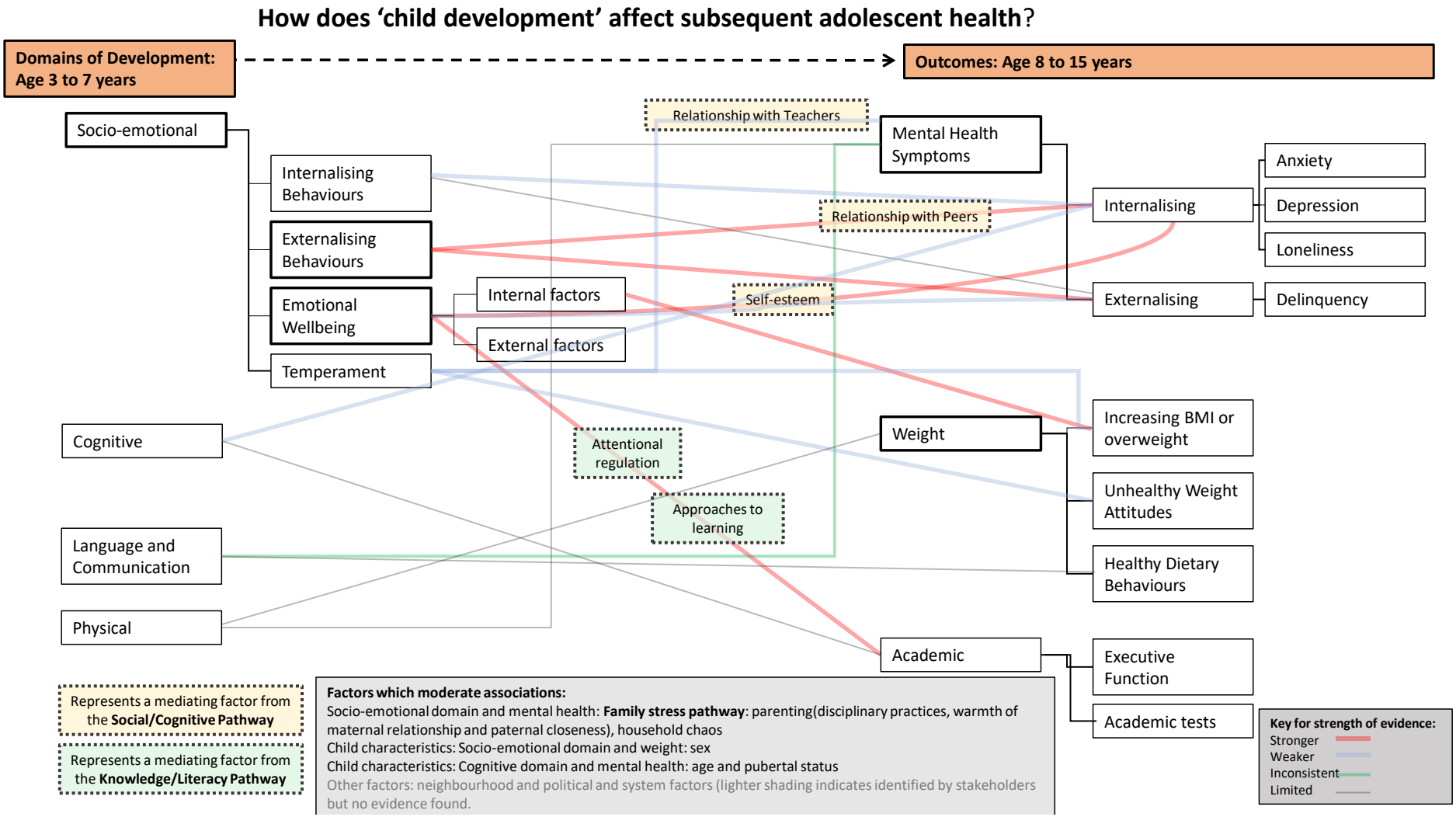


Figure 2: Diagram of the relationship between domains of child development and adolescent outcomes

4. Discussion

This review asked the questions: what are the associations between child development and adolescent health, and what factors explain or alter the associations? The review clearly shows that positive development on starting school is good for later health outcomes, but that the evidence is stronger for relationships between some domains of child development than others; with gaps in the evidence base across domains. In relation to mental health outcomes, there is stronger evidence for associations between socioemotional development and later mental health, weaker evidence for associations with cognitive development, inconsistent evidence for language and communication and limited evidence for physical development. In relation to adolescent weight, there is stronger evidence for associations with children's socioemotional development and limited evidence of relationships with language and communication, cognitive development or physical development. In relation to secondary (academic) outcomes, there was stronger evidence for associations with socioemotional development, limited evidence for an association with cognitive development and no evidence found for an association with language and communication or physical development. In relation to what factors explain or moderate the associations, the evidence identified in this review is largely limited to factors shaping the relationship between socioemotional development and mental health and academic outcomes with factors pertaining to the pathways of; family stress, knowledge/literacy and social/cognitive.

Our findings build upon the existing limited evidence that attendance at pre-school (a proxy for good child development) is associated with positive mental wellbeing and healthy weight in adolescence (35) and provides detail on which domains of child development are associated with these positive health outcomes. Supporting the existing literature we found positive relationships between both cognitive and socioemotional development (such as self-regulation and social competence) on mental health and academic outcomes in early adolescence (24, 73, 74), with stronger evidence found for socioemotional development. Additionally we identified evidence of a negative relationship between socioemotional wellbeing and unhealthy weight. The review provided a test of our conceptual model and we found that the evidence base was lacking for some of the proposed pathways between child development and later health.

Undertaking this review highlighted a complexity in classifying the rich and broad literature that exists on child development. In consequence, the review had to embed an inductive process of interpretation of how included studies had understood and measured child development. Using a classification system of four domains of child development to aid analysis of a very broad concept enabled us to categorise a multitude of measures of child development within this system. This

complexity and the need for interpretation is perhaps unsurprising given that the field of child development spans the disciplines of psychology, sociology education, biology, genetics and public health. That a classification system for understanding child development does not exist is in itself a finding of our review. Our classification of four domains of child development adds to the literature, providing a framework for other researchers to use and to critique.

Our findings show that conceptualising child development into domains of development matters because different aspects of development seem to have different impacts on later health outcomes. Understanding this can help to inform public health interventions in childhood. For example, in our review, we found that socioemotional development when children start school has the most evidence for subsequent impact on adolescent health, in terms of mental health and healthy weight, and as such could be a focus for intervention. The findings in relation to mental health are to be expected with much literature highlighting the continuity of early problems with socioemotional functioning and later onset of mental health conditions (219). The evidence is stronger for early externalising behaviours and their impact on both internalising and externalising behaviours in adolescence and this is supported by wider literature (220, 221). A finding of this review is that there is more evidence that behaviours such as aggression and hyperactivity pose a risk to future mental health than anxious/withdrawn behaviour, particularly for externalising outcomes. This finding should be interpreted cautiously because it might be that early internalising behaviours, compared to externalising, are more likely to resolve by early adolescence (222) or it could be that internalising is harder to identify, whereas externalising behaviours are more obvious and easier for parents and teachers to report, which could lead to less associations being observed for internalising behaviours and consequently less associations found (190, 220). The finding that emotional wellbeing was more closely associated with later internalising may be because emotional stability promotes regulation and mood stability leading to less internalising (223), but other studies have found that emotional wellbeing (in terms of regulation skills) is associated quite strongly with both internalising and externalising, but particularly so for internalising after the early years (224).

The findings in relation to stronger evidence on the associations between socioemotional development and weight add to a growing field of evidence exploring this relationship, with evidence of co-development and temporal associations in mid-childhood (225), evidence of obesity having a detrimental impact on socioemotional behaviour(226) and evidence on associations between social competence and weight with social competence reducing the odds of later overweight (227). From this review, emotional wellbeing and in particular self-regulation skills appear to be an important factor to study in this complex relationship between socioemotional

development and weight. However, other developmental pathways in the development of obesity, such as physical activity and cultural and social factors, are important to consider alongside self-regulation development (195).

More evidence is needed on how adolescent health outcomes are shaped by other domains of child development, particularly the impact of language and communication, and cognitive and physical development at school starting age. Evidence on these domains are important for engaging health and education sectors to work together because education and health services share a common goal for optimal developmental potential of children (228). This evidence would help the development of a shared understanding and provide a platform from which to develop the context and settings which may work best for optimal health and development of children, no matter what their stage of development on starting school. Including executive function as an exposure and outcome in this review allowed for inclusion of any evidence on the bi-directional relationship between executive function and health (229). The analysis of secondary outcomes of academic tests and executive function highlight the importance of socioemotional development on these outcomes (health improves executive function). Conversely, the protective effect of cognitive skills (measured as executive control) on adolescent mental health highlights that executive function improves health. However, age appears to be an important factor in this latter relationship with the protective effects of cognition on mental health being reversed or no associations found in mid-adolescence (191, 214) and this warrants further research.

Understanding the impact of domains of child development on later health has important policy implications in relation to reducing inequalities, and in relation to a policy extension beyond the first 1000 days. In relation to reducing inequalities, our review highlights a strong relationship between socioemotional development and later health. Applying a public health lens to 'child development' helps to understand exactly what it is that pre-school provision or early years centres may need to focus on if we are to improve adolescent health and wellbeing. Re-invigoration of early childhood programmes such as Sure-Start with a renewed focus on socioemotional development may be one area of policy improvement, particularly if we are to focus on their longer-term potential to reduce inequalities (230).

In addition, arguably a policy shift is required, which extends beyond the first 1,000 days, to understand and support optimal development throughout childhood and into adolescence (4), to address the consequences of inequalities in child development as children age and because adolescence is a significant period of development and an important period in the life course (31) . If we are to maximise the opportunities conferred by education as a platform to improve public health

and reduce health inequalities (9), policy which incorporates a life course approach to healthy development is needed and this requires cross-sector collaboration.

Fostering collaboration to inform policy on reducing child and adolescent health inequalities beyond the first 1000 days requires more research on how development and education translates into health throughout childhood, and on the effect of socioeconomic circumstances on this relationship. Findings in relation to the factors which explain or alter associations between child development and subsequent health were limited in this review with all findings pertaining to single studies. The most evidence was within the social-cognitive pathway with self-esteem, relations with peers, and teachers all providing some explanation for the relationship between socioemotional development and subsequent mental health outcomes, and this can inform interventions for optimal health and development through the primary school years. Surprisingly, in relation to the original conceptual diagram designed with stakeholders there was no literature found on material living circumstances, parent health behaviours, community factors, and political and system factors. To some extent this was because the studies controlled for the effect of income, housing, parental education and parent health behaviours. However, this presents a problem because we need to know more about how these elements of socioeconomic circumstance affect the associations under study in this review. For example, we know that children from more deprived backgrounds experience poorer health and development than their more affluent peers (159). If we are to pragmatically intervene to improve the health and development trajectory of children in more deprived circumstances, and reduce the attainment and health gap, we need to understand exactly how poverty, household circumstances and home environments affect learning and the co-development of education and health. This requires the design of public health research which respects agency but more clearly theorises children within their social and economic context (231), so as to encapsulate socio-political cultural and familial environments; as in many ways this is what 'defines' child development in practice, over and above genetic make-up.

In addition to collaborating to produce more evidence on individual, home or school-level interventions to mitigate against poor development, interventions at system level are required to tackle prevention earlier so that children reach a good stage of development, and to reduce inequalities in development measures upon starting school. This requires evidence in relation to macro-determinants such as political and system factors e.g. addressing poverty, the role of regulators in generating a target-driven culture that focuses attention on academic achievement, a political system not conducive to cross-departmental perspectives or action, a system which stifles innovation and creativity. Larger studies, such as natural experiments or evaluations of existing

policies, are needed which perhaps compare areas with different working systems or policies to identify any particular cultures or practices which are conducive to promoting positive trajectories for health and development of children. The participatory element of this research identified some of these macro determinants, identifying a gap between research and practice. This finding highlights the need to bring research and practice closer together (162) through listening to views and experience of those working in service roles, at system level and/or with children. It is hoped that this method can help to inform future research by highlighting what is evidenced in the literature, but also bringing to light views from lived experience which may not have any published evidence but could steer future research.

The strengths of this review are in its systematic design aiming to incorporate all relevant studies to answer the research question and in its engagement with a stakeholder group to steer the review and engage research with practice. The involvement of a sample of stakeholders raises the potential for biases to be introduced by selection of stakeholders with particular views, opinions or experiences. The use of replicable and transparent systematic review methods helps to minimise this risk. The research question was broad. This limited the search strategy in incorporating all possible terms to address the breadth of the research question and this may mean that some evidence was not found. Another limitation is that the secondary outcomes were only included where they were found in papers which also had the primary outcome. This likely means that the associations found are underestimated. Including any paper with the secondary outcomes would have led to an unmanageable number of papers and, given that the focus of the review was health outcomes, it steered the decision on only including secondary outcomes where relevant in understanding any temporal dynamics to the relationship under study. The grouping of child development measures, used for data synthesis, could be seen as both a strength and a weakness. A strength in that it allowed for the classification of a range of child development measures into developmental domains and a limitation in that it was a subjective process and as such is open to critique.

5. Conclusions

Positive socioemotional development at school starting age appears particularly important for subsequent mental health and weight in adolescence. There are gaps in the evidence about what factors affect the relationships between child development and subsequent health, in particular the effect of socioeconomic factors. More collaborative research across health and education is needed to develop and define appropriate measures of child development across key domains of child development and also on the relationships and mechanisms between domains of development,

particularly cognitive, language and communication and physical development, and later health, in the context of socioeconomic inequality. This requires the design of public health research which respects agency but more clearly theorises children within their social and economic context (231), so as to encapsulate socio-political, cultural and familial environments. Research designed using longitudinal cohorts could be one way forward here and be considered in future work on this topic. This theoretically-informed research and knowledge is imperative to inform interventions to address health inequalities in mid-childhood and adolescence.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Additional file 1: PRISMA 2020 Checklist, Additional file 2: Conceptual diagram, Additional file 3: Search Strategy, Additional file 4: Study Selection: Excluded papers, Additional file 5: Study Selection: Data extraction form, Additional file 6: Quality Assessment: Quality assessment form, Additional file 7: Data Synthesis: SWIM Checklist, Additional file 8: Results: Table of study characteristics, Additional file 9: Quality Assessment: Results of quality assessment process. (In this thesis these are available in Appendix 4)

Post publication note: As the bulk of the studies in the review were not from a UK setting, transferability of the findings to a UK setting should be considered. The volume and quality of the literature (69,152 children from 34 studies, 24 of which were of moderate to high quality), in the review, together with the strength of the relationships found for the associations between socio-emotional development, cognitive development and adolescent health were significant. Therefore, it is a reasonable justification to test the relationships between development trajectories, of these aspects of development throughout childhood, and their association with adolescent health in a UK cohort.

4.4. Chapter Summary

Overall, the systematic review found strong evidence of associations between social and emotional wellbeing at school starting age and adolescent weight and mental health. It found weaker evidence of a relationship between cognitive ability and these outcomes. There was limited evidence on factors shaping relationships and these pertained to socioeconomic factors (moderators) stemming from family stress such as household chaos and aspects of parenting and capabilities factors (mediators), such as self-esteem and peer relationships, stemming from the social/cognitive pathway.

Chapter 5: Impact of Development Trajectory on Adolescent Health

This chapter describes how the findings from the systematic review (paper2) informed the longitudinal analysis, phase 2 of my PhD. The chapter incorporates three separate pieces of longitudinal analyses: 1) trajectories of socioemotional and cognitive problems concurrently (presented as paper 3), 2) trajectories of socioemotional problems and 3) trajectories of cognitive problems. It culminates with a summary of the key findings from the analyses.

5.1. Introduction

This chapter presents the longitudinal analysis phase of my PhD in the format of a published paper (paper 3) and the analyses which informed the paper. Paper 3, submitted for publication and under review in the *Journal of Paediatrics* presents the multi-trajectory analysis of socioemotional and cognitive development concurrently. Additionally the chapter presents the results of the analyses of single trajectories of development; socioemotional development and then cognitive development. In both the paper and the formative analyses I identify trajectories of development from age 3-14 years; describe the trajectories by demographic, socioeconomic, parental and school factors; and quantify associations between the derived trajectories and overweight/obesity and mental ill health at age 14 and 17 years. The primary contribution to the design, data analysis, interpretation, and paper for publication was made by me as the first author. The contribution of the co-authors can be found in Appendix 1.

The following appendices have been provided to further support the methodology used in this systematic review:

Appendix 5 – additional files for the longitudinal analysis paper.

Appendix 6 – supporting work for the single trajectory analyses

5.2. Rationale for undertaking longitudinal analysis

The findings from the systematic review evidenced that the level of cognitive and social and emotional development that a child has reached when they start school impacts their weight, mental health and academic achievements in adolescence. It also highlighted that socioeconomic factors such as household chaos and parenting behaviours can moderate the relationship between development and health and that capabilities factors such as self-esteem and relationships with peers can help to mediate the development-health relationship. This informed the longitudinal analysis in terms of a focus on the domains of cognitive and socioemotional development in mid-childhood, to determine whether there are distinct trajectories of development as children age

through primary school and impacts on later health. Also, as the systematic review highlighted evidence on the impact of social causes and capabilities it was decided to determine the impact of socioeconomic circumstances, school factors and parental factors on trajectories of development. School factors such as enjoying school or being bullied and parenting factors such as reading or playing with child were considered as proxy measures of self-esteem and relationships which are indicative of capabilities or skills development as understood in this project. Maternal education qualifications, maternal mental health and relative neighbourhood deprivation were considered socioeconomic factors. Maternal education in particular has been shown as the measure of SES with the strongest association with children's development (232) and as such is commonly used as a marker of SES when analysing data in the Millennium Cohort Study. Quantifying associations between these factors, as predictors of developmental trajectories, would highlight whether there are socioeconomic inequalities in development in mid-childhood and the potential role of capabilities in mitigating its effect.

Informing interventions beyond the early years, in mid-childhood, relies on understanding more about the epidemiology of key aspects of development in terms of the factors which influence or predict development, and the impact of development on adolescent health. However, knowledge of trajectories of socioemotional and cognitive development; the interrelationships between them; and their socioeconomic and demographic make-up; is unclear in UK cohorts. Therefore **this research aimed** to: a) determine developmental trajectories of socioemotional behaviour and cognitive development, individually and concurrently, in mid-childhood; b) describe by socioeconomic, demographic, parental and school factors; and c) quantify the associations between the derived trajectories and adolescent health, in a UK cohort.

5.3. Paper 3: Trajectories of child cognitive and socioemotional development and associations with adolescent health in the UK Millennium Cohort Study.

The manuscript presented here is a copy of an article submitted for publication in the Journal of Paediatrics.

Abstract

Background

Optimal cognitive and socioemotional development in childhood are important for future health. Evidence regarding the longitudinal interaction of these aspects of development and their impact on later health is lacking. We aimed to identify groups of distinct trajectories of cognitive and

socioemotional development during childhood and to examine their relationships with adolescent health.

Method

We used group-based multi-trajectory modelling applied to longitudinal data on 11,564 children up to age 14 years from the UK Millennium Cohort study to identify trajectories of cognitive and socioemotional development measured using validated instruments. We assessed associations between the derived trajectories and baseline socioeconomic, parental and school factors using multinomial regression. Logistic regression was used to assess associations between trajectory groups and adolescent health at age 14 and 17.

Findings

Four child development trajectories were identified: 'no problems' (76.5%); 'late socioemotional problems' (10.1%); 'early cognitive and socioemotional problems' (8.6%); and 'persistent cognitive and socioemotional problems' (4.8%). Male sex, higher neighbourhood deprivation, low maternal education, poor maternal mental health and school factors were associated with adverse development trajectories. Minority ethnicity and neighbourhood deprivation were strongly associated with the early problems trajectory. Trajectories with late or persistent socioemotional problems, with or without cognitive problems, were associated with adverse health. Compared to the 'no problem' trajectory, the late onset trajectory had increased odds of overweight and mental ill health at age 14 of 1.50 (95% CI 1.24-1.81) and 2.51 (2.03-3.10) respectively. For the 'persistent problems' group the odds ratio for overweight was 1.41 (1.04-1.91), and for mental ill health, 3.01 (2.10-3.30). For both groups the associations persisted to age 17.

Interpretation

In a representative UK cohort, groups of distinct trajectories of cognitive and socioemotional development can be identified. Trajectories of persistent cognitive and socioemotional problems and late onset socioemotional problems are strongly associated with overweight and mental ill health in adolescence, with socioemotional development an important driver of adverse health. Policies to improve adolescent health should emphasise socioemotional development and account for the mix of factors that drive early, late onset and persistent developmental problems during childhood.

Introduction

Improving child and adolescent health and reducing health inequalities is a global priority (233) yet many countries, including the UK, do not have a child and adolescent health strategy. This is a missed opportunity as good health, in adolescence, is important for future health directly and indirectly by enabling educational opportunities (9). However, poor health in adolescence is increasingly common. Globally the prevalence of anxiety and depression has doubled from pre- to post-pandemic years and currently affects around 1 in 4 of those under the age of 18 years (49) with stark inequalities in high income settings. Children and adolescents in families with a lower socioeconomic status (SES) are two to three times more likely to develop mental health problems than their peers living in families with a higher SES (10). Prevalence of, and inequalities in childhood obesity is also increasing. For example, in the UK, 1 in 4 children are obese when they leave primary school at age 10-11 years (11), the start of their adolescent journey.

Early childhood cognitive and socioemotional skills are important predictors of later mental health problems and obesity. A recent systematic review suggests that socioemotional development, defined as internalising and externalising behaviours, emotional and social skills and temperament on starting school (age 3-7 years), has a strong influence on weight and mental health in adolescence (234). In addition, cognitive development was associated with subsequent risk of internalising behaviours such as anxiety and depression (234). Studies in the UK and Australia have found that risk factors such as SES, sex and maternal mental health are associated with trajectories of socioemotional behaviour during childhood (79, 80).

Despite these insights, few studies have assessed how early life risk factors influence the co-development of cognitive and socioemotional behaviour, and how different trajectories of development are related to adolescent health outcomes such as mental health and obesity. Studying the evolution of cognitive and socioemotional development together is important as children develop holistically, with their needs changing over time and in relation to their socioeconomic circumstances (63). Early childhood socioeconomic circumstances have a major influence on both socioemotional behaviour and cognitive development (235). Cognitive ability, particularly language skills develop rapidly and improve throughout childhood (236). However compared to more affluent peers, children living in disadvantaged circumstances are less likely to move up cognitive ability rankings (237). This highlights the importance of understanding the impact of socioeconomic circumstances on cognitive development in terms of educational attainment and the process of skills development (63). Socioemotional skills are fundamental to cognitive development as they improve the capacity to learn increasing educational attainment (81, 238). Attainment affects health through

greater self-efficacy, self-direction and the adoption of health behaviours (64), mediated by skills and personal control (65), This interplay between cognitive ability and the socioemotional behaviour conducive to optimising it may interact over time to influence adolescent health, which may be enhanced or limited by the child's socioeconomic circumstances.

To our knowledge no studies have analysed trajectories of concurrent cognitive and socioemotional development in childhood or the socioeconomic, school and parental factors associated with them. Identifying groups of children following similar developmental paths of antecedent socioemotional behaviour and cognitive abilities, describing the characteristics of those trajectories and their association with later health could help to inform times and targets for interventions to improve adolescent health. This is important against a background of increasing inequalities and to strengthen cross-sector policy beyond the early years. Therefore, in a nationally representative UK cohort, this research aims to: determine trajectories of socioemotional and cognitive development concurrently, in mid-childhood; characterise how these are influenced by socioeconomic, school and parent factors; and quantify the associations between any identified developmental trajectories and adolescent health.

Methods

Study design and population

We undertook longitudinal analysis of the Millennium Cohort Study (MCS), a nationally representative cohort of children in the UK. The MCS cohort was selected from all children in the UK who turned 9 months and were in receipt of child benefit (which at the time was a universal provision) in a sixteen-month survey window beginning in September 2000. The MCS was designed as a stratified clustered cohort, stratified at ward level in relation to ethnicity and area disadvantage (child poverty index), with similar wards clustered. The sample was then randomly selected from the stratified cluster population, but with over-representation of ethnic minorities and disadvantaged children. This resulted in a disproportionately stratified cluster sample, which means for example that children born in disadvantaged areas had a greater chance of being selected than children in advantaged areas. Weighting was used to account for differential representation because of the unequal selection probability. Further detail on MCS study design and weighting is detailed elsewhere (160).

The current total sample size of MCS is 19,243 families. Recruitment started when the child was 9 months old and follow ups took place at ages 3, 5, 7, 11, 14 and 17 years. We used data from surveys at age 3 years to age 17 years, for singleton children only. The number of cohort members at each

of these survey points were 15382, 15042, 13682, 13112, 11564 and 10500. The details of the number of families, number of cohort members and attrition at each wave is available in Appendix 5, Additional File 1. We did not do a formal sample size calculation.

Measures

Development Trajectories

Socioemotional behaviour was measured using the Strengths and Difficulties Questionnaire (SDQ) completed by the parent when cohort members were age 3, 5, 7, 11 and 14 years. The SDQ is a behavioural screening questionnaire with 25 measures of psychological attributes covering five sub-scales (emotional symptoms scale, conduct problems, hyperactive scale, peer problems and pro-social scale). The respondent classified statements about the child's behaviour as either true, somewhat true or certainly true. All of the sub-scales apart from pro-social scale are taken together to generate a total difficulty score. A score of 0-13 is 'normal', 14-16 is 'borderline' and 17-40 is 'abnormal' (239). Children were classified into two groups to create a binary category using the validated cut-offs of 0-16 for 'normal' to 'borderline' socioemotional behaviour and 17-40 for socioemotional behaviour problems.

Cognitive development was measured from the results of standard cognition tests administered individually to cohort members at ages 3, 5, 7, 11 and 14 years. The tests at ages 3-11 years used the British Ability Scales II (BAS II) which have demonstrated construct validity of cognitive ability and high test re-test reliability (240). The test(s) taken at each age, together with the ability that test is measuring, is illustrated in Appendix 5, Additional File 2. T-scores were used rather than raw scores as the t-scores are adjusted for age and item difficulty by standardising against a reference group (norming sample) (241). This is important because it removes the cognitive advantage conferred by older age within sweeps and allows for comparison between children who have been born at different times of the year and/or have tests administered at different times. The test at age 14 years is a subset of the vocabulary assessment in the 1970 British cohort study survey, with no reference sample available. Test scores were used to classify children into two groups to create a binary category with children classed as having cognitive problems if they scored -1.25 standard deviations (SDs) below the cohort mean score for the sample (242) and classed as no cognitive problems for all other scores.

Adolescent health outcomes

Two adolescent health outcomes measured at ages 14 and 17 years; overweight or obese and mental ill health. Classifications of weight were derived from the body mass index (BMI) (kg/m^2) of children, using the International Obesity Task Force age and sex specific BMI cut-offs (243).

Mental ill health was measured at age 14 years using the Short Moods and Feelings Questionnaire (244). The SMFQ is a 13-item self-report measure of DSM-IV depressive symptom severity in the past 2 weeks. Possible scores range from 0 to 26, with the cut-off for symptoms indicative of clinical depression at ≥12 (245). A score of 0-11 was classed as no mental ill health and a score of 12-26 was classed as mental ill health. At age 17 years mental ill health was measured using the Kessler 6 scale, a six item measure of psychological distress. Participants were asked how often in the last 30 days they felt: so depressed that nothing could cheer you up, hopeless, restless or fidgety, everything was an effort, worthless, and nervous, with response options ranging from "all of the time" to "none of the time". Possible scores range from 0-24 with 13 or more indicating mental illness (246). A score of 13-24 was classed as mental ill health and 0-12 classed as no mental ill health.

Predictors of developmental trajectories

Socio-demographic, school and parent factors were measured as possible predictors of the developmental trajectories.

Socio-demographic factors were child sex, UK country of residence, child ethnicity, maternal education, quintile of deprivation (all at 9 months), quintile of family income (at 9 months), maternal mental health (at age 3 years).

School factors were experience of being bulled (child self-completion), enjoying school (child self-completion) and parental involvement with school (self-report by parent); all at age 7 years, as a marker of the school environment during the trajectory period of age 3-14 years. Involvement was re-coded into 'involved' for any frequency of involvement and 'not involved' for no involvement.

Parental factors were frequency of reading with child, frequency of visiting library with child and frequency of playing games with child; all from parent interviews at age 5 years, as a marker of what parents did with their children during the trajectory period. Responses were recoded into regularly (frequency of at least monthly for library visits, weekly for playing games with child) and not regularly for all other responses. For helping with reading responses were re-coded into every day, several times a week and less than several times a week.

Co-variates

Co-variates used in the logistic regression model were child sex, child ethnicity (white, mixed, Indian, Pakistani, Bangladeshi, Black Caribbean, Black African or other ethnic group, maternal education (diploma/degree plus, A-Levels, GCSE A-C, GCSE D-G/other or none) and maternal mental health (no psychological distress or moderate/high psychological distress at baseline), as guided by the multi-nominal regression analysis of predictors of the trajectory groups.

Statistical Analysis

First, we used Group Based Trajectory Modelling (GBTM) to determine multi trajectory groups for cognitive and socioemotional development from age 3-14 years. GBTM is an application of finite mixture modelling which allows for populations to be organised into meaningful subgroups that show statistically similar trajectories (247). It does this by identifying unique features of the data and organising it into latent strata. These strata represent groups of individuals following similar trajectories for both of the developmental measures under study. Individuals do not belong to a trajectory but are assigned a probability of group membership. GBTM differs from growth curve modelling and growth mixture modelling, which define the number of population groups *a priori.* In contrast, GBTM encodes no prior information about the population distribution of trajectories and allows the data to drive the categorisation of trajectories (248). We determined the number of groups which best represented heterogeneity in the development trajectories based on model fit, model adequacy and parsimony. We did this by fitting between one and five trajectory groups using logistic regressions with quadratic and cubic polynomial functions of age (see Appendix 5, Additional File 3 for more details on model specification). Model fit was determined using conditional fit statistics, Bayesian Information Criteria (BIC) and Akaike Information Criterion (AIC). Using these criteria and qualitative judgement we determined that four groups was the optimal fit. As recommended by Nagin (248) model adequacy was further tested by determining the accuracy of individual assignment to trajectories using the average posterior probability with a minimum threshold of 0.7 and odds of correct classification based on the posterior probabilities of group membership greater than 5. Analysis was undertaken using STATA 17 and STATA Traj plug-in for GBTM (249), with full-imputation maximum likelihood (FIML) used to account for missing data.

Second, to determine predictors of the trajectory groups, we used univariate and multivariable multinomial regression analysis to assess the associations between socio-demographic, parent and school factors and the derived trajectories. Relative Risk Ratios and 95% confidence intervals were calculated.

Finally, logistic regression was used to assess associations between trajectory groups and adolescent health outcomes at age 14 and 17 years. The crude models were adjusted for the main predictors found in the multinomial regression; child sex, ethnicity, maternal mental health and maternal education. Odds ratios and confidence intervals were calculated. Complete case analysis was used with survey weights used to account for response bias and attrition, using the *svy* command in STATA (250). Results are reported as per the STROBE checklist (Appendix 5, Additional File 4).

Role of the funding source

The funder of the study had no role in the design, analysis or interpretation of the findings.

Results

Study population characteristics

When cohort members were aged 14 years there were 15,415 eligible families, from a sample size of 19,243. Of the eligible families 11726 responded (overall response rate of 60.9% and a productive response rate from eligible families of 76.1%). After removing twins and multiple births 11564 cohort members remained for the main analysis (study flow diagram available in Appendix 5, Additional File 5).

Prevalence of socioemotional behaviour problems and cognitive problems

The weighted cross-sectional prevalence of socioemotional behaviour problems and cognitive problems at ages 3, 5, 7, 11 and 14 years is available in Appendix 5, Additional File 6. At each age point over 1 in 10 children had either developmental problem and about 1 in 50 children had both.

Analysis Part I – Group Based Multi-Trajectory Modelling

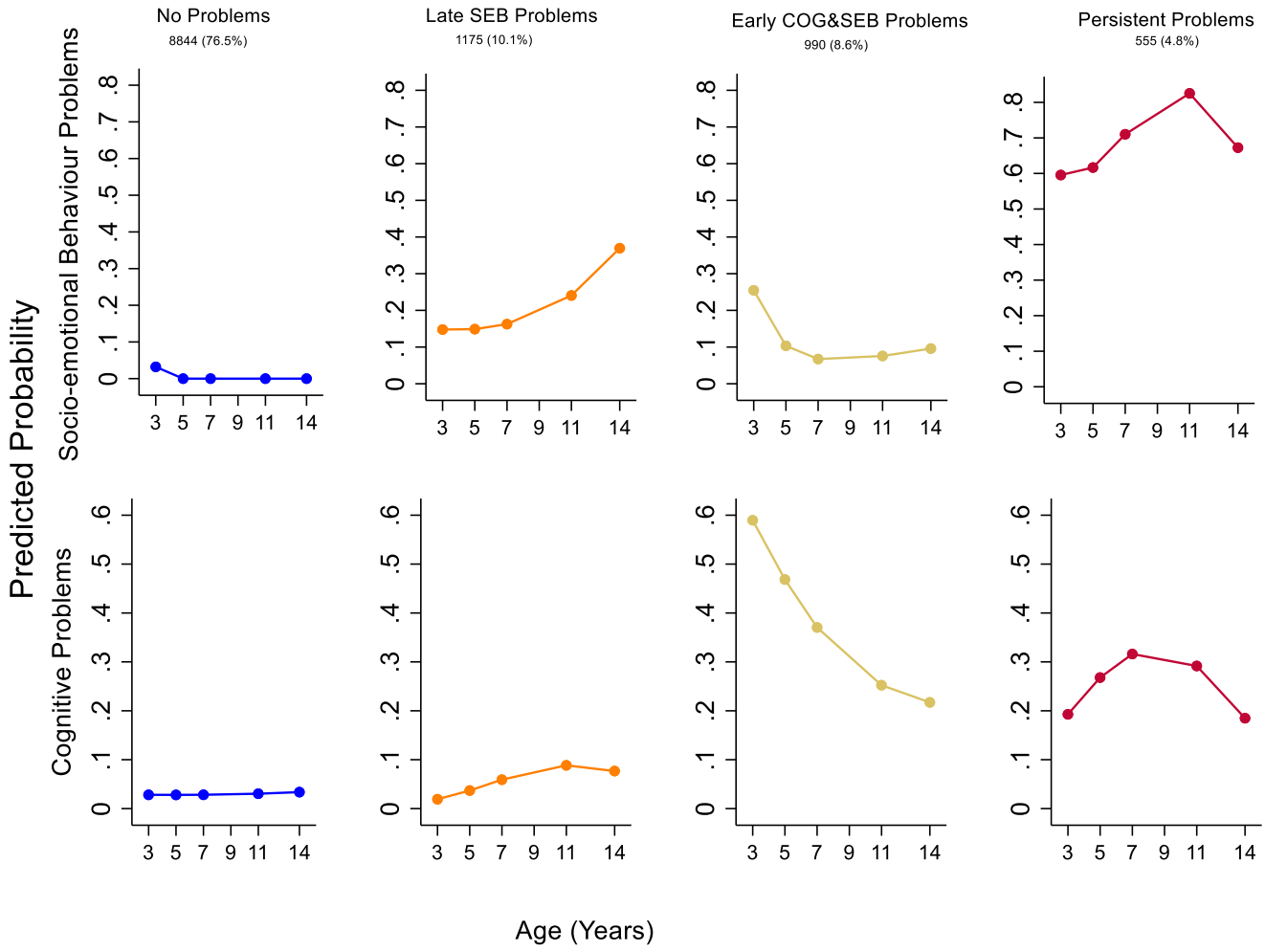
Development Trajectories

The multi-trajectory model with the best fit had four groups (figure 1). These four groups, based on predicted probabilities, were labelled as: no problems' (76.5%); 'late socioemotional problems' (10.1%); 'early cognitive and socioemotional problems' (8.6%); and 'persistent cognitive and socioemotional problems' (4.8%). Almost one in four children (23.5%) were in an adverse trajectory group. Population estimates for each group, based on average probabilities, are available in Appendix 5, Additional File 3b.

Table 1 shows the characteristic of the cohort by trajectory group. The vast majority of the population are resident in England and of white ethnicity, with slightly more males than females. Notably the prevalence of children in each of the adverse trajectory groups decreases as

socioeconomic factors of maternal education and income level increase and deprivation decreases. There is variation between groups in relation to all of the characteristics and this difference is statistically significant.

Figure 1: Predicted Probability of Socioemotional behaviour problems and cognitive problems by age and trajectory group in the Millennium Cohort Study



Note: COG = Cognitive development, SEB = Socioemotional behavioural development

Table 1: Description of Sample (observed data, weighted sample)

	Trajectory Groups n (%)				p	Total Sample n (%)
	No Problems n =8844 (76.5 %)	**Late SEB Problems n = 1175 (10.1%)**	**Early COG and SEB Problems n = 990 (8.6%)**	**Persistent COG and SEB Problems n = 555 (4.8%)**		**n = 11564**
Country						
England	5682 (81.5)	799 (84.0)	767 (86.6)	384 (85.2)	<0.001	7632 (82.5)
Wales	1246 (5.2)	164 (4.5)	106 (4.1)	83 (5.1)		1599 (5.0)
Scotland	1028 (8.9)	112 (7.7)	58 (6.0)	38 (5.8)		1236 (8.4)
Northern Ireland	888 (4.4)	100 (3.7)	59 (3.3)	50 (4.0)		1097 (4.2)
Gender						
Male	4219 (49.2)	642 (55.8)	575 (62.7)	368 (69.8)	<0.001	5804 (52.5)
Female	4625 (50.8)	533 (44.2)	415 (37.3)	187 (30.2)		5760 (47.5)
Ethnicity						
White	7177 (81.2)	903 (76.6)	383 (45.7)	377 (67.7)	<0.001	8840 (76.7)
Mixed	391 (5.1)	61 (5.6)	46 (4.6)	29 (5.6)		527 (5.2)
Indian	216 (1.9)	22 (2.2)	54 (4.4)	10 (1.3)		302 (2.1)
Pakistani	283 (2.2)	42 (2.2)	211 (15.1)	35 (3.1)		571 (3.4)
Bangladeshi	133 (1.0)	16 (0.7)	96 (5.2)	6 (0.6)		251 (1.3)
Black Caribbean	72 (1.1)	17 (1.6)	20 (3.2)	5 (0.7)		114 (1.3)
Black African	155 (2.1)	6 (0.5)	48 (6.4)	4 (2.2)		213 (2.2)
Other Ethnic Gp	165 (1.8)	32 (2.4)	85 (10.7)	23 (4.2)		305 (2.8)
Missing	252 (3.6)	76 (8.1)	47 (4.3)	66 (14.7)		441 (4.9)
Maternal Education						
Degree Plus	1985 (16.5)	119 (6.7)	24 (1.7)	19 (1.84)	<0.001	2147 (13.1)
Diploma	878 (8.2)	98 (5.4)	29 (2.0)	21 (3.0)		1026 (7.0)
A-Levels	918 (8.7)	97 (6.6)	58 (3.8)	25 (3.2)		1098 (7.7)
GCSE A-C	2847 (34.1)	389 (31.2)	222 (21.4)	161 (25.3)		3619 (32.1)
GCSE D-G	749 (10.7)	156 (16.2)	106 (11.0)	98 (19.0)		1109 (11.9)
Other qualifications	197 (2.2)	33 (2.5)	74 (6.7)	12 (1.8)		316 (2.6)
No qualifications	978 (15.2)	236 (25.8)	412 (47.1)	183 (38.9)		1809 (20.8)
Missing	292 (4.3)	47 (5.4)	65 (6.3)	36 (7.0)		440 (4.8)
Quintile of Deprivation						
Quintile 1(Most Deprived)	2098 (22.8)	401 (32.9)	556 (48.9)	247 (39.6)	<0.001	3302 (27.4)
Quintile 2	1874 (19.4)	281 (23.2)	179 (18.8)	134 (24.1)		2468 (20.1)
Quintile 3	1589 (19.6)	184 (17.6)	99 (13.3)	63 (13.2)		1935 (18.4)
Quintile 4	1405 (17.3)	133 (11.1)	66 (10.1)	41 (9.5)		1645 (15.4)
Quintile 5 (*Least Deprived)*	1600 (16.8)	133 (10.4)	29 (3.0)	36 (6.6)		1798 (14.2)
Missing	278 (4.2)	43 (4.8)	61 (5.9)	34 (6.9)		416 (4.6)
Income at baseline						
Inc Quint 1 *(Lowest)*	1365 (19.2)	339 (35.1)	422 (45.2)	223 (45.1)	<0.001	2349 (25.0)
Inc Quint 2	1613 (19.0)	290 (24.5)	298 (27.8)	140 (27.0)		2351 (21.0)
Inc Quint 3	1759 (20.2)	188 (14.0)	114 (12.5)	78 (11.8)		2139 (18.3)
Inc Quint 4	1914 (18.8)	182 (13.0)	55 (4.7)	42 (6.1)		2193 (16.1)
Inc Quint 5 *(Highest)*	1897 (18.4)	129 (8.1)	32 (3.0)	27 (3.0)		2085 (14.8)
Missing	296 (4.4)	47 (5.4)	69 (6.7)	35 (6.9)		447 (4.8)
Maternal Mental health (at baseline)						
No Psyc. Distress	5367 (59.3)	489 (38.5)	305 (33.0)	162 (30.0)	<0.001	6323 (52.7)
Mod/High Psyc. Distress	2164 (25.4)	477 (42.1)	234 (23.3)	242 (40.2)		3117 (28.2)
Missing	1313 (15.3)	209 (19.4)	451 (43.6)	151 (29.8)		2124 (19.2)

Note: COG = Cognitive development, SEB = Socioemotional behavioural development

Analysis Part II – Multinomial Regression

Predictors of Development Trajectories

Results of the univariate and multivariable multinomial regression model are illustrated in table 2. The income variable was removed from the multi-variable analysis to reduce multi-collinearity. Compared to the 'no problems' group; male sex, lower maternal education qualifications, being in the most deprived quintile of deprivation, poor maternal mental health and school factors of being bullied 'all the time' and parents not involved with school, were common risk factors for all of the adverse trajectory groups.

Additionally school factors increased the risk of being in the 'late socioemotional behaviour problems' group, such as any frequency of bullying and not enjoying school. For this group parenting factors were not a statistically significant factor. Ethnicity, increasing deprivation and parenting factors were additional risk factors for the 'early cognitive and socioemotional problems' group and whilst maternal mental health was a risk factor it was lower than for the other two adverse development groups. All non-white ethnicities, all quintiles of deprivation (compared to the least deprived quintile), parenting factors such as being read to less than several times a week (compared to every day) and not regularly visiting the library with the child increased the risk of being in this group. For the 'persistent problems' group, additional to the common risk factors were; school factors such as any frequency of bullying, and not enjoying school, and parenting factors such as reduced frequency of reading with child and not visiting library with child.

Table 2: Univariate and Multivariable Multinomial Regression Analysis – predictors of multi-trajectory development groups in the Millennium Cohort Study

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				**Multivariable Analyses *** Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Late SEB Problems**	**Early COG and SEB Problems**	**Persistent COG and SEB Problems**	**No Problems**	**Late SEB Problems**	**Early COG and SEB Problems**	**Persistent COG and SEB Problems**	**No Problems**
Sex								
Female	-	-	-	-	-	-	-	-
Male	1.32 (1.17,1.49)	1.52 (1.33,1.73)	2.16 (1.80,2.58)	Ref	1.26 (1.07,1.49)	1.59 (1.25,2.02)	2.05 (1.53,2.75)	Ref
Country								
England	-	-	-	-				-
Wales	0.94 (0.78,1.12)	0.63 (0.51,0.78)	0.98 (0.77,1.26)	Ref	0.93 (0.74,1.17)	1.59 (1.15,2.20)	0.88 (0.59,1.32)	Ref
Scotland	0.77 (0.63,0.95)	0.42 (0.32,0.55)	0.55 (0.29,0.77)	Ref	0.95 (0.72,1.24)	1.44 (0.93,2.24)	0.83 (0.47,1.46)	Ref
N.Ireland	0.80 (0.64,0.99)	0.49 (0.37,0.65)	0.83 (0.62,1.13)	Ref	0.71 (0.53,0.97)	1.28 (0.84,1.98)	1.18 (0.74,1.88)	Ref
Ethnicity								
White	-	-	-	-				-
Mixed	1.24 (0.94,1.64)	2.20 (1.60,3.04)	1.41 (0.95,2.09)	Ref	1.05 (0.72,1.54)	1.93 (1.15,3.22)	1.14 (0.60,2.19)	Ref
Indian	0.81 (0.5,1.26)	4.68 (3.42,6.42)	0.88 (0.46,1.67)	Ref	0.86 (0.47,1.60)	2.45 (1.20,4.98)	0.86 (0.29,2.50)	Ref
Pakistani	1.18 (0.85,1.64)	13.97 (11.37,17.16)	2.35 (1.63,3.39)	Ref	0.58 (0.31,1.12)	9.14 (5.95,14.04)	1.51 (0.73,3.10)	Ref
Bangladeshi	0.96 (0.57,1.61)	13.53 (10.20,17.93)	0.85 (0.37, 1.96)	Ref	0.48 (0.11,2.07)	12.03 (5.63,25.72)	1.44 (0.32,6.63)	Ref
Black Caribbean	1.87 (1.10.3.20)	5.21 (3.14, 8.63)	1.32 (0.53,3.29)	Ref	1.38 (0.65,2.94)	3.42 (1.43,8.16)	1.29 (0.37,4.45)	Ref
Black African	0.31 (0.14,0.70)	5.80 (4.13, 8.15)	0.49 (0.18,1.3)	Ref	0.60 (0.23,1.53)	3.08 (1.36,6.98)	0.36 (0.05,2.71)	Ref
Other	1.54 (1.05,2.27)	9.65 (7.29, 12.79)	2.65 (1.69,4.15)	Ref	1.73 (0.94,3.17)	6.45 (3.62,11.47)	2.93 (1.31,6.56)	Ref
Maternal Education								
Dip/Degree	-	-	-	-	-	-	-	-
A-Levels	1.39 (1.08,1.79)	3.41 (2.33,4.99)	1.95 (1.18,3.23)	Ref	1.36 (1.00,1.83)	2.47 (1.45,4.22)	1.44 (0.67,3.12)	Ref

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				Multivariable Analyses * Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Late SEB Problems**	**Early COG and SEB Problems**	**Persistent COG and SEB Problems**	**No Problems**	**Late SEB Problems**	**Early COG and SEB Problems**	**Persistent COG and SEB Problems**	**No Problems**
GCSE A-C	1.80 (1.51,2.14)	4.21 (3.11,5.71)	4.05 (2.85,5.74)	Ref	1.53 (1.23,1.89)	2.60 (1.72,3.94)	3.14 (1.91,5.15)	Ref
GCSE D-G/other	2.64 (2.14,3.25)	10.28 (7.50,14.08)	8.32 (5.75,12.04)	Ref	2.02 (1.53, 2.66)	5.21 (3.33,8.16)	5.36 (3.11,9.26)	Ref
None	3.18 (2.61,3.88)	22.76 (16.94,30.57)	13.39 (9.44,18.99)	Ref	2.58 (1.94,3.43)	7.66 (4.93,11.91)	7.48 (4.34,12.88)	Ref
IMD Quintile of Deprivation								
Q5 (Least)	-	-	-	-	-	-	-	-
Q4	1.14 (0.88,1.46)	2.59 (1.66,4.03)	1.29 (0.82,2.04)	Ref	1.01 (0.75,1.37)	2.76 (1.41,5.42)	0.82 (0.44,1.55)	Ref
Q3	1.39 (1.10,1.76)	3.44 (2.26,5.23)	1.76 (1.16,2.67)	Ref	1.10 (0.83,1.46)	2.99 (1.57,5.69)	0.90 (0.51,1.59)	Ref
Q2	1.80 (1.45,2,24)	5.27 (3.54,7.85)	3.18 (2.18,4.61)	Ref	1.39 (1.06,1.83)	3.25 (1.73,6.09)	1.25 (0.74,2.12)	Ref
Q1 (Most)	2.29 (1.87,2.83)	14.62 (10.01,21.36)	5.23 (3.66,7.47)	Ref	1.53 (1.16,2.01)	4.44 (2.39,8.25)	1.72 (1.03,2.86)	Ref
Maternal Mental Health at Baseline								
No Psyc.Distress	-	-		-	-	-	-	-
Mod/High Psyc.Distress	2.42 (2.11,2.77)	1.90 (1.59,2.27)	3.70 (3.02,4.55)		2.22 (1.88,2.61)	1.50 (1.81,1.90)	2.99 (2.25,3.98)	
SCHOOL ENVIRONMENT								
Bullied (Age 7)								
Never	-	-	-	-	-	-	-	-
Sometimes	1.34 (1.16,1.54)	1.23 (1.04,1.44)	1.79 (1.42,2.27)	Ref	1.36 (1.15,1.62)	1.20 (0.93,1.55)	1.65 (1.21,2.27)	Ref
All the time	2.97 (2.41,3.66)	2.87 (2.28,3.63)	5.99 (4.53,7.95)	Ref	2.35 (1.82,3.04)	2.25 (1.58,3.20)	3.78 (2.56,5.58)	Ref
Enjoys School (Age 7)								
Al lot	-	-	-	-	-	-	-	-
A bit	1.01 (0.86,1.17)	0.69 (0.58,0.83)	0.88 (0.68,1.12)	Ref	1.15 (0.96,1.39)	0.67 (0.50,0.89)	0.96 (0.69,1.34)	Ref
Don't enjoy	1.62 (1.36,1.94)	1.02 (0.82,1.26)	2.11 (1.65,2.71)	Ref	1.36 (1.09,1.70)	1.23 (0.91,1.69)	1.40 (0.98,2.01)	Ref
Parental Involvement with school (Age 7)								
Involved	-	-	-	-	-	-	-	-

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				Multivariable Analyses * Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Late SEB Problems**	**Early COG and SEB Problems**	**Persistent COG and SEB Problems**	**No Problems**	**Late SEB Problems**	**Early COG and SEB Problems**	**Persistent COG and SEB Problems**	**No Problems**
Not Involved	1.63 (1.44,1.86)	2.90 (2.50,3.37)	2.53 (2.09,3.06)	Ref	1.33 (1.12,1.56)	1.46 (1.14,1.86)	1.63 (1.22,2.18)	Ref
PARENTING								
Reads to Child (Age 5)								
Every Day	-	-	-	-	-	-	-	-
Several /week	1.14 (0.98,1.32)	1.28 (1.09,1.50)	1.09 (0.87,1.37)	Ref	1.11 (0.93,1.33)	1.27 (0.97,1.66)	1.22 (0.88,1.70)	Ref
Less than several /week	1.68 (1.38,2.04)	2.83 (2.33,3.42)	2.54 (1.96,3.29)	Ref	1.25 (0.97,1.63)	1.66 (1.18,2.33)	1.65 (1.11,2.45)	Ref
Visits Library (Age 5)								
Regularly	-	-	-	-	-	-	-	-
Not Reg.	1.13 (0.99,1.29)	1.68 (1.44,1.96)	1.95 (1.57,2.41)	Ref	0.92 (0.77,1.09)	1.47 (1.12,1.93)	1.40 (1.01,1.95)	Ref
Plays Games with Child (Age 5)								
Regularly	-	-	-	-	-	-	-	-
Not Reg.	1.23 (1.05,1.47)	2.13 (1.81,2.50)	1.79 (1.44,2.24)	Ref	1.04 (0.83,1.31)	0.98 (0.72,1.34)	1.22 (0.85,1.74)	Ref

Note: Model details: BIC 8943.63, AIC: 8322.76 and VIF 1.2 Note: COG = Cognitive, SEB = Socioemotional behaviour

Analysis Part III – Logistic Regression

Association between Development Trajectories (exposure) and Child Health Outcomes

Results for the associations between the development groups and weight and mental health outcomes at age 14 and 17 years are shown in table 3. All of the adverse development groups were associated with overweight or obesity at age 14 and 17 years, compared to the 'no problems' group, in the crude model (model 1). The associations remain (slightly attenuated) in the adjusted model (model 2) apart from the 'early cognitive and socioemotional problems' group, thereby leaving 15% of the study population (the 'late socioemotional behaviour problems' and 'persistent problems' group) with increased odds of overweight or obesity . For both groups, the odds increased from age 14 to 17 years. For example, in the late onset trajectory group the odds (adjusted OR) of overweight or obesity at age 14 were 1.50 (1.24, 1.81) and increased to 1.62 (1.32, 2.00) by age 17 years. For the 'persistent problems' group the odds were, 1.41 (1.04, 1.91), and increased to 1.51 (1.07, 2.14) by age 17 years.

In relation to mental ill health outcomes we observed similar patterns with the 'late socioemotional behaviour problems' and 'persistent problem' groups having increased odds of mental ill health at ages 14 and 17 years, but not the 'early cognitive and socioemotional problems' group. The late and persistent problems group had over twice the odds of mental ill health in adolescence compared to the 'no problems' group. Unlike weight, the odds of the association reduced slightly from age 14 to 17 years for both groups.

Table 3: Associations of predicted multi development trajectory groups and child health outcomes at age 14 and 17 years in the UK Millennium Cohort Study

Odds Ratio	Model*	No Problems	Late SEB Problems	Early COG and SEB Problems	Persistent COG and SEB Problems
Age 14 years Overweight or Obese	1	Ref.	1.56 (1.30,1.87)	1.38 (1.12,1.70)	1.63 (1.27,2.09)
	2	Ref.	1.50 (1.24,1.81)	0.92 (0.67,1.27)	1.41 (1.04,1.91)
Age 17 years Overweight or Obese	1	Ref.	1.64 (1.36,1.97)	1.36 (1.10,1.69)	1.41 (1.05,1.88)
	2	Ref.	1.62 (1.32,2.00)	0.94 (0.67,1.32)	1.51 (1.07,2.14)
Age 14 years Mental ill health	1	Ref.	2.28 (1.89,2.74)	0.55 (0.41,0.75)	2.33 (1.74,3.11)
	2	Ref.	2.51 (2.03,3.10)	0.89 (0.58,1.35)	3.01 (2.10,3.30)
Age 17 years Mental Ill health	1	Ref.	2.03 (1.63,2.52)	0.92 (0.70,1.19)	1.82 (1.32,2.51)
	2	Ref.	2.13 (1.62,2.80)	1.17 (0.78,1.78)	2.24 (1.55,3.23)

*Model 1: Crude model; Model 2: adjusted for confounders (child sex, Child ethnicity, MMH and maternal education)
Note: COG = Cognitive, SEB = Socioemotional behaviour

Discussion

Using the MCS, a large nationally representative UK cohort, we have shown that it is possible to identify characteristic trajectories of children's socioemotional and cognitive development concurrently, which is a novel contribution to this field. One in 4 children (23.5%) were in an adverse development trajectory with problems in either or both aspects of development during childhood. These trajectories were 'late socioemotional problems', 'early cognitive and socioemotional problems' and 'persistent cognitive and socioemotional problems'. The common risk factors for the adverse trajectories were socioeconomic (maternal education, maternal mental health and the most deprived quintile of deprivation), demographic (male sex) and school factors (bullying and low parental involvement). Compared to those with no problems, the late and persistent problems trajectories had increased odds of overweight or obesity and mental ill health at age 14 and 17 years, whereas those with early problems did not.

Socioemotional development during childhood appears to be the main driver of adolescent health rather than cognitive development, as indicated by our finding that the trajectory groups with increased odds of overweight and mental ill health in adolescence were those with socioemotional behaviour problems with or without cognitive problems. This is coherent with, and builds upon, other research which highlights that socioemotional development in early childhood is strongly associated with adolescent health whilst cognitive development has weaker associations (234). We show that the persistence of or emergence of socioemotional problems during childhood, even in the absence of any cognitive problems, has an adverse impact on adolescent health. Further research is needed to unpick the interactions between these aspects of development over time. Our suggestion that socioemotional behaviour and cognitive development interact over time to affect health, akin to the evidence for their effect on attainment (81, 238) is not fully supported by the analysis. Further research would help to ascertain how one aspect of development affects or informs the other, the main direction of effect and the impact that has on health.

The trajectories of development that we have identified show that the timing of emergence or resolution of developmental problems has implications for health in adolescence. The early problems trajectory (8.6%) in which socioemotional problems resolved and cognitive problems reduced, by age seven, was not associated with adverse health outcomes. This concurs with other research around the importance of acting early to optimise development (177). It suggests that enhanced support to children who start school (perhaps identifiable as not 'school ready'), to improve their socioemotional and cognitive development, may be beneficial for their weight and mental health in adolescence. The group of children who develop socioemotional behaviour problems in later childhood with no co-emergence of cognitive problems is an important group to be alert to because of their increased risk of overweight and mental ill health.

For the trajectory groups associated with adverse health the strength of the relationship between trajectory of development and weight increased from age 14 to 17 years but for mental health the strength of the relationship reduced. This suggests that weight problems are rooted in childhood and mental ill health more amenable to interventions in adolescence. This may reflect the strong relationship between weight and regulation behaviours (as captured in socioemotional behaviours) (225) with unresolved regulation problems in childhood (which may stem from the familial and wider environments) having lasting effects on weight (251). Whereas mental ill health may be affected by more external factors throughout adolescence (252). This finding could have important implications for the timing of interventions and warrants further research to integrate developmental trajectories into the multitude of risk factors for overweight and mental ill health throughout childhood and adolescence.

The adverse development trajectories were socioeconomically patterned in relation to neighbourhood deprivation, maternal education and maternal mental health. This concurs with much research on the negative impact of adverse socioeconomic circumstances on child health and development (235). Specifically, minority ethnicity (particularly Bangladeshi and Pakistani children) and/or living in more deprived areas were predictive of early development problems which again is perhaps suggestive of socioeconomic conditions and disadvantages experienced by particular children and their families (253). School and parental factors were less strongly associated with the adverse trajectories and this may have been because the measures used were simply markers of school and parental factors during the trajectory period. Nonetheless our findings suggest that school environments which tackle bullying, involve parents and increase the enjoyment of pupils may help to limit the development of socioemotional behaviour problems in late childhood. For those with 'persistent problems' our findings build on the evidence that school factors together with parenting factors such as encouraging reading with children are beneficial for optimising development (254).

In our introduction we highlighted the crisis in adolescent health and the lack of policy to address it. Drawing on this research we suggest there is value in developing child and adolescent health policies which; continue beyond the early years, are focused, targeted, and realistic about what individual child/family/school interventions can achieve against the backdrop of adverse socioeconomic conditions driving adolescent health inequality. Policy which builds upon and extends 'best start' is needed, as children continue to develop as they age and their trajectory of development matters for later health. Policy to improve adolescent health should prioritise supporting children's socioemotional development. This raises questions for the education sector in terms of further focusing on and resourcing this aspect of development. It also raises questions for the health sector in terms of prevention efforts and identifies a clear area of focus for collaboration with the education sector to improve adolescent health. Policy needs to be targeted and informed by trajectories of development. We suggest that who to target and how to intervene are different in those with early development problems as opposed to those with development problems in later childhood. For example, minority ethnicity and neighbourhood deprivation appear to be important targets in the early years whereas a continued focus on socioeconomic factors such as maternal mental health and maternal education is required throughout the school years. Policy needs to place a strong emphasis on socioeconomic factors which drive adverse development and subsequent health. The effectiveness of parental and school interventions may be limited without much broader structural interventions to improve the socioeconomic context of the child and family.

The strengths and limitations of our study highlight further areas for research. Whilst many studies have analysed socioemotional and cognitive development trajectories separately (79, 80, 82), ours is the first to analyse these aspects of development concurrently. These trajectories can now be tested in further analyses of other population cohorts and perhaps using alternate measures of socioemotional or cognitive development to see if the same trajectories are found. As with any observational study we cannot determine causality of the relationships between risk factors, development trajectory and health as we could not control for unknown confounders. More causally informed analyses are needed to better understand these relationships. Our results are strengthened as we used the most contemporary UK cohort and as such the findings are generalisable to UK policy. The modelling technique allowed for complex longitudinal data to be summarised by grouping individuals together. Whilst reducing data to groups introduces bias, as the groups will not be completely homogenous, this type of modelling enables us to improve our understanding of groups of people over time (247). Our model adequacy results provide reassurance of the model in classifying group membership with a high degree of confidence. Although we used validated measures where possible there could be an element of reporter bias and measurement error and this could have affected our results in either direction. A further limitation was in relation to the measurement of cognitive problems whereby different tests of cognitive ability were used at different ages as determined by the dataset. However the derived cognitive development trajectories reassures us that the trends we found are as expected (236).

Conclusion

In a representative UK cohort, groups of distinct trajectories of cognitive and socioemotional development can be identified. Trajectories of persistent cognitive and socioemotional problems and late onset socioemotional problems are strongly associated with overweight and mental ill health in adolescence, with socioemotional development an important driver of adverse health. Policies to improve adolescent health should emphasise socioemotional development and account for the mix of factors that drive early, late onset and persistent developmental problems during childhood.

Ethics approval and consent to participate

Ethics: Ethical approval for the Millennium Cohort Study was sought from a UK NHS research ethics committee prior to each survey.(255) Written consent was obtained from all participating parents at each survey; MCS1: South West MREC (MREC/01/6/19); MCS2 and MCS3: London MREC (MREC/03/2/022, 05/MRE02/46); MCS4: Yorkshire MREC (07/MRE03/32); MCS5: Yorkshire and The Humber-Leeds East (11/YH/0203); MCS6: London MREC (13/LO/1786), MCS7: REC North East – York (REC ref: 17/NE/0341). This study does not require additional ethical approval.

Contributors

MB identified the topic and led the study design process with contributions from all authors. MB led the statistical analysis (supported by MS, HJ and NA). MB and NA accessed and verified the data reported in the study. All authors have read and approved the final version of the manuscript.

Declaration of Competing Interest

The authors have no conflicts of interest to declare. The research was funded by the National Institute for Health Research (NIHR Doctoral Fellowship, Mrs Michelle Black, NIHR300689). The views expressed are those of the authors and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health and Social Care. DTR is funded by the MRC on a Clinician Scientist Fellowship (MR/P008577/1).

Data Sharing

Data from the Millennium Cohort Study is available via the UK Data Service, found here: https://beta.ukdataservice.ac.uk/datacatalogue/series/series?id=2000031. Further information about the study is found at https://cls.ucl.ac.uk/cls-studies/millennium-cohortstudy. STATA code is available from the author on request.

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Supplementary materials

Supplementary files are available in the appendix. (Appendix 5)

Research in context

We undertook a systematic review of the relationship between child development and adolescent health, searching electronic databases (MEDLINE, PsycINFO, ASSIA and ERIC) for articles published between November 1990 and November 2020. Observational, intervention and review studies reporting a measure of child development and adolescent weight and mental health, were included. Studies were assessed for quality individually and collectively using a comparative rating system. The review highlighted that of all the domains of child development the evidence for associations between socioemotional development on starting school (age 3-7 years) and subsequent weight and mental health in early adolescence is particularly strong. In addition it highlighted some evidence of associations between cognitive development and subsequent internalising behaviours. No studies were found on concurrent development of socioemotional and cognitive trajectories or the association with adolescent health.

Added value of this study

Our study is the first to analyse the co-development of socioemotional and cognitive development and to characterise children into groups, using multi-trajectory analysis on a nationally representative UK cohort. Our results show that trajectories of persistent cognitive and socioemotional problems and late onset socioemotional problems are associated with overweight and mental ill health in adolescence, whilst early problems which are resolving are not. It also highlights that socioemotional development appears to be the main driver of the associations.

Implications of all the available evidence

We suggest there is value in countries developing child and adolescent health strategies and strengthening the evidence base to further explore the relationship between socioemotional and cognitive development in childhood and adolescent health. We infer that policy and action which builds upon and extends 'best start' policies with a focus on socioemotional development is needed across the child life-course and into adolescence, if we are to improve adolescent health and reduce inequalities. Policy should be informed by trajectories of development. For example we suggest that who to target and how to intervene are different in those with early development problems as opposed to persistent problems or those with development problems in later childhood.

5.4. Analyses of single trajectories of development; socioemotional development and cognitive development

In this section I provide detail of the analyses of single trajectories of cognitive and socioemotional development which informed the paper on multi-trajectories of development.

Introduction

Children who are not school ready or have poor cognitive and non-cognitive skills upon starting school may experience worse academic, mental and physical health outcomes in adolescence (24, 73, 74). The systematic review element of this PhD has shown that the particular aspects of child development, at school starting age, that are most associated with adolescent health are socioemotional and cognitive development (234). The review highlighted strong evidence of an association between adverse socioemotional development (age 3-7 years) and subsequent overweight and mental ill health in early adolescence and slightly weaker evidence of associations between adverse cognitive development and subsequent internalising behaviours (234). Specifically both externalising and poor emotional wellbeing at school entry were strongly associated with internalising behaviours in early adolescence, with poor emotional wellbeing also strongly associated with overweight.

The abundance of literature on the impact of the early years of childhood on later academic and health outcomes has driven a strong policy focus on giving children the best start in life, as this is a critical point in the life course. However, there are gaps in our understanding of the epidemiology and impact of mid-childhood development. Specifically in terms of understanding whether there are certain patterns or trajectories of development, the characteristics (in terms of demographics and socioeconomic circumstances) of children following similar trajectories, and associations with adolescent health, in UK cohorts.

Taking socioemotional development first, studies in the UK and Australia have found that risk factors such as SES, child sex and maternal mental health are associated with trajectories of socioemotional behaviour during childhood (79, 80). Additionally, there is evidence that trajectories of some aspects of socioemotional development are associated with later health. For example, the US studies show that trajectories of high internalising symptoms between the ages of 2 and 10 years are associated with self-reported depression (256) and peer problems (257) in early adolescence. A Dutch study analysed development trajectories of internalising symptoms from age 1.5 to 10 years and found that trajectories of increasing symptoms and pre-school limited had worse psychosocial and school outcomes (258). In relation to socioemotional development and obesity, there is evidence that

emotional problems and obesity in childhood, tend to develop together, with a bi-directional relationship between the ages of 7 to 14 years (225). The many aspects of socioemotional development are dynamic with complex interactions between them (259). However there are common socioemotional causative factors underlying most common mental health disorders (80). This lends support for taking a holistic approach and using an overall measure such as socioemotional behaviour in identifying cohorts of children at risk of developing mental ill health and related diseases with psychological risk factors such as obesity.

In relation to cognitive development, knowledge of the epidemiology of children following similar cognitive developmental trajectories in mid-childhood and their associations with subsequent adolescent health in UK cohorts is limited. However the impact of disadvantage is clear. Children living in disadvantaged circumstances are less likely to move up cognitive ability rankings (237) compared to more affluent peers. Lower cognitive ability in childhood is associated with lower academic achievements (260), worse self-reported health and unhealthy weight in adulthood (261).

There is scope for research and action on child health and development to extend and build on the first 1,000 days and 'school readiness' to the first 8,000 days in order to support development throughout childhood and adolescence (4). Research is needed which furthers our understanding of the health impact of trajectories of development, in the context of socioeconomic circumstances and other child factors, in order to inform adolescent health policy. Therefore **this research aims** to: determine developmental trajectories of socioemotional behaviour and cognitive development, individually, in mid-childhood; describe the trajectories by demographic, socioeconomic, parental and school factors; and quantify the associations between the developmental trajectories and adolescent health, in a UK cohort.

Method

The same study design, population and measures were used as described in paper 3. Additional information, where relevant is provided here.

Study Design and Population

Longitudinal analysis of the Millennium Cohort Study (MCS), a nationally representative UK cohort. The MCS cohort was derived from all children in the UK who turned 9 months and were in receipt of child benefit (which at the time was a universal provision) in a sixteen-month survey window from September 2000. The cohort was stratified at area level (wards) into three strata; ethnic minority (wards where at least 30% of the population were ethnic minorities according to 1991 census), disadvantage (poorest 25% of wards according to the child poverty index for England and Wales) and

advantage (wards other than the previous two). In Wales, Scotland and Northern Ireland there was no ethnic minority stratum because of smaller population sizes of ethnic minorities (<1% of the population).

The cohort was clustered by ward characteristics, with similar wards clustered together and all children within that ward included if selected in the sample, rather than sub-sampling children across wards. This was to keep field costs down and to bring in the broader socioeconomic context into the analysis as represented by the place in which children live. The disadvantage of clustering is that it is less precise than simple random stratification because independence is lost.

The sample was then randomly selected from the stratified cluster population, but with over-representation for ethnic minorities and disadvantaged children. This resulted in a disproportionately stratified cluster sample, which means for example that children born in disadvantaged areas had a greater chance of being selected than children in advantaged areas. Weighting was used to account for differential representation as a result of the unequal selection probability. The weight represents the link between the sample and the population.

Measures

Trajectory of Socioemotional development – as described in paper 3 (Page 112: Measures, Development Trajectories).

Trajectory of Cognitive development as described in paper 3 (Page 112: Measures, Development Trajectories). Specifically the test(s) taken at each age, together with the ability that test is measuring, is illustrated in table 4.

Table 4: Cognitive assessments used at each MCS wave, ages 3-14 years

Cognitive Test	Ability measured	MCS2 (Age 3)	MCS3 (Age 5)	MCS4 (Age7)	MCS5 (age 11)	MCS6 (Age 14)
BAS Naming Vocabulary	Expressive verbal ability	X	X			
BAS Word Reading	Reading ability			X		
BAS Verbal Similarities	Verbal reasoning and verbal knowledge				X	
Word Activity Test (subset of the vocab assessment in the 1970 British cohort study survey)	Verbal vocabulary					X

Note: BAS is the British Ability Scales Test

Adolescent health outcomes –as described in paper 3 (Page 113: Measures, Development Trajectories).

Predictors of developmental trajectories – as described in paper 3 (Page 113: Measures, Development Trajectories).

Co-variates

Co-variates used in the logistic regression model (for the associations between trajectory of socioemotional development and health) were child sex, maternal education (diploma/degree plus, A-Levels, GCSE A-C, GCSE D-G/other or none) and maternal mental health (no psychological distress or moderate/high psychological distress at baseline), as guided by the multi-nominal regression analysis of predictors of the trajectory groups.

Co-variates used in the logistic regression model (for the associations between trajectory of cognitive development and health) were child sex, child ethnicity (white, mixed, Indian, Pakistani, Bangladeshi, Black Caribbean, Black African or other ethnic group and maternal education (diploma/degree plus, A-Levels, GCSE A-C, GCSE D-G/other or none), as guided by the multi-nominal regression analysis of predictors of the trajectory groups.

Statistical Analysis

The cross-sectional prevalence of the trajectories of development of socioemotional behaviour problems and cognitive problems at ages 3, 5, 7 11 and 14 years were estimated. Group Based Trajectory Modelling (GBTM) was used to determine longitudinal trajectory groups for the development trajectories from age 3-14 years. The decision on the number of groups which best represented heterogeneity in the development trajectories was based on model fit, model adequacy and parsimony. This was done by fitting between one and five trajectory groups using logistic regressions with quadratic and cubic polynomial functions of age (see appendix 6 for more details on model specification). Model fit was determined using conditional fit statistics, Bayesian Information Criteria (BIC) and Akaike Information Criterion (AIC), entropy and the size of the smallest group. As suggested by Nagin (248) model adequacy was further tested by determining the accuracy of individual assignment to trajectories using the average posterior probability with a minimum threshold of 0.7 and odds of correct classification based on the posterior probabilities of group membership greater than 5. Analysis was undertaken using STATA and STATA Traj plug in for GBTM (249).

To determine predictors of the trajectory groups, I used univariate and multivariable multinomial regression analysis to assess the associations between socio-demographic, parent and school factors and the derived trajectories. Relative Risk Ratios and 95% confidence intervals were calculated.

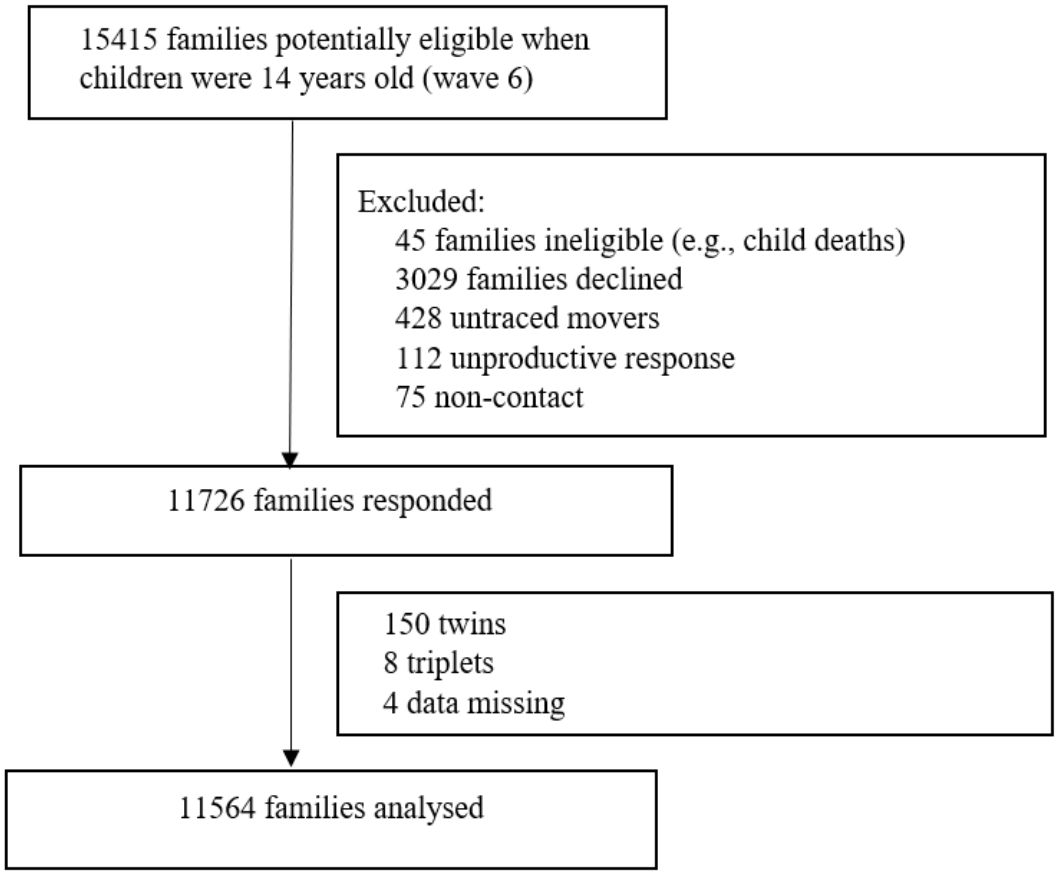
Finally, I used logistic regression to assess associations between trajectory groups and adolescent health outcomes at age 14 and 17 years. The crude models were adjusted for the main predictors found in the multinomial regression; for the trajectories of socioemotional development these were: child sex, maternal mental health and maternal education; for the trajectories of cognitive development these were child sex, ethnicity and maternal education.

Odds ratios and confidence intervals were calculated. Complete case analysis was used with survey weights used to account for response bias and attrition, using the *svy* command in STATA (29).(250)

Results

When cohort members were aged 14 years there were 15,415 eligible families, from a sample size of 19,243. Of the eligible families 11726 responded (overall response rate of 60.9% and a productive response rate from eligible families of 76.1%). After removing twins and multiple births 11564 cohort members remained for the main analysis, as illustrated in the study flow diagram figure 3.

Figure 3: Study Flow Diagram



Prevalence of socioemotional behaviour problems and cognitive problems

The weighted cross-sectional prevalence of socioemotional behaviour problems and the prevalence of cognitive problems at ages 3, 5, 7, 11 and 14 years is illustrated in table 5. Prevalence of socioemotional behaviour problems reduced from age 3 to age 5 and then increased to age 14 years. Prevalence of cognitive problems is relatively consistent other than a slight increase at age 7 years.

Table 5: Cross-sectional Prevalence of socioemotional behaviour problems and cognitive problems in the UK millennium cohort study, weighted sample

Development	**Age 3 years** n=15382 (%)	**Age 5 years** n=15042 (%)	**Age 7 years** n=13682 (%)	**Age 11 years** n=13112 (%)	**Age 14 years** n=11564 (%)
Socioemotional Behaviour Problems	9.9 (9.4-10.4)	5.6 (5.2,5.9)	7.6 (7.2-8.1)	10.0 (9.5,10.5)	12.1 (11.5,12.7)
Cognitive Problems	7.2 (6.8-7.6)	7.8 (7.3,8.2)	9.1 (8.6,9.6)	7.6 (7.2,8.1)	7.3 (6.8,7.7)

Note: 95% Confidence Interval, Clopper-Pearson. Weighting variables: pttype2 (strata variable), sptn00 (Primary Sampling Unit: clustered at ward level), nh2 (finite population correction factor), survey weight ((bovwt2 (age 3), (covwt2 (age 5), (dovwt2 (age 7), (eovwt2 (age 11), (fovwt2 (age 14))

Analysis of Trajectories of Development

Part I – Group Based Trajectory Modelling

Trajectories of Socioemotional Development

The trajectory model with the best fit for the socioemotional development trajectories had four groups (figure 4). These four groups, based on predicted probabilities, were labelled as: 'no problems' (82.6%); 'late socioemotional problems' (6.8%); 'early socioemotional problems' (6.5%); and 'persistent socioemotional problems' (4.1%). Almost one in six children (17.4%) were in an adverse trajectory group. Population estimates for each group, based on average probabilities, are available in appendix 6, table b.

Trajectories of Cognitive Development

The trajectory model with the best fit for the cognitive development trajectories also had four groups (figure 5). These groups were labelled as: 'no problems' (80.1%); 'late cognitive problems' (9.4%); 'early cognitive problems' (6.2%); and 'persistent cognitive problems' (4.3%). Almost one in five children (20.9%) were in an adverse trajectory group. The early problems group appear to illustrate a group for which the early years of schooling reduce cognitive problems significantly. Population estimates for each group, based on average probabilities, are available in appendix 6, table e.

Description of Trajectories

Table 6 and 7 illustrate the characteristics of the cohort by trajectories of socioemotional problems and trajectories of cognitive problems respectively. For both aspects of development the vast majority of the population are resident in England and of white ethnicity, with slightly more males than females. Notably the prevalence of children in each of the adverse trajectory groups decreases as socioeconomic factors of maternal education and income level increase and deprivation decreases. There is variation between groups in relation to all of the characteristics and this difference is statistically significant.

Figure 4: Predicted Probability of Socioemotional Behaviour Problems by age and trajectory group from age 3 to 14 years, UK MCS

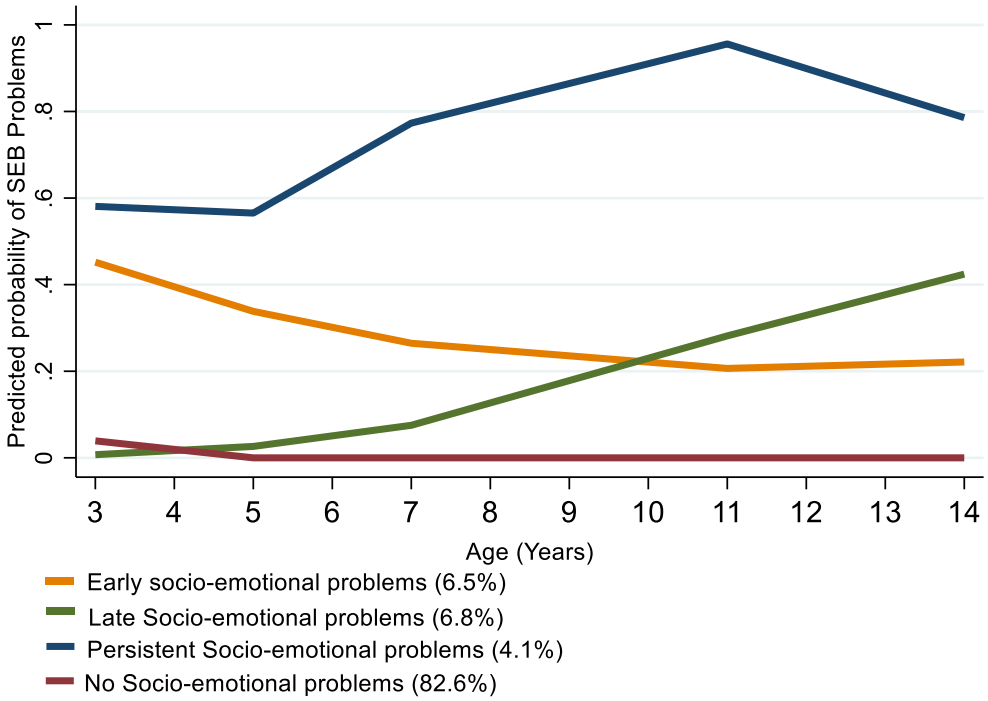


Figure 5: Predicted Probability of Cognitive Problems by age and trajectory group

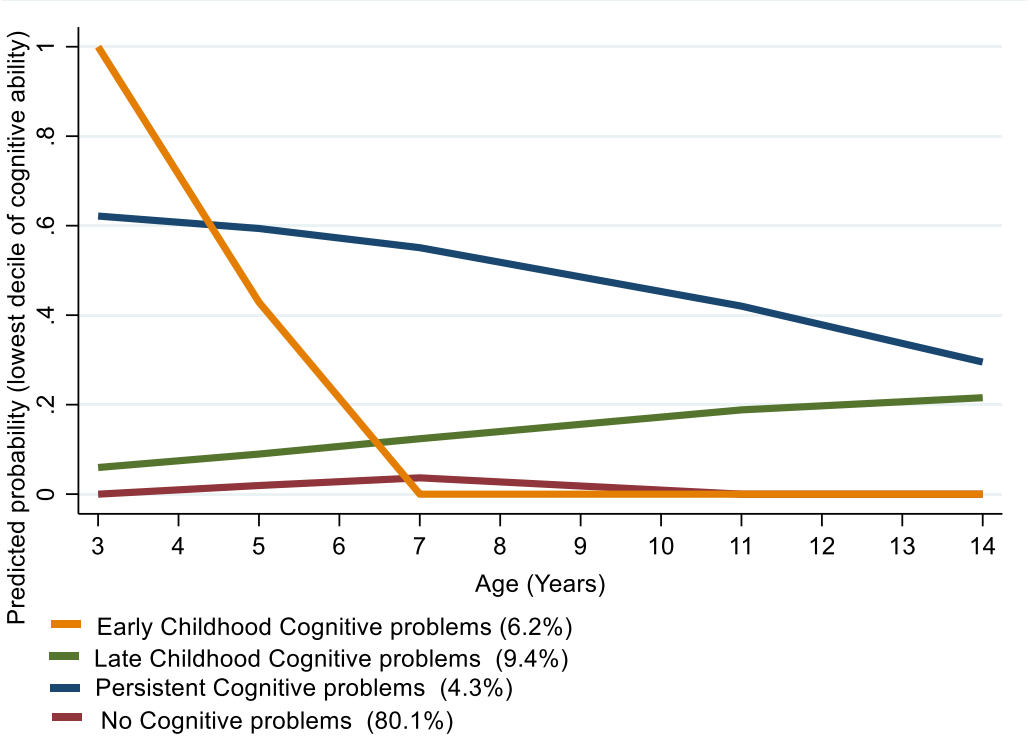


Table 6: Description of Sample (observed data, weighted sample) – Trajectories of Socioemotional Development

	Trajectory Groups n (%)				p	Total Sample n (%)
	Early SEB Problems n = 754 (6.5)	Late SEB Problems n = 789 (6.8)	Persistent SEB Problems n = 477 (4.1)	No SEB Problems n =9544 (82.6)		n = 11564
Country						
England	543 (86.1)	557 (84.7)	316 (83.4)	6216 (81.8)	**<0.001**	7632 (82.5)
Wales	88 (4.0)	110 (4.8)	71 (4.7)	1330 (5.1)		1599 (5.0)
Scotland	59 (6.1)	68 (7.3)	41 (7.2)	1068 (8.8)		1236 (8.4)
Northern Ireland	64 (3.8)	54 (3.1)	49 (4.8)	930 (4.3)		1097 (4.2)
Gender						
Male	451 (61.0)	412 (54.8)	323 (70.6)	4618 (50.2)	**<0.001**	5804 (52.5)
Female	303 (39.0)	377 (45.2)	154 (29.4)	4926 (49.8)		5760 (47.5)
Ethnicity						
White	490 (67.3)	567 (72.0)	342 (72.0)	7441 (78.5)	**<0.001**	8840 (76.7)
Mixed	36 (4.5)	40 (5.8)	27 (6.2)	424 (5.1)		527 (5.2)
Indian	20 (2.9)	16 (1.4)	8 (1.2)	258 (2.2)		302 (2.1)
Pakistani	79 (7.1)	43 (3.7)	21 (1.9)	428 (3.1)		571 (3.4)
Bangladeshi	26 (1.8)	20 (1.3)	2 (0.2)	203 (1.3)		251 (1.3)
Black Caribbean	12 (2.0)	12 (2.4)	5 (0.7)	85 (1.2)		114 (1.3)
Black African	12 (2.7)	7 (0.9)	1 (0.1)	193 (2.5)		213 (2.2)
Other Ethnic Gp	36 (4.6)	25 (3.4)	18 (4.2)	226 (2.5)		305 (2.8)
Missing	43 (7.1)	59 (9.2)	53 (13.6)	286 (3.7)		441 (4.9)
Maternal Education						
Degree Plus	55 (4.0)	69 (6.6)	26 (3.0)	1997 (15.4)	**<0.001**	2147 (13.1)
Diploma	43 (3.8)	57 (5.0)	25 (3.5)	901 (7.8)		1026 (7.0)
A-Levels	44 (4.3)	73 (7.6)	24 (3.1)	957 (8.3)		1098 (7.7)
GCSE A-C	195 (22.4)	250 (30.8)	161 (30.7)	3013 (33.3)		3619 (32.1)
GCSE D-G	102 (16.2)	102 (14.7)	80 (18.9)	825 (10.8)		1109 (11.9)
Other Qual	21 (2.0)	29 (3.3)	10 (1.8)	256 (2.6)		316 (2.6)
No Qual	248 (40.2)	175 (26.6)	125 (31.8)	1261 (17.5)		1809 (20.8)
Missing	46 (7.10	34 (5.5)	26 (7.1)	334 (4.4)		440 (4.8)
Quintile of Deprivation						
Quintile 1 (Most Deprived)	345 (42.6)	276 (32.7)	191(36.2)	2490 (24.7)	**<0.001**	3302 (27.4)
Quintile 2	165 (21.9)	189 (23.2)	115 (22.7)	1999 (19.4)		2468 (20.1)
Quintile 3	87 (14.6)	125 (17.4)	62 (14.2)	1661 (19.1)		1935 (18.4)
Quintile 4	61 (7.6)	80 (11.3)	46 (11.6)	1458 (16.9)		1645 (15.4)
Quintile 5 (Least Deprived)	51 (6.2)	90 (10.8)	37 (8.1)	1620 (15.7)		1798 (14.2)
Missing	45 (7.0)	29 (4.5)	26 (7.1)	316 (4.2)		416 (4.6)
Income at baseline						
Inc Quint 1 (Lowest)	271 (42.8)	243 (36.0)	184 (41.6)	1651 (21.0)	**<0.001**	2349 (25.0)
Inc Quint 2	200 (25.7)	203 (25.0)	124 (27.4)	1824 (19.6)		2351 (21.0)
Inc Quint 3	101 (11.6)	116 (13.1)	72 (12.7)	1850 (19.8)		2139 (18.3)
Inc Quint 4	83 (8.1)	115 (12.8)	40 (7.0)	1955 (17.8)		2193 (16.1)
Inc Quint 5 (Highest)	53 (4.7)	79 (7.8)	31 (4.2)	1922 (17.3)		2085 (14.8)
Missing	46 (7.1)	33 (5.3)	26 (7.1)	342 (4.4)		447 (4.8)
Maternal Mental health (at baseline)						
No Psyc. Distress	235 (29.4)	350 (43.2)	144 (29.8)	5594 (57.5)	**<0.001**	6323 (52.7)
Mod/High Psyc. Distress	322 (42.4)	253 (33.2)	225 (44.6)	2317 (25.1)		3117 (28.2)
Missing	197 (28.2)	186 (23.6)	108 (25.6)	1633 (17.4)		2124 (19.2)
School Environment: (Age 7)						
Bullying						
All of the time	105 (13.8)	104 (12.9)	77 (14.5)	572 (6.0)	**<0.001**	858 (7.6)
Some of the time	256 (32.2)	256 (28.3)	147 (27.2)	3258 (32.0)		3917 (331.5)
Never	254 (31.8)	273 (32.4)	112 (21.3)	4492 (45.0)		5131 (41.6)
Missing	139 (22.1)	156 (26.3)	141 (37.0)	1222 (17.0)		1658 (19.2)

Enjoys school						
Enjoy a lot	301 (36.4)	340 (38.0)	151 (30.2)	4473 (44.7)	**<0.001**	5265 (42.8)
Enjoy a bit	185 (24.8)	174 (19.7)	96 (14.8)	2626 (25.7)		3081 (24.6)
Don't enjoy	129 (17.1)	120 (15.7)	89 (18.1)	1182 (12.1)		1520 (13.1)
Missing	139 (21.7)	155 (26.6)	141 (36.8)	1263 (17.5)		1698 (19.6)
Parental involvement						
Involved	290 (34.2)	296 (32.7)	159 (25.5)	5032 (48.3)	**<0.001**	5777 (44.7)
Not Involved	402 (53.4)	384 (46.2)	249 (51.3)	3754 (39.4)		4789 (41.7)
Missing	62 (12.4)	109 (21.1)	69 (23.2)	758 (12.3)		998 (13.6)
Parenting: (Age 5)						
Reads with child						
Every day	340 (41.2)	388 (46.9)	193 (39.5)	5279 (53.8)	**<0.001**	6200 (51.5)
Several times a week	198 (30.4)	217 (29.0)	105 (18.7)	2592 (27.5)		3112 (27.4)
Less than once or twice a week	123 (16.0)	90 (11.3)	73 (17.0)	874 (9.0)		1160 (10.2)
Missing	93 (12.4)	94 (12.9)	106 (24.7)	799 (9.7)		1092 (11.0)
Visits Library						
Regularly	203 (23.3)	247 (30.3)	114 (21.3)	3297 (31.4)	**<0.001**	3861 (30.1)
Not Regularly	494 (68.0)	483 (61.4)	308 (63.9)	5706 (61.1)		6991 (61.8)
Missing	57 (8.7)	59 (8.3)	55 (14.9)	541 (7.5)		712 (8.1)
Plays games with child						
Regularly	550 (68.7)	598 (75.2)	327 (63.6)	7666 (78.2)	**<0.001**	9141 (76.5)
Not Regularly	147 (22.6)	132 (16.5)	94 (21.1)	1336 (14.2)		1709 (15.4)
Missing	57 (8.7)	59 (8.3)	56 (15.3)	542 (7.6)		714 (8.1)

Note: SEB = Socioemotional behaviour

Table 7: Description of Sample (observed data, weighted sample) - Trajectories of Cognitive Development

	Trajectory Groups n (%)				p	Total Sample n (%)
	Early COG Problems n =719 (6.2)	Late COG Problems n = 1084 (9.4)	Persistent COG Problems n = 498 (4.3)	No COG Problems n = 9263 (80.1)		n = 11564
Country						
England	648 (94.4)	688 (80.7)	390 (86.9)	5906 (81.5)	**<0.001**	7632 (82.5)
Wales	29 (1.7)	185 (6.1)	55 (4.5)	1330 (5.2)		1599 (5.0)
Scotland	26 (2.6)	111 (9.4)	25 (5.6)	1074 (8.8)		1236 (8.4)
Northern Ireland	16 (1.3)	100 (3.4)	28 (2.9)	953 (4.5)		1097 (4.2)
Gender						
Male	389 (57.4)	545 (52.5)	305 (65.8)	4565 (51.3)	**<0.001**	5804 (52.5)
Female	330 (42.6)	539 (47.5)	193 (34.2)	4698 (48.7)		5760 (47.5)
Ethnicity						
White	186 (30.6)	800 (74.2)	210 (52.6)	7644(82.0)	**<0.001**	8840 (76.7)
Mixed	24 (3.9)	60 (5.5)	25 (4.6)	418 (5.3)		527 (5.2)
Indian	71 (7.7)	17 (2.5)	20 (3.0)	194 (1.6)		302 (2.1)
Pakistani	187 (18.5)	51 (2.9)	105 (12.4)	228 (1.8)		571 (3.4)
Bangladeshi	90 (7.9)	28 (1.6)	44 (4.6)	89 (0.5)		251 (1.3)
Black Caribbean	6 (1.1)	14 (1.6)	12 (4.2)	82 (1.1)		114 (1.3)
Black African	56 (12.0)	16 (1.4)	10 (1.9)	131 (1.6)		213 (2.2)
Other Ethnic Gp	76 (13.8)	27 (1.8)	32 (8.0)	170 (1.8)		305 (2.8)
Missing	23 (4.5)	71 (8.5)	40 (8.4)	307 (4.3)		441 (4.9)
Maternal Education						
Degree Plus	32 (3.1)	77 (3.7)	11 (1.1)	2027 (15.9)	**<0.001**	2147 (13.1)
Diploma	25 (2.5)	68 (4.2)	16 (2.2)	917 (8.0)		1026 (7.0)
A-Levels	45 (5.0)	65 (4.3)	28 (3.3)	960 (8.6)		1098 (7.7)
GCSE A-C	147 (18.7)	348 (31.7)	107 (20.7)	3017 (33.8)		3619 (32.1)

GCSE D-G	61 (11.1)	179 (18.1)	53 (12.8)	816 (11.1)		1109 (11.9)
Other qualifications	74 (9.1)	22 (1.4)	32 (6.2)	188 (2.0)		316 (2.6)
No qualifications	280 (44.7)	268 (30.3)	219(46.7)	1042 (16.1)		1809 (20.8)
Missing	55 (5.8)	57 (6.2)	32 (6.9)	296 (4.4)		440 (4.8)
Quintile of Deprivation						
Quintile 1 (Most Deprived)	412 (47.9)	404 (36.3)	285 (48.3)	2201 (23.3)	**<0.001**	3302 (27.4)
Quintile 2	131 (20.8)	228 (19.2)	96 (21.0)	2013 (20.1)		2468 (20.1)
Quintile 3	65 (14.0)	172 (17.5)	47 (13.5)	1651 (19.1)		1935 (18.4)
Quintile 4	39 (8.1)	126 (12.6)	23 (7.8)	1457 (16.8)		1645 (15.4)
Quintile 5 (Least Deprived)	19 (3.6)	100 (8.3)	18 (3.2)	1661 (16.4)		1798 (14.2)
Missing	53 (5.6)	54 (6.1)	29 (6.3)	280 (4.2)		416 (4.6)
Income at baseline						
Inc Quint 1 (Lowest)	272 (39.5)	342 (38.3)	224 (49.2)	1511 (20.7)	**<0.001**	2349 (25.0)
Inc Quint 2	226 (30.1)	265 (23.6)	149 (26.9)	1711 (19.5)		2351 (21.0)
Inc Quint 3	79 (13.3)	189 (15.9)	50 (9.8)	1821 (19.5)		2139 (18.3)
Inc Quint 4	42 (5.6)	142 (9.9)	26 (4.2)	1983 (18.4)		2193 (16.1)
Inc Quint 5 (Highest)	44 (5.6)	88 (6.0)	15 (2.5)	1938 (17.5)		2085 (14.8)
Missing	56 (5.8)	58 (6.3)	34 (7.4)	299 (4.4)		447 (4.8)
School Environment: (Age 7)						
Bullying						
All of the time	63 (9.6)	115 (11.1)	72 (15.3)	608 (6.6)	**<0.001**	858 (7.6)
Some of the time	256 (33.2	327 (27.2)	125 (21.5)	3209 (32.5)		3917 (31.5)
Never	262 (34.3)	405 (34.7)	162 (32.9)	4302 (43.7)		5131 (41.6)
Missing	138 (22.9)	237 (27.0)	139 (30.3)	1144 (17.2)		1658 (19.2)
Enjoys school						
Enjoy a lot	362 (48.2)	439 (36.9)	210 (37.9)	4254 (43.4)	**<0.001**	5265 (42.8)
Enjoy a bit	154 (19.6)	216 (18.2)	85 (19.3)	2626 (26.1)		3081 (24.6)
Don't enjoy	58 (7.6)	194 (18.2)	62 (13.1)	1206 (12.8)		1520 (13.1)
Missing	145 (24.6)	235 (26.7)	141 (29.7)	1177 (17.6)		1698 (19.6)
Parental involvement						
Involved	218 (26.7)	422 (35.1)	150 (25.8)	4987 (48.6)	**<0.001**	5777 (44.7)
Not Involved	410 (57.5)	523 (45.2)	296 (61.9)	3560 (38.8)		4789 (41.7)
Missing	91 (15.7)	139 (19.6)	52 (12.3)	716 (12.7)		998 (13.6)
Parenting: Reads with child (Age 5)						
Every day	313 (44.4)	542 (47.7)	207 (39.6)	5138 (53.2)	**<0.001**	6200 (51.1)
Several times a week	211 (30.1)	255 (23.3)	125 (26.4)	2521 (27.8)		3112 (27.4)
Less than once or twice a week	114 (16.0)	140 (12.4)	87 (17.8)	819 (9.0)		1160 (10.2)
Missing	81 (9.5)	147 (16.7)	79 (16.2)	785 (9.9)		1092 (11.0)
Visits Library						
Regularly	194 (21.2)	270 (23.8)	124 (26.1)	3273 (31.9)		3861 (30.1)
Not Regularly	479 (73.8)	713 (63.7)	334 (66.1)	5465 (60.3)	**<0.001**	6991 (61.8)
Missing	46 (5.0)	101 (12.5)	40 (7.8)	525 (7.8)		712 (8.1)
Plays games with child						
Regularly	479 (67.7)	817 (71.9)	326 (65.7)	7519 (78.4)		9141 (76.5)
Not Regularly	194 (27.3)	165 (15.4)	131 (26.4)	1219 (13.8)	**<0.001**	1709 (15.4)
Missing	46 (5.0)	102 (12.7)	41 (7.9)	525 (7.8)		714 (8.1)

Note: COG = Cognitive

Part II – Multinomial Regression

Predictors of Trajectories of Socioemotional Development

Results of the univariate and multivariable multinomial regression model are illustrated in table 8. The income variable was removed from the multi-variable analysis to reduce multi-collinearity. In the multivariable model, compared to the 'no problems' group; socioeconomic factors of maternal education qualifications and poor maternal mental health; and school factors of being bullied, were common risk factors for all of the adverse trajectory groups. Minority ethnicity was not associated with the adverse trajectory groups. Parental factors were only associated with the persistent problems group.

Higher levels of neighbourhood deprivation were only associated with the early problems group and not the persistent and late problems group, unlike indicators of family socioeconomic circumstances (maternal mental health and maternal education) which were associated with all the adverse development trajectories. This may indicate that family socioeconomic factors are a stronger influence on late and persistent socioemotional problems than levels of neighbourhood deprivation.

In addition to the common risk factors, male sex, higher levels of neighbourhood deprivation and school factors of child not enjoying school and parents not involved with school were associated with the early problems group. Additional risk factors for the persistent problems group were male sex, child not enjoying school and the parental factor of low frequency of reading with child. The only additional risk factor for the late problems group was parents not involved with school. It is notable that male sex was not associated with the late problems group.

Table 8: Univariate and Multivariable Multinomial Regression Analysis - predictors of Socioemotional Development groups in the Millennium Cohort Study

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				**Multivariable Analyses *** Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Early SEB**	**Late SEB**	**Persistent SEB**	**NP**	**Early SEB**	**Late SEB**	**Persistent SEB**	**NP**
Sex								
Female	-	-	-	-	-	-	-	-
Male	1.59 (1.36,1.85)	1.17 (1.01,1.35)	2.24 (1.84,2.72)	Ref	1.45 (1.16,1.81)	1.11 (0.90,1.36)	1.86 (1.38,2.51)	Ref
Ethnicity								
White	-	-	-	-				-
Mixed	1.29 (0.91,1.83))	1.24 (0.88,1.73)	1.38 (0.93,2.07)	Ref	1.08 (0.66,1.78)	1.07 (0.67,1.71)	1.36, (0.73,2.52)	Ref
Indian	1.17 (0.74,1.87)	0.81 (0.49,1.36)	0.67 (0.33,1.37)	Ref	1.25 (0.64,2.45)	0.42 (0.15,1.15)	0.96 (0.34,2.75)	Ref
Pakistani	2.80 (2.17,3.62)	1.32 (0.95,1.82)	1.07 (0.68,1.67)	Ref	1.06 (0.62,1.81)	0.45 (0.21,0.99)	1.29 (0.63,2.63)	Ref
Bangladeshi	1.95 (1.28,2.95)	1.29 (0.81,2.06)	0.21 (0.05,0.87)	Ref	1.26 (0.46,3.45)	0.26 (0.03,1.92)	1.18 (0.26,5.23)	Ref

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				Multivariable Analyses * Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Early SEB**	**Late SEB**	**Persistent SEB**	**NP**	**Early SEB**	**Late SEB**	**Persistent SEB**	**NP**
Black Caribbean	2.14 (1.16,3.95)	1.85 (1.01,3.41)	1.28 (0.52, 3.17)	Ref	1.41 (0.57,3.47)	1.16 (0.45,2.99)	1.36 (0.40,4.62)	Ref
Black African	0.94 (0.52,1.70)	0.46 (0.22,1.02)	0.11 (0.02,0.80)	Ref	0.53 (0.16,1.74)	0.73 (0.26,2.6)	-	Ref
Other	2.42 (1.68,3.47)	1.45 (0.95,2.21)	1.73 (1.05,2.83)	Ref	1.47 (0.71,3.08)	2.31 (1.26,4.21)	2.02 (0.84,4.87)	Ref
Maternal Education								
Dip/Degree	-	-	-	-	-	-	-	-
A-Levels	1.36 (0.95,1.9)	1.75 (1.30,2.36)	1.43 (0.87,2.32)	Ref	1.23 (0.78,1.95)	1.64 (1.14,2.37)	1.16 (0.59,2.29)	Ref
GCSE A-C	1.91 (1.49.2.45)	1.91 (1.53,2.38)	3.04 (2.21,4.18)	Ref	1.60 (1.17,2.18)	1.58 (1.20,2.08)	2.35 (1.53,3.61)	Ref
GCSE D-G/other	3.36 (2.56,4.42)	2.78 (2.16,3.59)	4.73 (3.33,6.72)	Ref	2.20 (1.51,3.21)	2.21 (1.57,3.11)	3.12 (1.88,5.17)	Ref
None	5.82 (4.45,7.41)	3.19 (2.52,4.05)	5.63 (4.04,7.85)	Ref	3.69 (2.58,5.27)	2.42 (1.67,3.48)	3.39 (2.02,5.70)	Ref
IMD Quintile of Deprivation								
Q5 (Least)	-	-	-	-	-	-	-	-
Q4	1.33 (0.91,1.94)	0.98 (0.73,1.35)	1.38 (0.89,2.14)	Ref	1.04 (0.66,1.65)	0.81 (0.55,1.19)	1.28 (0.72,2.28)	Ref
Q3	1.66 (1.17,2.37)	1.35 (1.02,1.79)	1.63 (1.08,2.47)	Ref	0.96 (0.62,1.50)	1.08 (0.77,1.53)	1.16 (0.67,2.02)	Ref
Q2	2.62 (1.90, 3.61)	1.70 (1.32,2.21)	2.52 (1.73,3.67)	Ref	1.68 (1.13,2.59)	1.26 (0.91,1.76)	1.25 (0.74,2.13)	Ref
Q1 (Most)	4.40 (3.26,5.94)	1.99 (1.56,2.55)	3.36 (2.35,4.80)	Ref	1.99 (1.34,2.96)	1.22 (0.86,1.72)	1.67 (0.99,2.81)	Ref
Income Quintile at baseline (9 months)								
Q5 (Highest)	-	-	-	-	-	-	-	Ref
Q4	1.54 (1.08,2.18)	1.43 (1.07,1.92)	1.27 (0.79,2.03)	Ref				Ref
Q3	1.98 (1.41,2.78)	1.53 (1.14,2.04)	2.41 (1.57,3.69)	Ref				Ref
Q2	3.97 (2.91,5.42)	2.71 (2.07,3.54)	4.21 (2.83,6.28)	Ref				Ref
Q1 (Lowest)	5.95 (4.40,8.05)	3.58 (2.75,4.65)	6.90 (4.69,10.17)	Ref				Ref
Maternal Mental Health at Baseline								
No Psyc.Distress	-	-	-	-	-	-	-	-
Mod/High Psyc.Distress	3.31 (2.78,3.94)	1.75 (1.47,2.07)	3.77 (3.04, 4.67)		2.79 (2.25,3.46)	1.65 (1.43,2.02)	3.28 (2.46,4.38)	
SCHOOL ENVIRONMENT								
Bullied (Age 7)								
Never	-	-	-	-	-	-	-	-
Sometimes	1.39 (1.16, 1.66)	1.29 (1.08,1.54)	1.81 (1.41,2.32)	Ref	1.38 (1.09,1.74)	1.41 (1.13,1.74)	1.73 (1.26,2.37)	Ref
All the time	3.25 (2.54,4.14))	2.99 (2.35,3.81)	5.40 (3.98,7.31)	Ref	2.29 (1.66,3.16)	2.49 (1.82,3.41)	3.38 (2.26,5.05)	Ref
Enjoys School (Age 7)								
Al lot	-	-	-	-	-	-	-	-
A bit	1.05 (0.87,1.26)	0.87 (0.72,1.05)	1.08 (0.83,1.41)	Ref	1.25 (0.98,1.60)	0.98 (0.78,1.23)	1.15 (0.85,1.59)	Ref
Don't enjoy	1.62 (1.31,2.01)	1.34 (1.07,1.66)	2.23 (1.70,2.92)	Ref	1.52 (1.14,2.03)	1.01 (0.75,1.34)	1.50 (1.04,2.17)	Ref
Parental Involvement with school (Age 7)								
Involved	-	-	-	-	-	-	-	-
Not Involved	1.86 (1.58,2.17)	1.74 (1.49,2.04)	2.10 (1.71,2.57)	Ref	1.34 (1.09,1.70)	1.33 (1.08,1.63)	1.31 (0.98,1.75)	Ref

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				Multivariable Analyses * Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Early SEB**	**Late SEB**	**Persistent SEB**	**NP**	**Early SEB**	**Late SEB**	**Persistent SEB**	**NP**
PARENTING								
Reads to Child (Age 5)								
Every Day	-	-	-	-	-	-	-	-
Several /week	1.19 (0.98,1.42)	1.14 (0.96,1.35)	1.11 (0.87,1.41)	Ref	1.19 (0.87,1.43)	1.11 (0.89,1.39)	1.39 (1.01,1.93)	Ref
Less than several /week	2.18 (1.76,2.72)	1.40 (1.10,1.78)	2.28 (1.73,3.02)	Ref	1.34 (0.97,1.85)	1.03 (0.73,1.44)	2.22 (1.5,3.27)	Ref
Visits Library (Age 5)								
Regularly	-	-	-	-	-	-	-	-
Not Reg.	1.41 (1.19,1.66)	1.13 (0.96,1.32)	1.56 (1.25,1.94)	Ref	1.13 (0.89,1.43)	0.92 (0.74,1.13)	1.16 (0.98,1.75)	Ref
Plays Games with Child (Age 5)								
Regularly	-	-	-	-	-	-	-	-
Not Reg.	1.53 (1.27,1.86)	1.27 (1.04,1.54)	1.65 (1.30,2.09)	Ref	1.20 (0.84,1.49)	1.13 (0.86,1.49)	1.14 (0.78,1.65)	Ref

*VIF <5 for all variables (indicating no issues of co-linearity), BIC 8200 Pseudo R 0.08
Note: SEB: Socioemotional Behaviour Problems. NP: No Problems

Predictors of Trajectories of Cognitive Development

Results of the univariate and multivariable multinomial regression model are illustrated in table 9. Compared to the 'no problems' group; socioeconomic factors of maternal education qualifications and high neighbourhood deprivation; and school factors of low parental involvement with school, were common risk factors for all of the adverse trajectory groups. Male sex was associated with the persistent and early cognitive problems groups, whereas female sex was associated with the late cognitive problems group. Minority ethnicity was associated with the persistent and early cognitive problems group. All school factors were associated with the late cognitive problems groups. Parental factors were predictors of the early and persistent problems group.

Table 9: Univariate and Multivariable Multinomial Regression Analysis predictors of Cognitive Development groups in the Millennium Cohort Study

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				Multivariable Analyses * Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Early COG**	**Late COG**	**Persistent COG**	**NP**	**Early COG**	**Late COG**	**Persistent COG**	**NP**
Sex								
Female	-	-	-	-	-	-	-	-
Male	1.21 (1.04,1.41)	1.04 (0.92,1.18)	1.63 (1.35,1.96)	Ref	1.40 (1.12,1.75)	0.83 (0.70,0.97)	1.65 (1.27,2.16)	Ref
Ethnicity								
White	-	-	-	-	-	-	-	-
Mixed	2.46 (1.52,3.65)	1.37 (1.04,1.82)	2.18 (1.42,3.33)	Ref	1.32 (0.72,2.44)	1.12 (0.77,1.65)	1.79 (1.01,3.12)	Ref
Indian	15.04 (11.05,20.47)	0.84 (0.51,1.38)	3.75 (2.32,6.07)	Ref	9.00 (6.03,13.44)	1.05 (0.59,1.85)	2.68 (1.39,5.18)	Ref
Pakistani	33.71 (26.46,42.93)	2.14 (1.56,2.92)	16.76 (12.81,21.93)	Ref	16.21 (11.59,22.68)	1.24 (0.78,1.96)	7.00 (4.64,10.57)	Ref

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				Multivariable Analyses * Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Early COG**	**Late COG**	**Persistent COG**	**NP**	**Early COG**	**Late COG**	**Persistent COG**	**NP**
Bangladeshi	41.56 (29.96,57.64)	3.01 (1.95,4.62)	17.99 (12.23,26.48)	Ref	22.30 (13.71,36.27)	1.80 (0.88,3.68)	10.46 (5.77,18.95)	Ref
Black Caribbean	3.01 (1.29,6.97)	1.63 (0.92,2.88)	5.32 (2.86,9.91)	Ref	1.60 (0.48,5.29)	1.53 (0.71,3.31)	2.95 (1.11,7.85)	Ref
Black African	17.56 (12.44,24.81)	1.17 (0.70,1.97)	2.78 (1.44,5.36)	Ref	8.53 (5.34,13.91)	0.58 (0.23,1.45)	1.75 (5.77,18.96)	Ref
Other	18.37 (13.51,24.97)	1.52 (1.00,2.29)	6.85 (4.58,10.24)	Ref	10.47 (6.96,15.73)	0.97 (0.55,1.73)	4.15 (2.41,7.16)	Ref
Maternal Education								
Dip/Degree	-	-	-	-	-	-	-	-
A-Levels	2.42 (1.63,2.60)	1.37 (1.02,1.86)	3.18 (1.86, 5.42)	Ref	2.43 (1.52,3.90)	1.26 (0.88,1.79)	3.53 (1.76,7.10)	Ref
GCSE A-C	2.52 (1.85,3.43)	2.34 (1.92,2.86)	3.87 (2.52,5.92)	Ref	2.28 (1.56,3.34)	2.01 (1.58,2.55)	3.13 (1.75,6.60)	Ref
GCSE D-G/other	6.94 (5.05,9.54)	4.06 (3.24,5.09)	9.23 (5.95,14.32)	Ref	3.46 (2.31,5.19)	3.40 (2.57,4.50)	5.77 (3.16,10.54)	Ref
None	13.88 (10.35,18.61)	5.22 (4.22,6.47)	22.92 (15.27,34.39)	Ref	5.89 (4.04,8.59)	3.78 (2.85,5.01)	11.10 (6.27,19.6)	Ref
IMD Quintile of Deprivation								
Q5 (Least)	-	-	-	-	-	-	-	-
Q4	2.34 (1.35, 4.01)	1.44 (1.09,1.88)	1.45 (0.78, 2.71)	Ref	1.51 (0.81,2.81)	1.30 (0.94,1.80)	1.45 (0.56,3.85)	Ref
Q3	3.44 (2.05, 5.76)	1.73 (1.34,2.23)	2.62 (1.52, 4.54)	Ref	1.57 (0.88,2.81)	1.31 (0.96,1.78)	2.61 (1.13,6.01)	Ref
Q2	5.69 (3.50, 9.24)	1.88 (1.47,2.40)	4.40 (2.65, 7.31)	Ref	2.07 (1.19,3.60)	1.33 (0.99,1.79)	3.25 (1.45,7.27)	Ref
Q1 (Most)	16.36 (10.28,26.03)	3.04 (2.43,3.83)	11.95 (7.39, 19.32)	Ref	2.35 (1.37,4.04)	1.52 (1.13,2.04)	4.58 (2.01,10.09)	Ref
Income Quintile at baseline (9 months)								
Q5 (Highest)	-	-	-	-	-	-	-	Ref
Q4	0.93 (0.61, 1.43)	1.58 (1.20,2.07)	1.69 (0.89, 3.21)	Ref				Ref
Q3	1.91 (1.31,2.77)	2.28 (1.76,2.97)	3.55 (1.98, 6.34)	Ref				Ref
Q2	5.81 (4.18,8.09)	3.41 (2.66,4.38)	11.25 (6.59, 19.21)	Ref				Ref
Q1 (Lowest)	7.93 (5.73, 10.98)	4.98 (3.91,6.36)	19.15 (11.31,32.44)	Ref				Ref
SCHOOL ENVIRONMENT								
Bullied (Age 7)								
Never	-	-	-	-	-	-	-	-
Sometimes	1.31 (1.09, 1.56)	1.08 (0.93,1.26)	1.03 (0.82, 1.31)	Ref	1.31 (1.04,1.64)	1.06 (0.89,1.27)	0.99 (0.74,1.33)	Ref
All the time	1.70 (1.28, 2.27)	2.09 (1.61,2.51)	3.14 (2.35,4.20)	Ref	1.26 (0.86,1.85)	1.70 (1.32,2.19)	2.55 (1.78,3.64)	Ref
Enjoys School (Age 7)								
Al lot	-	-	-	-	-	-	-	-
A bit	0.69 (0.57,0.84)	0.80 (0.67,0.94)	0.65 (0.51,0.85)	Ref	0.88 (0.69,1.14)	0.90 (0.74,1.09)	0.67 (0.49,0.93)	Ref
Don't enjoy	0.56 (0.43,0.84)	1.55 (1.30,1.87)	1.04 (0.78, 1.39)	Ref	0.82 (0.57,1.17)	1.64 (1.32,2.03)	0.88 (0.61,1.29)	Ref
Parental Involvement with school (Age 7)								
Involved	-	-	-	-	-	-	-	-
Not Involved	2.63 (2.22,3.12)	1.74 (1.52,1.99)	2.76 (2.26,3.38)	Ref	1.38 (1.09,1.73)	1.36 (1.15,1.61)	1.51 (1.14,2.00)	Ref
PARENTING								
Reads to Child (Age 5)								

	Univariate Analyses Relative Risk Ratio (95% Confidence Interval)				Multivariable Analyses * Relative Risk Ratio (95% Confidence Interval)			
Predictor	**Early COG**	**Late COG**	**Persistent COG**	**NP**	**Early COG**	**Late COG**	**Persistent COG**	**NP**
Every Day	-	-	-	-	-	-	-	-
Several /week	1.37 (1.15,1.65)	0.96 (0.82,1.21)	1.23 (0.98,1.54)	Ref	1.27 (0.99,1.62)	0.97 (0.80,1.17)	1.32 (0.98,1.77)	Ref
Less than several /week	2.28 (1.82,2.86)	1.62 (1.33,1.98)	2.64 (2.03,3.42)	Ref	1.42 (1.04,1.94)	1.20 (0.93,1.53)	1.43 (0.98,2.10)	Ref
Visits Library (Age 5)								
Regularly	-	-	-	-	-	-	-	-
Not Reg.	1.48 (1.25,1.76)	1.58 (1.36,1.83)	1.61 (1.31,1.99)	Ref	1.27 (0.99,1.61)	1.29 (1.07,1.54)	1.43 (1.05,1.94)	Ref
Plays Games with Child (Age 5)								
Regularly	-	-	-	-	-	-	-	-
Not Reg.	2.50 (2.09,2.98)	1.25 (1.04,1.48)	2.48 (2.01,3.06)	Ref	1.31 (1.00, 1.68)	0.98 (0.78,1.23)	1.51 (1.11,2.04)	Ref

*VIF <5 for all variables (indicating no issues of co-linearity), BIC 9444, Pseudo R 0.18
Note: COG: Cognitive Problems. NP: No Problems

Summary of Factors Associated with Trajectories of Socioemotional and Cognitive Problems

A table illustrating a summary of the factors associated with trajectories of socioemotional and cognitive problems is available in table 10.

Table 10: Summary of factors associated with trajectories of Socioemotional and Cognitive Problems

	Socioemotional Problems Trajectory Groups			Cognitive Problems Trajectory Groups		
Predictive Factors	**Early SEB**	**Late SEB**	**Persistent SEB**	**Early COG**	**Late COG**	**Persistent COG**
Socioeconomic:						
High Deprivation	√			√	√	√
Low Mat education	√	√	√	√	√	√
Low Mat Mental Health	√	√	√	-	-	-
Demographic:						
Male	√		√	√		√
Female					√	
Minority Ethnicity				√		√
School:						
Low Parental Involvement	√	√		√	√	√
Being Bullied	√	√	√		√	√
Not enjoying	√		√		√	
Parental:						
Infreq. reading with child			√	√		
Infreq. playing with child				√		√

Part III – Logistic Regression

Associations between Trajectories of Socioemotional Development and Adolescent Health

Results for the associations between the trajectory groups and weight and mental health outcomes at age 14 and 17 years are shown in table 11. All of the adverse development groups were associated with overweight or obesity at age 14 and 17 years, compared to the 'no problems' group,

in the crude model (model 1). The associations remain (slightly attenuated) in the adjusted model highlighting 17% of the study population with increased odds of overweight or obesity. For all the adverse trajectory groups the odds of overweight or obesity were approximately 1.5 times that of the no problems group at age 14 and 17 years.

In relation to mental ill health outcomes similar patterns were observed with all the adverse trajectory groups having increased odds of mental ill health at age 14 and 17 years compared to the no problems group, in the adjusted model. The odds were 2-4 times greater at age 14, reducing to 1.5 to 2.5 times greater at age 17.

Table 11: Associations of predicted Socioemotional Development trajectories and adolescent health outcomes at age 14 and 17 years in the UK Millennium Cohort Study

Odds Ratio	Model*	No Behaviour Problems	Early SEB Problems	Late SEB Problems	Persistent SEB Problems
Age 14 years Overweight or Obese	1	Ref.	1.53 (1.19,1.96)	1.53 (1.25,1.87)	1.73 (1.31,2.26)
	2	Ref.	1.36 (1.01,1.81)	1.51 (1.21,1.89)	1.51 (1.10,2.06)
Age 17 years Overweight or Obese	1	Ref.	1.47 (1.15,1.88)	1.55 (1.24,1.93)	1.47 (1.07,2.02)
	2	Ref.	1.59 (1.20,2.09)	1.44 (1.11,1.88)	1.54 (1.09,2.18)
Age 14 years Mental Ill health	1	Ref.	3.36 (2.35,4.78)	3.51 (2.64,4.68)	6.08 (4.41,8.37)
	2	Ref.	2.04 (1.38,3.03)	2.87 (2.05,4.04)	4.19 (2.84,6.18)
Age 17 years Mental Ill health	1	Ref.	1.29 (0.98,1.72)	2.25 (1.76,2.89)	2.07 (1.50,2.85)
	2	Ref.	1.50 (1.07.2.12)	2.45 (1.78,3.36)	2.21 (1.56,3.14)

*Model 1: Crude model; Model 2: adjusted for confounders (child sex, MMH and maternal education)

Associations between Trajectories of Cognitive Development and Adolescent Health

Results for the associations between the cognitive development groups and weight and mental health outcomes at age 14 and 17 years are shown in table 12. In contrast to the trajectories of socioemotional development where associations were found for all health outcomes, only the persistent cognitive problem group was associated with adverse health; mental ill health at age 14 years, in the adjusted model.

Table 12: Associations of predicted Cognitive Development trajectories and child health outcomes at age 14 and 17 years in the UK Millennium Cohort Study

Odds Ratio	Model*	Low Cognitive Problems	Early Childhood Cognitive Problems	Late Childhood Cognitive Problems	Persistent Cognitive Problems
Age 14 years Overweight or Obese	1	Ref.	1.15 (0.89-1.47)	1.26 (1.05-1.52)	1.38 (1.02-1.86)
	2	Ref.	0.92 (0.69-1.22)	1.14 (0.93-1.38)	1.07 (0.76-1.50)
Age 17 years Overweight or Obese	1	Ref.	1.23 (0.94-1.61)	1.14 (0.94-1.38)	1.56 (1.15-2.14)
	2	Ref.	0.95 (0.70-1.29)	1.05 (0.85-1.29)	1.22 (0.85-1.77)
Age 14 years Mental Ill health	1	Ref.	1.02 (0.66-1.58)	1.69 (1.25-2.30)	2.18 (1.43-3.31)
	2	Ref.	0.77 (0.45-1.32)	1.34 (0.95-1.89)	1.84 (1.15-2.91)
Age 17 years Mental Ill health	1	Ref.	0.83 (0.63-1.11)	0.99 (0.79-1.24)	1.05 (0.70-1.57)
	2	Ref.	0.94 (0.65-1.35)	0.94 (0.72-1.22)	1.21 (0.79-1.87)

*Model 1: Crude model; Model 2: adjusted for confounders (child sex, child ethnicity and maternal education)

Brief Discussion

The analyses of single trajectories of development highlighted the differences in factors associated with socioemotional development and cognitive development. Minority ethnicity and deprivation were more associated with cognitive development. There were sex differences in late development problems, with females more likely to develop cognitive problems in late childhood.

It also highlighted differences in the strength of the associations between these aspects of development and adolescent weight and mental health with trajectories of socioemotional problems more strongly associated with overweight and mental ill health in adolescence. For mental health these were attenuated (odds reduced) when co-variates included which indicated an interaction effect.

This work informed the multi-trajectory analysis as children develop holistically and these two aspects of development are associated with health. In the multi-trajectory analysis what became apparent in relation to associations with later health was the timing of emergence or resolution of problems, which were less important in the single trajectories.

5.5. Chapter Summary

This chapter incorporated three separate pieces of longitudinal analyses: 1) trajectories of socioemotional and cognitive problems concurrently (paper 3), 2) trajectories of socioemotional problems and 3) trajectories of cognitive problems. It found that 1 in 6 children growing up in the UK are in an adverse trajectory of socioemotional development, 1 in 5 in an adverse trajectory of cognitive development and 1 in 4 in an adverse trajectory of both cognitive and socioemotional development. Adverse socioeconomic factors and school factors were associated with all adverse development trajectories. Socioemotional development had a stronger relationship with adolescent health than cognitive development. In summary there were three key findings:

Key Finding 1: There are inequalities in children's development in mid-childhood, strongly driven by disadvantage, and this will impact adolescent health.

Key Finding 2: The relationship between children's development and adolescent health exists after accounting for disadvantage.

Key Finding 3: Social and Emotional wellbeing in childhood is a key driver of adolescent health.

Chapter 6: Discussion – Building on 'Best Start in Life' to improve Adolescent Health

This chapter provides a summary of the research findings from the systematic review and the longitudinal analysis and discusses them in the context of the literature. It describes the strengths and limitations of the research. It culminates with a summary of implications for research, policy and practice, and a researcher reflection.

6.1. Introduction

The aim of this research was to explore the relationships between development in primary school age children and subsequent health in adolescence in the context of socioeconomic inequality. The research was guided by a systematic review (phase 1 of the thesis), the findings from which helped further refine the focus of the research: identifying and understanding the relationships between trajectories of child cognitive and socioemotional development and adolescent overweight/obesity and mental health. To this end, empirical work was undertaken using longitudinal analysis (phase 2) and had three specific aims; to determine trajectories of socioemotional and cognitive development individually and concurrently, in mid-childhood; to describe associations between these trajectories and socioeconomic, school and parental factors; and to quantify the associations between any identified developmental trajectories and adolescent health. Both the systematic review and empirical quantitative work are presented as academic publications in Chapters 4 and 5.

This discussion chapter briefly re-summarises the main findings from the systematic review and the longitudinal analysis. It then discusses what the main findings of the research, as a whole, contributes to our understanding of the relationships between development in primary school age children and subsequent health in adolescence, in the context of socioeconomic inequality.The contributions of the research to the evidence base are highlighted throughout. Strengths and limitations of the research are described and discussed. Main conclusions are drawn for research, policy and practice. Finally, a researcher reflection concludes the thesis.

6.2. Summary of findings

6.2.1. Systematic Review

RQ1: What are the associations between measures of child development recorded at primary school starting age (3-7 years) and subsequent weight and mental health in adolescence (8 -15 years)?

The review included 69,152 children from 34 studies, 24 of which were of moderate to high quality. The review found strong evidence of associations between measures of social and emotional development at school starting age and weight, mental health and academic outcomes in

adolescence. Good social and emotional wellbeing (measured, for example as social competence, self-regulation, and peer relations) was found to be associated with later healthy weight and positive mental health. The review also found positive associations between cognitive development and mental health and academic outcomes but the quality of the evidence was less strong. For aspects of development such as communication and language and physical development the evidence was inconsistent or limited in relation to the associations with adolescent health. This highlights an evidence gap in our understanding of the relationships between communication and language and physical development and later health.

RQ2: What factors modify or mediate the relationships between child development and adolescent health?

The systematic review also sought to tease out evidence on factors which modify (moderators) or explain (mediators) the relationships between aspects of development and adolescent health. These factors were highlighted in the initial conceptual model for the research (see chapter 2, figure 2) and fell under the headings of social causation and capabilities theories. The conceptual model illustrated how social causes (such as low income or neighbourhood deprivation) may moderate the development-health relationship via the pathways of family stress or material living (as outlined in chapter 2, section 2.2.), with for example economic hardship leading to stress in the home which in turn could have an adverse effect on the development-health relationship. The model also illustrated factors which may explain the development-health relationship. These stemmed from capabilities theory, understood here as skills developed via social/cognitive and knowledge/literacy pathways, which explain how aspects of development translate into health outcomes.

The review found limited evidence on factors that mediated or moderated associations, with most existing evidence focusing on factors shaping the relationship between social and emotional wellbeing and later weight, mental health and academic outcomes. For weight, evidence was found for child sex, with females more likely to be overweight if they had socioemotional problems. For mental health, evidence was found in relation to household chaos and aspects of parenting (warmth and discipline). Household chaos made the effect of adverse socioemotional development on later mental ill health stronger. Warm parenting weakened the effect of adverse socioemotional development on later mental ill health. Additionally child self-esteem, internalising and externalising in mid-childhood and relationships with teachers and friends were found to mediate the relationship between socioemotional behaviour and later mental health. For academic outcomes, evidence was found in relation to attentional regulation and approaches to learning as mediators of the relationship between socioemotional behaviour and later academic outcomes.

Most of these factors relate to theories of social causation and capabilities as outlined in the conceptual model. Household chaos and parental practices can be classed as social causes stemming from the family stress pathway, that is the impact that adverse socioeconomic circumstances has on stress in the home. Attentional regulation and approaches to learning can be classed as capabilities stemming from the knowledge/literacy pathway. Self-esteem, internalising and externalising in mid-childhood and relationships with teachers and friends also relate to capabilities theory. These factors stem from the social/cognitive pathway, that is they stem from individual experiences, the actions of others, and environmental factors which provide the social context for learning to influence health behaviours.

The review also found that the relationship between cognitive development and later mental health was moderated by age. Childhood cognitive ability had a positive effect on mental health in early adolescence. This diminished in mid adolescence having a negative effect on mental health with a positive effect returning in late adolescence.

Overall, the systematic review found strong evidence of associations between social and emotional wellbeing and later weight and mental health. It found weaker evidence of a relationship between cognitive ability and these outcomes. There was limited evidence on factors shaping relationships and these pertained to socioeconomic factors (moderators) stemming from family stress such as household chaos and aspects of parenting, and capabilities factors (mediators), such as self-esteem and peer relationships, stemming from the social/cognitive pathway. This informed the longitudinal analysis in terms of a focus on the domains of cognitive and socioemotional development in mid-childhood, to determine whether there are distinct trajectories of development as children age through primary school and impacts on later health.

As the systematic review highlighted evidence on the impact of social causes and capabilities on the development-health relationship, it was decided to determine the impact of socioeconomic circumstances, school factors and parental factors on trajectories of development. School factors such as enjoying school or being bullied and parenting factors such as reading or playing with child were considered as proxy measures of self-esteem and relationships which are indicative of capabilities or skills development as understood in this project. This would highlight whether there are socioeconomic inequalities in development in mid-childhood and the role of capabilities in mitigating its effect.

6.2.2. Longitudinal analysis

The longitudinal analysis identified trajectories of cognitive and socioemotional development in children from age 3-14 years in order to understand socioeconomic, school and parental characteristics of developmental trajectories and to identify associations between the derived trajectories and adolescent weight and mental health. There were three separate pieces of longitudinal analyses: 1) trajectories of socioemotional and cognitive problems concurrently (paper 3), 2) trajectories of socioemotional problems and 3) trajectories of cognitive problems. Overall there were three key findings:

Key Finding 1: There are inequalities in children's development in mid-childhood, strongly driven by disadvantage, and this will impact adolescent health.

Key Finding 2: The relationship between children's development and adolescent health exists after accounting for disadvantage.

Key Finding 3: Social and Emotional wellbeing in childhood is a key driver of adolescent health.

RQ3: Are there specific trajectories of concurrent socioemotional and cognitive development in mid-childhood?

In the longitudinal analysis four distinct trajectories of development were found, when socioemotional and cognitive development were analysed together from age 3-14 years. These trajectories were 'no problems' (76.5%); 'late socioemotional problems' (10.1%); 'early cognitive and socioemotional problems' (8.6%); and 'persistent cognitive and socioemotional problems' (4.8%). This illustrates that approximately 1 in 4 children were in an adverse development trajectory in the UK. The 'no problems' group represented children who were below the threshold for socioemotional behaviour problems and cognitive problems (1.25 SD below cohort mean) throughout childhood, from age 3 to 14 years. The 'late socioemotional problems' group represented children in whom socioemotional problems emerge in late childhood, from age 7 onwards, without any concurrent cognitive problems. The 'early cognitive and socioemotional problems' group represented children who started school with both cognitive and socioemotional problems but appeared to be on a resolving trajectory throughout childhood. The 'persistent cognitive and socioemotional problems' group represented children who had persistent problems in both aspects of development throughout childhood.

RQ3: What are the characteristics of the developmental trajectories in terms of socioeconomic, school and parental factors?

In the analysis of concurrent socioemotional and cognitive problems, compared to the 'no problems' group; male sex, lower maternal education qualifications, living in an area that is in the most deprived quintile of deprivation, poor maternal mental health and school factors of being bullied 'all the time' and parents not involved with school, were common risk factors for the three adverse trajectory groups.

In addition to these common risk factors, school factors of being bullied and not enjoying school increased the risk of being in the 'late socioemotional problems' and 'persistent problems' groups whereas parenting factors were identified as a significant factor for the 'persistent problems' group only. Minority ethnicity, increasing relative levels of neighbourhood deprivation and parenting factors were additional risk factor for the 'early cognitive and socioemotional problems' group.

The analysis found that there are socioeconomic inequalities in child development (socioemotional and cognitive development studied separately and concurrently) from age 3-14 years. The inequalities (or social patterning) are driven by disadvantage when measured as neighbourhood deprivation and familial disadvantage (maternal education and maternal mental health). Relative familial disadvantage was more strongly associated with adverse development than relative neighbourhood deprivation. However relative neighbourhood deprivation was associated with persistent cognitive problems and early socioemotional and cognitive problems concurrently. All of these measures of disadvantage are considered as markers of SES.

The findings from the analysis suggest that SES affects trajectory of cognitive and socioemotional development when analysed separately and concurrently. A lower SES increased the risk of a child being in an adverse development trajectory but how SES is measured matters. Using familial disadvantage (maternal education) exposed a social gradient in all the aspects of development studied. Neighbourhood disadvantage (quintiles of deprivation) exposed a gap between the lowest and highest quintiles of deprivation but not a statistically significant gradient apart from persistent cognitive problems and early problems in concurrent cognitive and socioemotional development where a social gradient was found. This highlights that, for children with early problems in both cognitive and socioemotional development, neighbourhood deprivation at all levels is an important risk factor.

The analysis found that demographic factors of minority ethnicity were also associated with inequalities in development but only in relation to the timing of cognitive problems and early problems in concurrent socioemotional and cognitive development. Minority ethnicity increased

the risk of early or persistent cognitive problems and early problems in concurrent socioemotional and cognitive development. Minority ethnicity did not impact on inequalities in socioemotional development when studied as a separate domain. This implies minority ethnicity is an important risk factor for cognitive problems and for early problems in both cognitive and socioemotional development.

The analysis found that the demographic factor of child sex was associated with inequalities in development. Males were more likely to be in an adverse development trajectory in the concurrent development analysis. However when the aspects of development were analysed separately female sex was associated with late cognitive problems and no association was found for sex in relation to late socioemotional problems. This implies that the association between male sex and adverse development is stronger in early childhood and for persistent problems and that female sex may be more of a factor for children who develop cognitive or socioemotional problems in late childhood.

Parental and school factors also influence inequalities in development, with school factors such as bullying and low parental involvement increasing the risk of being in an adverse development group. Parental factors such as reading with child were important for persistent and early problems and more of a factor for cognitive than socioemotional development.

RQ3: What are the associations between the developmental trajectories and adolescent health?

The analysis showed that these inequalities in development driven by SES, ethnicity, sex, parental and school factors, impact weight and mental health at age 14 and 17 years. The aspect of development and timing of problems matters in terms of the impact on health.

The analysis found a stronger and more consistent relationship between socioemotional problems and later health, than cognitive problems, for all adverse development trajectories. Adverse development trajectories of socioemotional problems at any stage of development (early, late or persistent) were associated with overweight or obesity and mental ill health at age 14 and 17 years. For adverse cognitive development only persistent problems were associated with mental ill health and at age 14 only. This implies that if adolescent weight and mental health is the focus, socioemotional development during primary school and into early adolescence is a key factor to focus on. Persistent cognitive problems require a focus for impact on later mental ill health.

The analysis showed that when these aspects of development were studied concurrently, the timing of the emergence or resolution of problems was important. The late onset of socioemotional problems and persistent cognitive and socioemotional problem trajectories were associated with overweight or obesity and mental ill health at age 14 and 17 years compared to the no problems

group, after adjusting for confounders. For both groups the odds of overweight or obesity were around 1.5 times greater at age 14 years and increased to around 1.6 at age 17 years. The odds were stronger for mental ill health, for both groups, at 2.5-3 at age 14 and reducing to round 2.2 at age 17. Conversely the analysis showed that the trajectory group with early problems in both aspects of development but on a resolving trajectory were not associated with later adverse health. This implies that identifying problems early to resolve them appears positive for later health, particularly so for children with problems in both aspects of development.

These findings highlight that when socioemotional and cognitive development are analysed separately and concurrently for their impact on adolescent health, the relationship between development and health is driven mainly by socioemotional rather than cognitive development. The original hypothesis was that socioemotional wellbeing provided the context for learning and that the co-development of these aspects of development could shape health. That hypothesis was neither fully supported nor rejected. It seems to apply for early and persistent problems (whereby early problems which resolve are not associated with adverse health, whereas persistent problems are associated with adverse health). However for late socioemotional problems without concurrent cognitive problems there is a relationship with adverse health implying that it is the socioemotional wellbeing that is driving the relationship with health rather than the co-development of these aspects of development. Nonetheless the co-development of these aspects of development does warrant further research.

The analysis also highlighted that when the relationships between development and health were studied, and key factors (disadvantage, ethnicity and sex (as appropriate to the outcome under study)) controlled, there was still a relationship between development and health. This implies that upstream prevention work is needed but that also there is a role for mitigation policy particularly in schools and with parents, as will be discussed in the section below. Development of capabilities may help guide mitigation strategies. Further work on social factors is needed as most studies control these as confounders so it is difficult to unpick the effect of socioeconomic context.

6.3. Discussion of findings

In this project I have addressed the study aim which was to explore the relationships between development in primary school age children and subsequent health in adolescence in the context of socioeconomic inequality, and to inform interventions to improve health and reduce health inequalities in adolescence. As suggested by the review of findings above, this study provides a number of novel insights into this relationship.

6.3.1. Novelty and Contribution to Knowledge

Firstly, by focusing on mid-childhood and unpicking the development-health relationship, through a systematic review and complementary theory review, the research has produced a conceptual model, grounded in multiple health inequalities theories. This model brings social causation, health selection, human capital and capabilities theories together, to provide a framework for exploring and unpicking whether and how development in childhood translates into health in adolescence, in the context of socioeconomic inequality and from a life course perspective. No other study has brought these theories together to understand this part of the child-adolescent life course. The model is further strengthened by the inclusion of a stakeholder group to inform it as part of the systematic review. This conceptual model builds on existing early child development frameworks (34) extending into mid-childhood and highlights the continuing and pervasive role of socioeconomic circumstances on children's development beyond the early years and the impact that this has on subsequent health.

Secondly, to my knowledge, this is the first study to analyse aspects of development concurrently over time in mid-childhood, identifying four distinct trajectories of development. Whilst existing research has studied some elements of these developmental domains separately over time (79-82) little was known about population level trajectories of concurrent development in mid-childhood nor the impact of trajectory of development on adolescent weight and mental health. Yet it is recognised that children develop holistically and that their needs change over time and in relation to their socioeconomic circumstances (63), with research needing to find ways to take this into account. This study has contributed knowledge about the co-development of socioemotional and cognitive problems over time in children, in terms of inequalities and health impacts, and adds to our understanding of the impact of socioeconomic inequalities in development on health in the child to adolescent life course.

Thirdly, the research provides a novel contribution by furthering our knowledge about education-health relationships in children and adolescents earlier than much academic literature focuses on in the life course. Much of the existing research focuses on the relationships between education in childhood and health in adulthood (262). This research has extended our understanding to adolescence, contributing that socioemotional and cognitive development (which precedes and is integral to formal education) in childhood impacts health in adolescence with socioeconomic factors modifying and capabilities factors explaining the relationship. This highlights the potential of intervening on the development-health relationship, via these factors, in mid-childhood to improve health at a crucial time in the life course, adolescence.

6.3.2. Overall themes

Interventions to optimise development and reduce inequalities are needed throughout childhood

This research shows that there are inequalities in children's socioemotional and cognitive development in mid-childhood, strongly driven by disadvantage, and that this will impact adolescent health. This key finding builds on what we know about earlier inequalities in these aspects of development which , by age three, are substantial and pervasive (263). Indeed, intervening in the early years of a child's life is well evidenced and supported by the science of neurodevelopment (50-54) and health economics (56). My findings show that we need to continue to address developmental inequality beyond the early years as it impacts adolescent health. It implies that interventions to optimise development and reduce inequalities are needed throughout childhood.

The analysis highlighted that if the adverse development, which is socially patterned, is unresolved it risks having a negative effect on adolescent health. This builds on evidence that inequalities in early years development will cause health and wellbeing problems through to adulthood (263). This poses the question, what if we could address inequalities in development throughout childhood, would that improve later health, or is the damage done in the early years? There is little research on inequalities in mid-childhood development; that is, patterns of development at population-level over time. The longitudinal analysis filled this knowledge gap and highlighted that socially patterned adverse development (concurrent cognitive and socioemotional) in mid-childhood (age 3-14 years) which was not on a resolving trajectory was associated with adverse adolescent health. Therefore, if we could address inequalities in development throughout childhood, then that could benefit adolescent health. Indeed, recent evidence has shown that addressing inequalities in skills (cognitive and socioemotional) in later childhood is beneficial for weight, educational qualifications and emotional wellbeing in adulthood (263). In terms of life course development, it is helpful to know that whilst the early years are a critical period of development, addressing developmental inequalities throughout childhood appears beneficial for adolescent health.

Prevention and Mitigation Strategies are needed

The findings from this research suggest that tackling inequalities in child development requires a focus on two things; prevention and mitigation. Prevention because of the effect of socioeconomic circumstances on developmental trajectory. Mitigation, because the relationship between development and health exists even after controlling for socioeconomic confounders.

Taking prevention first, the longitudinal analysis highlighted that children are at increased risk of adverse socioemotional and cognitive development (concurrently) if they live conditions of socio-

economic disadvantage, have a mother with lower educational qualifications or poor mental health. The effect of the disadvantage starts from before birth and, as this research shows, continues throughout childhood. The closer the disadvantage is felt by the child the more pervasive it appears to be, as highlighted by the findings which highlight the stronger relationship between relative familial disadvantage and child development than neighbourhood deprivation. This is consistent with a recent policy review which found that the main influence on child development in the early years is the emotional environment in the family home (263). However, the same review found that inequalities, in early child development, remain stubbornly high because the central focus of policy has been on early education (in countries such as the UK) (263). This implies that a stronger policy focus on the wider determinants which influence family environments, in addition to central actions on universal childcare, health visiting and access to early education, may be needed to reduce inequalities in development.

Another interesting finding in relation to prevention is that a general 'catch up' was evidenced in the longitudinal analysis whereby a trajectory group with early problems upon starting school, but on a resolving trajectory, was identified. This suggests that access to population-level universal education supports children in this trajectory to catch up (perhaps catching those who did not access early years education). This concurs with other evidence which shows that in large scale early years prevention initiatives, such as the Perry Preschool and Abecedarian programmes in the US, an initial fade out is seen after interventions followed by positive impacts in some outcomes in adulthood (264). This fade out can be explained by other children catching up when they start school (264). For prevention initiatives to endure over time it is argued that interventions need to focus on fundamental skills such as literacy, maths or emotional regulation which are amenable to change and would have been unlikely to develop in the absence of the intervention (264). So, if the education system were to strive to reduce inequalities in cognitive and socioemotional skills, particularly for those with persistent or late onset problems, it may need to do something over and above the universal school offer with children who have skills deficits that are amenable to change.

In terms of mitigating the effects of socioeconomic inequality in development this research offers some important insights. The longitudinal analysis highlighted that relationship between children's development and adolescent health exists after accounting for disadvantage. This suggests that interventions which boost capabilities such as those found in the systematic review, self-esteem and relationships with peers, may counter the effect of adverse socioeconomic circumstances on health. Additionally, the importance of the environment is evidenced in this analysis by the relationship between school factors, such as bullying and parents not being involved with school, which

increased the risk of being in an adverse development group. Therefore there is potential benefit from interventions in schools, with parents and other environments where children live, play and learn to boost children's capabilities. That is not to say that problems in development should be perceived as an individual problem. Rather that development is grounded in the broader socioeconomic environment (which can limit or enhance development) but that the development of capabilities is also an important pathway to redress inequality. Thought needs to be given to sustaining the benefits of any interventions to increase capabilities which require sustaining quality environments which can support positive development (265). There may be more that schools can do to improve the emotional environments they operate in and the connections made with communities and parents.

In summary, development is not static, we all continually develop over time. At population-level there appears to be patterns of development. Development can be informed and impacted by socioeconomic circumstance, schooling and parental factors with opportunities to intervene across the child-adolescent life course. This research shows that inequalities in development are apparent in mid-childhood (age 3-14 years). These inequalities are largely driven by disadvantage and will influence adolescent health. To address inequalities in development, to improve adolescent health, we need to build upon and extend best start in life policy incorporating both prevention and mitigation approaches.

The complexity of measuring disadvantage or SES requires thorough consideration in research seeking to address inequalities

In this research I have found that if we are to address socioeconomic inequalities in development we need to give careful consideration to how we measure disadvantage or SES because different measures have different impacts. This builds on the discussion in the introductory chapter, where I highlighted the limitations of social causation theory in terms of the under theorisation of SES leading to it being conceptualised as a static entity with different findings and indeed policy implications depending on the maker of SES used. I measured SES at neighbourhood level (quintiles of deprivation) and at familial level (maternal education and maternal mental health). A social gradient was found for the familial measure of maternal education for all the adverse development groups (persistent, early and late). That is the lower the mother's education the greater the risk of being in any of the adverse development groups. A social gradient was found for neighbourhood measures of disadvantage for children with early cognitive and socioemotional problems only. For the late and persistent groups only the higher quintiles of neighbourhood deprivation increased the risk. The different impact of disadvantage, depending on what measure is used, has also been

recently evidenced by others (266) and highlights the need to measure disadvantage transparently and explicitly with a clear rationale as to why measures are selected. This is not to say that we need narrow definitions to chase causal evidence as that could have the unintended effect of limiting action by looking for the perfectly understood cause (267). Rather, in recognising that the science of cause and effect is nuanced (268) it highlights the need to underpin research with theory that helps us to formulate cause and effect relationships which are generative and dynamic (155). So, whilst it is intuitive to optimise child development, to understand how best to do it and what the implications might be, we need to understand it at each stage of life. For example, development affects health in childhood by generating skills, health can then enable further educational opportunity in adolescence as well as directly influence later health itself. Research which analyses these relationships over time (with supporting theory) may help to inform health inequalities policy.

The finding that trajectories of development are socially patterned, with measures of disadvantage having a different effect on trajectories of development, could be used in conjunction with other available evidence to build causal conceptual models, represented as directed acyclic graphs (DAGs), to study the effects of disadvantage at different stages of the life course. So, if socioeconomic circumstances are influencing a child's trajectory of development through neighbourhood and familial factors and the resulting trajectory affects health differentially a DAG needs to represent these different effects at different stages of the life course.

Where possible, DAGs should also represent mechanisms between cause and effect. However, my systematic review found that whilst some causes and effects of poor child development are known the mechanisms between cause and effect and the contexts which they operate is less clear and this can be because of our methods of controlling for confounding, which washes away the effect of 'context'. This can limit effective action. Indeed evidence from a review of child development prevention policies in the UK found that the biggest influencing factors for children's outcomes were poverty and resourcing, such as financial stability of services, austerity policies and funding cuts (83). If we are to address these factors and build effective 'prevention' policy, we need research and methods which unpicks the mechanisms between socioeconomic circumstances and child development and health outcomes in specific contexts.

To improve adolescent health, there is a need to focus on socioemotional development in childhood

The research found that social and emotional wellbeing matters most for health when socioemotional and cognitive development are studied concurrently and when these aspects of development were studied as distinct developmental domains. These findings are illuminating for three reasons: 1) the strength of the relationship between socioemotional development and

adolescent weight and mental health and 2) that the relationship was less strong for cognitive development even though that is an established relationship in adulthood and 3) the hypothesis that socioemotional wellbeing provides the context for learning throughout childhood, which in turn could shape adolescent health, was neither fully supported nor refuted.

The relationship between socioemotional development and adolescent health was summarised in the systematic review and the empirical findings and highlighted a strong relationship, building on existing literature. Additionally the empirical research highlighted that it is the population-level emergence or persistence of problems which is indicative of later health problems. The links between socioemotional development in childhood and self-esteem, social skills, peer relations and academic performance in later childhood are well evidenced (269). The associations with later mental health outcomes (depression symptoms at 14 and diagnosed depression at 17), as found in the empirical work, are perhaps unsurprising as socioemotional behaviour was measured using the Strengths and Difficulties Questionnaire (SDQ) which is a tool which can be used to predict mental health problems in certain populations (270). The positive associations found between socioemotional problems and overweight were strong and add to the literature which explores relationships between psychological wellbeing and weight (271). The strength of the relationship together with the timing of emergence of problems could be helpful for informing interventions to redress socioemotional behaviour problems and improve health.

It is perhaps surprising that a weaker relationship was found between trajectory of cognitive development and adolescent health, given the causal evidence of the positive effect of child cognitive ability on health in adulthood (272). This could be because the effect is mediated by employment/income later in life (272), so the benefit is delayed. Or a relationship may not have been fully detected because cognitive problems was measured as a simple binary outcome – problems or not and in reality there is a range of levels of cognitive ability throughout childhood. Further research which measures cognitive ability on a scale may be helpful in determining more fully any relationship between cognitive ability in childhood and adolescent health outcomes.

When the trajectories of socioemotional and cognitive development were studied concurrently the hypothesis was that the socioemotional wellbeing would provide the context for learning (development of cognitive ability) and that the co-development could shape health akin to findings on how the co-development of these domains of development affect adolescent educational attainment (81, 238). The hypothesis was neither fully supported nor refuted. Whilst the co-development of resolving problems and the co-development of persistent problems were associated with health in the expected direction, the development of late socioemotional problems without

concurrent cognitive problems was also associated with health, indicating that it is the socioemotional development driving the relationship with health rather than the co-development of cognitive and socioemotional problems. However the full extent of the relationships may not have been elucidated as non-granular binary outcome measures were used. Using continuous rather than binary measures of development may be helpful in disentangling the interrelationship between socioemotional and cognitive development.

6.4. Strengths and Limitations

6.4.1. Strengths

The research presented in this thesis has a number of strengths. First, it was underpinned by a large and comprehensive participatory systematic review. This review incorporated 69,152 children across high income countries recruited between 1986 and 2009 and synthesised the relationships between domains of development and later health. It was participatory in nature involving a stakeholder group to steer the review in relation to the initial conceptual model providing a framework for the review. Engaging stakeholders allowed for any insights not found in the evidence review to be incorporated in the discussion of the findings by reflecting on which aspects of the initial conceptual model were not found in the literature for example, the political cycles which can affect relationships between development and health. Highlighting factors considered important to stakeholders (people working in practice) but not found in an evidence review is an important step in engaging practice with research.

Second, using a large contemporary cohort representative of the UK population for the longitudinal analysis strengthens generalisability of findings. The MCS is multidisciplinary in nature with health, social, economic and demographic data from the year 2000 onwards enabling public health research to better understand health inequalities.

Third, the modelling technique of group based trajectory modelling, may be helpful in informing population level policy. It allowed for complex longitudinal data to be summarised into groups highlighting patterns of development at population level over time.

Fourth, to my knowledge, this is the first study to analyse socioemotional and cognitive development trajectories concurrently in mid-childhood, providing an insight into the inter-relationships between these aspects of development over time. Studying development in mid-childhood was also a strength in addressing the research and policy gap during this period.

6.4.2. Limitations

The research presented in this thesis should also be considered in the context of several limitations. First, the participatory nature of the systematic review may have introduced bias as stakeholders may have particular views, opinions or experiences. The use of replicable and transparent systematic review methods helped to minimise this risk. Additionally the stakeholder group helped to refine the conceptual model which steered the review by adding their views as to what factors may be important for the relationships under study, adding to the breadth and depth of the review.

Second, whilst the MCS is a cohort with a multitude of health and socioeconomic factors it did limit the development measures which could be used. This was particularly the case for cognitive development whereby the British Ability Scale (BAS) tests were available to age 11 and at age 14 a subset of the vocabulary test in the 1970 British cohort study was used. For the BAS tests a reference sample was available but none was available for the test from the 1970 study. This meant that to create the binary measure of cognitive problems the cut-off of 1.25 SD below the cohort mean was used rather than the reference population mean, so as to be consistent over the time period under study. The cohort mean for cognitive scores was higher than the reference sample mean and this highlights that MCS cohort had better ability than the reference sample. Therefore fewer children would have been classed as having cognitive problems if the reference sample mean was used. This may have overestimated the prevalence of cognitive problems and weakened the sensitivity of the analysis to detect associations between cognitive development and later health.

Third, using binary measures to determine trajectories of development problems may have oversimplified complex development patterns. If continuous measures (SDQ scores and cognitive scores developed using principal component factor analysis to derive latent cognitive ability scores) had been used there may have been a greater number of groups detected and may more closely reflect the breadth of levels of development in the population.

Fourth, there are limitations in the modelling technique which means there is a need for caution in interpreting the findings. GBTM is a technique which allows for the unknown population distribution of trajectories to be estimated. The model has in effect two outputs, trajectory shapes (in this case a polynomial function of age) and probability of trajectory group membership (in this case membership of groups of behaviour/cognitive problems). The latter is a latent group in that it is not a distinct group of individuals but represents latent clusters of individuals following similar trajectories. Therefore the extent to which the groups have real meaning is contestable. However that limitation is not unique to GBTM as all models are wrong in the sense that they don't represent reality perfectly. An assumption inherent in GBTM is that of conditional independence. This means

that for each individual within a given latent trajectory group it is assumed that the distribution of the outcome for that time period is independent of the outcome in previous time periods. In essence this assumes there is no variation within groups other than random variation. This is unlikely to be the case as undoubtedly there will be variation within groups and this will not be captured by this analysis, for example a child that starts higher than average in a group might be expected to remain higher than average but the model does not capture this. The implication of this is that it may lead to an increase in bias in the co-efficient that describes trajectory shape. A decreased standard error of those coefficients is a classic bias-variance trade off. However, the intention was not to determine the exact shapes but rather categorise the trajectories in terms of qualitative factors such socioeconomic, demography etc. and the final model accuracy results demonstrated a high ability to classify individuals into groups, providing assurance about the specified model.

Fifth, the policy context during the 2000's, when the MCS children were growing up, is different to the current context, now. For example provision with regard to children's centres and early years. It would not be expected that trajectories of development or factors associated with trajectories would be significantly different in these different contexts but it is possible. Therefore findings in relation to policy implications need to be interpreted with policy context in mind.

6.5. Summary of Implications for Research, Policy and Practice

6.5.1. Research

Future research could test the findings from the longitudinal analysis in multiple cohorts. This would further strengthen the generalisability of findings and recommendations for policy. Additionally the analysis could be repeated using different measures for socioemotional and cognitive development to determine the sensitivity of different measures used for these aspects of development.

Further analysing the relationship between cognitive development and health using a scale of cognitive ability rather than binary measures would be helpful to analyse the relationship at a more granular level and to determine whether there are more patterns of cognitive development over time. Re-analysing the co-development of socioemotional and cognitive development using continuous measures may help to illuminate more about the inter-relationships between these aspects of development and how that shapes later health.

Given that some children start school and are not school ready, it would be helpful to know the school characteristics associated with helping children to catch up (resolving trajectory) in the early years of school. Understanding the impact of schools in terms of their structures, ethos and

interventions, on development trajectories would be helpful in understanding their role in reproducing or reducing inequalities.

In order to better understand how to intervene as children age beyond the 'best start', research on intervention simulation and also qualitative work with families may be helpful. The simulation of interventions in mid-childhood would be helpful in assessing the impact of different interventions on trajectory of development and subsequent health. Structural equation modelling may be a helpful technique in further research to understand the generative and dynamic relationships between socioeconomic status, development and health as children age and the impact of interventions at different stages of development. In depth qualitative studies with families would help to understand how certain factors in the home environment impact on development and contribute to inequalities in development at population level.

The other domains of child development such as language and communication and physical could be further explored for associations with later health. This could be done by undertaking systematic reviews on those specific aspects of development to illicit measures used and any associations with later health.

Understanding the potential impact of the findings on policy would be a helpful piece of research in itself. A deliberative dialogue with stakeholders may be helpful to identify and inform policy implications.

6.5.2. Policy and Practice

The main implications for policy and practice are in relation to; the opportunity for institutions to enhance social and emotional wellbeing in children, targeting of interventions at different stages of the life course, the need for prevention and mitigation policy beyond the 'best start in life' period to address socioeconomic inequality and its impact throughout childhood. These policy implications were discussed with, and informed by, the stakeholder group involved with the research.

Schools are an obvious point for action. Implementing policy on health promoting schools has demonstrated improvements in child wellbeing, mental health, physical activity and diet (273, 274). Additionally, enhancing and evaluating initiatives such as mental health support teams into schools (275) could help to improve social and emotional wellbeing of children. Schools ensuring that they have policies which clearly tackle bullying and clear opportunities for parental engagement also appear important for supporting positive development of children. Poverty proofing schools (276) may help in some way to mitigate the effect of the cost of living crisis currently seen in countries such as the UK. This is an initiative which supports schools to find ways of enabling all students to

learn regardless of financial background, it helps a school to consider initiatives such as school trips through the lens of poverty in order to remove any barriers to educational activities because of financial constraints felt in children's homes. It also supports schools in terms of advice on how best to spend the *Pupil Premium*. This is a grant that schools in England receive to support educational attainment of disadvantaged pupils. The grant is allocated according to the number of pupils eligible for Free School Meals (FSM) and the number of looked after children in the school. Using this grant to place health and wellbeing at the centre of education may be a positive area of focus in terms of realising health gains in mental health and healthy weight in adolescence, with subsequent positive impact on educational attainment. Committing to awards such as the UNICEF *Rights Respecting Schools* awards which focus on children's rights specifically to improve wellbeing, participation, relationships and self-esteem (277), is a positive initiative which schools could consider.

For schools to improve social and emotional wellbeing of children there is a need for joint action between the health and education sectors. Given the holistic development of children, and the inter relationships between development and health, there is an opportunity for health and education sectors to work collaboratively to improve adolescent health. Efforts on obesity reduction and improving mental health are important health outcomes. For the health sector, working with schools to tackle those outcomes should be a priority area of focus. No education system can be effective unless it places the health and wellbeing of children at its centre (278). Therefore at national and local level education and health systems should be encouraged to work together to develop joint plans for the health and wellbeing of children. Adopting WHO and UNESCO global standards and indicators for health-promoting schools and systems may be a good place to start (279).

At government level, implications for policy include; the structure and resourcing of education and schools, the need for prevention and mitigation policy beyond the 'best start in life' period and a policy focus on socioemotional development. There is a fundamental opportunity to maximise the state/individual interaction during the school years for overall population health gain e.g. feeding all children nutritious food (through universal access to FSM) and better resourcing school outreach to reduce pupil absence (particularly post COVID). However, schools may be limited in what they can do without adequate resources, and strike action in countries such as the UK imply that there is a fundamental issue in relation to how education is structured and funded. Given the ultimate issue of intergenerational inequality and the power of education to redress this, the government could undertake a needs assessment of the educational system to consider what structural changes may be possible and what the potential benefits of those changes would be in terms of social mobility for future generations. For example, there are links between school catchments and social segregation with more affluent families living in catchments areas of the highest performing schools and more

disadvantaged families in catchment areas of the lower performing schools (280). Considering fully the international evidence base in relation to admission policies, long term outcomes and impacts on socioeconomic inequality would be of policy interest.

The second point for government action is in relation to developing policy which addresses health in the child-adolescent life course, building upon 'best start in life' policy. This policy gap was outlined at the beginning of this thesis together with the dissonance between public health narratives and action. New policy should focus policy and action upstream. As this research has shown, socioeconomic inequalities in development on starting school and throughout the schools years are apparent and this may adversely affect adolescent health. Therefore policy which continues to try and prevent early years disadvantage and mitigate its effects through the development of capabilities, and addressing the wider determinants, may benefit adolescent health. For example taxes such as the soft drinks industry levy (SDIL) which placed a tax on sugar sweetened beverages (incentivising manufacturers to reformulate their products to reduce the sugar content) has been shown to have been successful in preventing over 5000 cases of childhood obesity, particularly in girls and those from deprived areas(281). This highlights the learning from initiatives such as the SDIL in terms of its use as an tactic to address the commercial determinants of health (incentivising the food industry towards more nutritious food) and also that further strategies are needed to combat obesity prevalence overall and particularity in adolescence. The importance of social and emotional wellbeing in driving adolescent health highlights that it requires a central focus in policy that seeks to improve adolescent health. This may mean that the focus of the educational regulator, (such as OFSTED in the UK), needs strengthening in relation to social and emotional wellbeing, for example a measure of the level of social and emotional wellbeing could be used as part of the rating system for schools. In addition to regulation, government policy should consider; the resourcing of schools, as highlighted above, addressing inequalities through for example existing levelling up plans (282), and actions to improve outcomes in schools in more deprived areas. Policy and action should be informed by trajectories of development. For example who to target and how to intervene are different in those with early development problems as opposed to persistent problems or those with development problems in later childhood. Development of a child-adolescent life course strategy which considers these points could help to fill the current policy void for this part of the life course.

At local level, implications for local authority areas include; continuing to support the early years, considering provision of enhanced support upon starting school, encouraging a cross sector approach to health and wellbeing through integrated care partnerships, and considering becoming a child friendly city. In relation to early years support, targeting support towards areas of neighbourhood deprivation and minority ethnicity may help identify the schools which need most

resource to help children catch up upon starting school at a lower level of development than expected. Through integrated care partnerships, health and education could proactively develop child wellbeing plans which highlight; the health and development benefits of enhanced support for some children upon starting school, the potential emergence of late socioemotional problems, the need for a focus on social and emotional wellbeing and the positive benefits of engaging with parents and involving them with school. Additionally, for local authorities, focusing on initiatives such as *Child Friendly Cities* (283), a UNICEF initiative which encourages cities to consider the environment from a child's perspective, should be encouraged.

6.6. Recommendations for Policy and Practice

Schools:

- Become a Health Promoting School
- Consider action to Poverty Proof settings
- Further emphasis on social and emotional wellbeing in schools
- Extra support to children who start school but not school ready (cognitive and social and emotional skills)
- Engage with Mental health support teams in schools.

Local Authorities:

- Continue/Enhance early years support such as family hubs and start for life programmes and early years educational provision. Target by neighbourhood deprivation and to minority ethnicity
- Consider becoming Child *Friendly Cities.*

National – Education:

- Regulator to further consider aspects of social and emotional wellbeing in schools when rating/monitoring schools
- Undertake a needs assessment to consider what structural change may be required, to the education system, to fully realise the potential of education to reduce intergenerational socioeconomic inequality
- Consider whether resourcing of schools is sufficient to need.

National – Health:

- Work with the education sector to develop joint plans for enhancing social and emotional wellbeing in childhood. Incorporate these in any health 'prevention' plans at national, regional and local level
- Link obesity and mental health strategies to educational strategies.

National - cross government:

- Develop a child and adolescent strategy which focuses on reducing socioeconomic inequality in development and health
- Encourage health and education sectors to have joint plans around children's wellbeing
- Better use the state/individual interaction during the school year for overall population health gain e.g. consider things such as feeding all children nutritious food through for example universal Free School Meals, better resource school outreach to reduce pupil absence (particularly post COVID)
- Fully commit to levelling up plans (these are plans to reduce socioeconomic inequalities in different regions of the UK)

6.7. Conclusion

Overall, the findings suggest that there are inequalities in children's socioemotional and cognitive development when studied concurrently and as separate developmental domains. This socioeconomically driven adverse development, if unresolved, will have a negative impact on weight and mental health in early and late adolescence and highlights the importance of redressing disadvantage throughout childhood. There is a relationship between development and health after accounting for disadvantage and this highlights the importance of the development of capabilities to help mitigate the effect of disadvantage. Socioemotional development in children is the main driver of the impact on adolescent health. Child and adolescent health policy, with a central focus on social and emotional wellbeing of children using prevention and mitigation approaches, is needed to improve health and reduce health inequalities in adolescents.

6.8. Researcher reflections

Undertaking this PhD has been the most enjoyable experience of my career to date. Having the time and resource to contribute to research, develop myself and be challenged by and challenge others has been a fantastic opportunity for which I am very grateful to both the funder and ScHARR.

Identifying and articulating a research gap is incredibly intense and requires a depth of understanding and engagement with other people's work. I had very much underestimated that requirement when I first started to consider doing a PhD. However that engagement and understanding has been extremely interesting, satisfying and rewarding. Developing my own knowledge in the field has been a journey and now at the 'end' there are times when I feel I know less than I did at the beginning but on reflection I think this is because I have engaged so much with the work of others, I can see more of the gaps in knowledge that I was so desperately seeking at the outset.

The level of detail required to do good research is immense. From which measures to select and how to analyse them and all the 'micro' decisions along the way were tremendous and all bring their own uncertainties and assumptions to analysis. I have a new appreciation for understanding and critiquing research.

The trepidation of putting findings 'out there' is daunting and beset by the issues described in the previous two paragraphs. I have tried to rest with this by simplifying my findings so that they are easy to understand, being explicit about limitations but also being assured that as decisions are made all the time on very little evidence providing evidence and being confident about what it means (and doesn't mean) has got to be helpful to others. Therefore I have tried as much as possible to share findings through networks as difficult as that has been at times because of chasing 'perfection' which does not exist.

I hope to continue to read, learn, listen, develop, support others and generate more research. It has been an absolute pleasure.

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Appendices

Appendix 1: Summary of Author Contributions

Paper	Study Conceptualisation	Data gathering	Data Extraction/Screening	Quality Assessment	Analysis	Interpretation	Writing – original draft	Writing – review and editing
Protocol	MB with input from AB, MS, DTR	MB	-	-	-	-	MB	MB, AB, MS, DTR
Systematic Review	MB with input from AB, MS, DTR	MB	MB, AB, CF, BH, AR, AB	MB, BH, CF, AB	MB, AB	MB with input from AB	MB	MB, AB, MS, DTR, CF, BH, AR, AB
Longitudinal Analysis	MB with input from AB, MS, DTR	MB, NA	-	-	MB, NA	MB with input from NA, HJ, MS	MB	MB, AB, MS, DTR, HJ, NA

MB – Michelle Black AB – Amy Barnes MS – Mark Strong DTR – David Taylor-Robinson CF – Clare Foster BH – Ben Holden AR – Anna Ray AB – Anna Brook HJ – Hannah Jordan

NA – Nicholas Adjei

Appendix 2: Permission to reproduce publications in this thesis

Paper 1: Protocol Paper

On Tue, 8 Nov 2022 at 14:43, Journalpermissions <journalpermissions@springernature.com> wrote:
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doi: https://doi.org/10.1186/s13643-021-01694-6

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Paper 2: Systematic Review

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Appendix 3: Supplementary files for Paper 1 (Protocol)

Additional File 1: PRISMA-P 2015 Checklist

For: Impact of child development at primary school entry on adolescent health – protocol for a participatory systematic review(page numbers relate to published paper).

Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
ADMINISTRATIVE INFORMATION					
Title					
Identification	1a	Identify the report as a protocol of a systematic review	☒	☐	6
Update	1b	If the protocol is for an update of a previous systematic review, identify as such	☐	☐	N/A
Registration	2	If registered, provide the name of the registry (e.g., PROSPERO) and registration number in the Abstract	☒	☐	87
Authors					
Contact	3a	Provide name, institutional affiliation, and e-mail address of all protocol authors; provide physical mailing address of corresponding author	☒	☐	9-40
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review	☒	☐	489-491
Amendments	4	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments	☐	☐	N/A
Support					
Sources	5a	Indicate sources of financial or other support for the review	☒	☐	481-487
Sponsor	5b	Provide name for the review funder and/or sponsor	☒	☐	482
Role of sponsor/funder	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	☐	☐	N/A
INTRODUCTION					
Rationale	6	Describe the rationale for the review in the context of what is already known	☒	☐	94-196

Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
Objectives	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	☒	☐	207-216
METHODS					
Eligibility criteria	8	Specify the study characteristics (e.g., PICO, study design, setting, time frame) and report characteristics (e.g., years considered, language, publication status) to be used as criteria for eligibility for the review	☒	☐	256-304 and Table 1
Information sources	9	Describe all intended information sources (e.g., electronic databases, contact with study authors, trial registers, or other grey literature sources) with planned dates of coverage	☒	☐	239-250
Search strategy	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	☒	☐	Additional file 2
STUDY RECORDS					
Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review	☒	☐	251-255
Selection process	11b	State the process that will be used for selecting studies (e.g., two independent reviewers) through each phase of the review (i.e., screening, eligibility, and inclusion in meta-analysis)	☒	☐	258-363
Data collection process	11c	Describe planned method of extracting data from reports (e.g., piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators	☒	☐	363-372
Data items	12	List and define all variables for which data will be sought (e.g., PICO items, funding sources), any pre-planned data assumptions and simplifications	☒	☐	281-326 and Table 1
Outcomes and prioritization	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	☒	☐	307-326 and Table 1
Risk of bias in individual studies	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis	☒	☐	373-379 and 391-394
DATA					
Synthesis	15a	Describe criteria under which study data will be quantitatively synthesized	☐	☒	N/A

Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data, and methods of combining data from studies, including any planned exploration of consistency (e.g., I^2, Kendall's tau)	☐	☒	N/A
	15c	Describe any proposed additional analyses (e.g., sensitivity or subgroup analyses, meta-regression)	☒	☐	402-405
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned	☒	☐	381-401
Meta-bias(es)	16	Specify any planned assessment of meta-bias(es) (e.g., publication bias across studies, selective reporting within studies)	☐	☒	
Confidence in cumulative evidence	17	Describe how the strength of the body of evidence will be assessed (e.g., GRADE)	☒	☐	406-420

Additional File 2: Search Terms

Sample search strategy (Using obesity and mental health as example outcomes) for Impact of child development at primary school entry on adolescent health – protocol for a participatory systematic review.

Population	**Exposure**	**Outcome**
Child*	School adj3 read*	Weight
Infant*	Early years and ed*	Obes*
Adolesc*	Early years and child dev*	Mental Health
Teen*	Pre-school	Socioemotional behavio*
	Cognitive adj3 dev*	Social competence
	Math	
	Writing	
	Test scores	
	Achiev*	
	Socioemo*	
	Behavio*	
	Physical dev*	

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations and Daily <1946 to September 15, 2020>

Search Strategy:

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1 Child/ (1693243)

2 Adolescent/ (2034954)

3 Infant/ (793637)

4 Young Adult/ (857712)

5 teen*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (31116)

6 1 or 2 or 3 or 4 or 5 (3538881)

7 school read*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word,

protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (741)

8 (early years and child dev*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (227)

9 (early years and ed*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (851)

10 pre-school.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (4711)

11 (cognitve adj3 dev*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (0)

12 math*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (185812)

13 writing.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (37834)

14 test score.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (3201)

15 achiev*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1060284)

16 abilit*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (939244)

17 socioemo*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1781)

18 behaviour*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (289949)

19 physical dev*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (3168)

20 weight.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1093674)

21 obesity.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (329062)

22 mental health.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (196134)

23 socioemotional behaviour.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (4)

24 social comp*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (5981)

25 20 or 21 or 22 or 23 or 24 (1501079)

26 7 or 8 or 9 (1724)

27 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 (2412026)

28 26 and 27 (616)

29 25 and 28 (92)

Additional File 3 – Data Extraction Form

<table>
<tr>
<td>

Authors:

Country:

Study objectives:

Study design :

<table>
<tr><td>**Descriptive**</td><td></td></tr>
<tr><td>**RCT**</td><td></td></tr>
<tr><td>**Cohort**</td><td></td></tr>
<tr><td>**Sys. review**</td><td></td></tr>
<tr><td>**Longitudinal Analysis**</td><td></td></tr>
<tr><td>**Qualitative**</td><td></td></tr>
<tr><td colspan="2">**Other:**</td></tr>
</table>

Study population:

Contextual factors:

Data collection methods/sources:

</td>
<td>

Exposure and measurement instrument:

Outcomes and measurement instrument:

Health Inequalities/SES/Deprivation discussed?:

Mechanisms between exposure and outcome:

Moderators of the relationship between exposure and outcome:

Summary of Findings:

</td>
<td>

Main author conclusions:

Strengths:

Weaknesses:

</td>
</tr>
</table>

Appendix 4: Supplementary files for Paper 2 (Systematic Review)

Additional file 1: PRISMA 2020 Checklist

For: Relationships between child development at school entry and adolescent health – a participatory systematic review (page numbers relate to published paper)

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Pg1, Line 3
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Done
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Pgs 2,3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Pg 2, Line 133-136
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Pg 5, Table1
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Pg 6, Lines 201
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Pg 6, Lines 203-207 and Additional file 3

Section and Topic	Item #	Checklist item	Location where item is reported
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Pg 6, Lines 210 - 216
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Pg 6, Lines 217- 226 and additional file 5
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	P4, Lines 171-189 and table 1
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	P4, Lines 171-189 and table 1
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Pg 6, lines 227-242 and additional file 6
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Pg 6 & 7, Lines 252-279
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Pg 6 & 7, Lines 252-279

Section and Topic	Item #	Checklist item	Location where item is reported
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	n/a
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Pg 6 & 7, Lines 252-279
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Pg 6 & 7, Lines 252-279
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Pg 6 & 7, Lines 252-279
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	n.a
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Pg 6, lines 227-242
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Pg 6, lines 243-251
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Pg 7, lines 281-285 and Prisma diagram
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Additional file 4

Section and Topic	Item #	Checklist item	Location where item is reported
Study characteristics	17	Cite each included study and present its characteristics.	Pg 10, table 3
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Pg 19 lines 344-351 and additional file 9
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Page 20 Table 4 and additional file 8
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 20, table 4
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	n/a
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Not done
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Not done
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Additional file 9
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Pgs 22-28 throughout synthesis
DISCUSSION			

Section and Topic	Item #	Checklist item	Location where item is reported
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Pg 31 and 32
	23b	Discuss any limitations of the evidence included in the review.	Pg 33
	23c	Discuss any limitations of the review processes used.	Pg 33
	23d	Discuss implications of the results for practice, policy, and future research.	Pgs 32 and 33
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Pg 1, line 39
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Pg 3, line 140
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Pg 3, line 144. Pg 6, lines 228-231
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Pg 34, Line 942
Competing interests	26	Declare any competing interests of review authors.	Pg324, Line 952
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Pg 34, Line 947-948

Additional File 2: Initial Conceptual Model

Please refer to figure 1a in protocol paper (page 57 in thesis)

Additional File 3: Search Strategy

For Relationships between child development at school entry and adolescent health

Exposure	Outcome	Relationship	Studies
"school readiness"	((health outcome* or health behavio* or "executive function" or anx* or depress* or "social competence" or "self-esteem" or wellbeing or obesity or weight or "mental health" or health* or diet*) adj3 (child* or adolesc* or teen*))	(caus* or predict* or assoc* or correlat* or influence* or impact* or improve* or determin*)	(review* or cohort or longitudinal or long-term or "RCT" or "random* control* trial*" or epidemiol* or experiment*)
school adj3 read*			
early adj3 educat*			
"early child development"			
(child develop* adj3 (measure* or outcome*))			
((preschool or pre-school) adj4 (dev* or outcome))			
(cognit* adj3 (develop* or skill*) adj3 (child* or primary school*))			
(physical adj3 (develop* or skill*) adj3 (child* or primary school*))			
(language adj3 (develop* or skill*) adj3 (child* or primary school*))			
(emotion* adj3 (develop* or competen*) adj3 (child* or primary school*))			
(socioemotion* adj3 (develop* or competen*) adj3 (child* or primary school*))			
((IQ or math* or writing or "test score" or "exam score" or reading or vocabulary or literacy or numeracy or behavio* or self-regulation or achiev* or abilit*) adj3 (child* or primary school*))			

Medline (OVID) Search 12 Nov 2020:

Exposure AND Outcome = 13,622

Exposure AND outcome AND Relationship = 10381

Exposure AND outcome AND Relationship AND Studies = 5996

Limit to English language only and the last 30 years = 5734

Exposure	Outcome	Relationship	Studies
"school readiness"	((health outcome* or health behavio* or "executive function" or anx* or depress* or "social competence" or "self-esteem" or wellbeing or obesity or weight or "mental health" or health* or diet*) adj3 (child* or adolesc* or teen*))	(caus* or predict* or assoc* or correlat* or influence* or impact* or improve* or determin*)	(review* or cohort or longitudinal or long-term or "RCT" or "random* control* trial*" or epidemiol* or experiment*)
school adj3 read*			
early adj3 educat*			
"early child development"			
(child develop* adj3 (measure* or outcome*))			
((preschool or pre-school) adj4 (dev* or outcome))			
(cognit* adj3 (develop* or skill*) adj3 (child* or primary school*))			
(physical adj3 (develop* or skill*) adj3 (child* or primary school*))			
(language adj3 (develop* or skill*) adj3 (child* or primary school*))			
(emotion* adj3 (develop* or competen*) adj3 (child* or primary school*))			
(socioemotion* adj3 (develop* or competen*) adj3 (child* or primary school*))			
((IQ or math* or writing or "test score" or "exam score" or reading or vocabulary or literacy or numeracy or behavio* or self-regulation or achiev* or abilit*) adj3 (child* or primary school*))			

Psychinfo (OVID) Search 12 Nov 2020:

Exposure AND Outcome = 18,836

Exposure AND outcome AND Relationship = 14151

Exposure AND outcome AND Relationship AND Studies = 5455

Limit to English language only and the last 30 years = 5109

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noft(health outcome* OR health behavio* OR "executive function" OR anx* OR depress* OR "social competence" OR "self-esteem" OR wellbeing OR obesity OR weight OR "mental health" OR health* OR diet*) AND noft(adolesc* OR child* OR teen*) **AND** noft("school readiness" OR school adj3 read* OR early adj3 educat* OR "early child development") **AND** noft((caus* OR predict* OR assoc* OR correlat* OR influence* OR impact* OR improve* OR determin*))

Note: noft means not full text search

ASSIA (ProQuest) Search 12 Nov 2020:

Exposure AND Outcome = 656

Exposure AND outcome AND Relationship = 397

Limit to English language only and the last 30 years = 391

AB (school readiness or early child development or early adj3 educat*) OR AB (IQ or math* or writing or "test score" or "exam score" or reading or vocabulary or literacy or numeracy or behavio* or self-regulation or achiev* or abilit*) AND AB (child* or primary school) **AND** (adolescents or teenagers or young adults or child*) AND AB (health outcome* or health behavio* or "executive function" or anx* or depress* or "social competence" or "self-esteem" or wellbeing or obesity or weight or "mental health" or health* or diet*)) **AND** AB caus* or predict* or assoc* or correlat* or influence* or impact* or improve* or determin* **AND** (review* or cohort or longitudinal or long-term or "RCT" or "random* control* trial*" or epidemiol* or experiment*)

ERIC (EBSCO) Search 12 Nov 2020:

Exposure AND Outcome = 16330

Exposure AND outcome AND Relationship = 9582

Exposure AND outcome AND Relationship AND Studies = 5455

Limit to English language only and the last 30 years (and journal articles only) = 1307

Additional File 4: Study Selection: Excluded Studies with Reasons

Authors	Year	Title	Journal	Reason
Kouros, C. D., Cummings, E. M. and Davies, P. T.	2010	Early trajectories of interparental conflict and externalising problems as predictors of social competence in preadolescence	Development & Psychopathology	Exposure outside scope
Leech, Sharon L., Larkby, Cynthia A., Day, Richard and Day, Nancy L.	2006	Predictors and Correlates of High Levels of Depression and Anxiety Symptoms among Children at Age 10	Journal of the American Academy of Child and Adolescent Psychiatry	Exposure outside scope
Lloyd, Jennifer E. V., Li, Leah and Hertzman, Clyde	2010	Early experiences matter: Lasting effect of concentrated disadvantage on children's language and cognitive outcomes	Health & Place	Exposure outside scope
Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M. and Okely, A. D.	2010	Fundamental movement skills in children and adolescents: review of associated health benefits	Sports Medicine	Systematic review - relevant studies extracted
Lucia, V. C. and Breslau, N.	2006	Family cohesion and children's behaviour problems: a longitudinal investigation	Psychiatry Research	Exposure outside scope
Mazza, James J., Abbott, Robert D., Fleming, Charles B., Harachi, Tracy W., Cortes, Rebecca C., Park, Jisuk, Haggerty, Kevin P. and Catalano, Richard F.	2009	Early Predictors of Adolescent Depression: A 7-Year Longitudinal Study	Journal of Early Adolescence	Exposure outside scope
McCormack, Jane, Harrison, Linda J., McLeod, Sharynne and McAllister, Lindy	2011	A Nationally Representative Study of the Association between Communication Impairment at 4-5 Years and Children's Life Activities at 7-9 Years	Journal of Speech, Language, and Hearing Research	Subset of children
D'Onise, K., Lynch, J. W., Sawyer, M. G. and McDermott, R. A.	2010	Can preschool improve child health outcomes? A systematic review	Social Science & Medicine	Systematic review - relevant studies extracted
Dodge, K. A., Godwin, J. and Conduct Problems Prevention Research, Group	2013	Social-information-processing patterns mediate the impact of preventive intervention on adolescent antisocial behaviour	Psychological Science	Subset of children
El Nokali, N. E., Bachman, H. J. and Votruba-Drzal, E.	2010	Parent involvement and children's academic and social development in elementary school	Child Development	Exposure outside scope
Drake, K., Belsky, J. and Fearon, R. M.	2014	From early attachment to engagement with learning in school: the role of self-regulation and persistence	Developmental Psychology	Outcome outside scope

Authors	Year	Title	Journal	Reason
Hedenbro, M.; Rydelius, P. A.	2019	Children's abilities to communicate with both parents in infancy were related to their social competence at the age of 15	Acta Paediatrica	Exposure outside scope
Helland, Siri Saugestad; Roysamb, Espen; Wang, Mari Vaage; Gustavson, Kristin	2018	Language difficulties and internalising problems: Bidirectional associations from 18 months to 8 years among boys and girls	Development and Psychopathology	Outcome outside scope
Hendricker, Elise; Reinke, Wendy M.	2017	Conceptualising Family Risk in a Racially/Ethnically Diverse, Low-Income Kindergarten Population	Contemporary School Psychology	Exposure outside scope
Hinkley, T.; Timperio, A.; Salmon, J.; Hesketh, K.	2017	Does Preschool Physical Activity and Electronic Media Use Predict Later Social and Emotional Skills at 6 to 8 Years? A Cohort Study	Journal of Physical Activity & Health	Exposure outside scope
Jamnik, M. R.; DiLalla, L. F.	2019	Health Outcomes Associated With Internalising Problems in Early Childhood and Adolescence	Frontiers in Psychology	Outcome outside age range
Jaspers, M.; de Winter, A. F.; Veenstra, R.; Ormel, J.; Verhulst, F. C.; Reijneveld, S. A.	2012	Preventive child health care findings on early childhood predict peer-group social status in early adolescence	Journal of Adolescent Health	Exposure outside age range
Kantomaa, Marko T.; Stamatakis, Emmanuel; Kankaanpaa, Anna; Kaakinen, Marika; Rodriguez, Alina; Taanila, Anja; Ahonen, Timo; Jarvelin, Marjo-Riitta; Tammelin, Tuija	2013	Physical activity and obesity mediate the association between childhood motor function and adolescents' academic achievement	PNAS Proceedings of the National Academy of Sciences of the USA	Exposure and Outcome outside age range
Kim, Hyunah; Chang, Hyein	2019	Longitudinal association between children's callous-unemotional traits and social competence: Child executive function and maternal warmth as moderators	Frontiers in Psychology Vol 10 2019, ArtID 379	Exposure outside scope
Mesman, J.; Koot, H. M.	2000	Child-reported depression and anxiety in preadolescence: II. Preschool predictors	Journal of the American Academy of Child & Adolescent Psychiatry	Exposure outside age range
Miller, A. B.; Machlin, L.; McLaughlin, K. A.; Sheridan, M. A.	2020	Deprivation and psychopathology in the Fragile Families Study: A 15-year longitudinal investigation	Journal of Child Psychology & Psychiatry & Allied Disciplines	Exposure outside scope
Nantel-Vivier, Amelie; Pihl, Robert O.; Cote, Sylvana; Tremblay, Richard E.	2014	Developmental association of prosocial behaviour with aggression, anxiety and depression from infancy to preadolescence	Journal of Child Psychology and Psychiatry	Exposure outside age range

Authors	Year	Title	Journal	Reason
Oberer, Nicole; Gashaj, Venera; Roebers, Claudia M.	2018	Executive functions, visual-motor coordination, physical fitness and academic achievement: Longitudinal relations in typically developing children	Human Movement Science	Outcome outside scope
Piche, G.; Fitzpatrick, C.; Pagani, L. S.	2015	Associations Between Extracurricular Activity and Self-Regulation: A Longitudinal Study From 5 to 10 Years of Age	American Journal of Health Promotion	Duplicate data from same author
Piek, J. P.; Barrett, N. C.; Smith, L. M.; Rigoli, D.; Gasson, N.	2010	Do motor skills in infancy and early childhood predict anxious and depressive symptomatology at school age?	Human Movement Science	Exposure outside age range
Pihlakoski, Leena; Sourander, Andre; Aromaa, Minna; Rautava, Paivi; Helenius, Hans; Sillanpaa, Matti	2006	The continuity of psychopathology from early childhood to preadolescence: A prospective cohort study of 3-12-year-old children	European Child & Adolescent Psychiatry	Subset of children
Pitzer, M.; Jennen-Steinmetz, C.; Esser, G.; Schmidt, M. H.; Laucht, M.	2011	Prediction of preadolescent depressive symptoms from child temperament, maternal distress, and gender: results of a prospective, longitudinal study	Journal of Developmental & Behavioural Pediatrics	Exposure outside age range
Prior, M.; Smart, D.; Sanson, A.; Oberklaid, F.	2001	Longitudinal predictors of behavioural adjustment in pre-adolescent children	Australian & New Zealand Journal of Psychiatry	Exposure outside age range
Rende, Richard D.	1993	Longitudinal relations between temperament traits and behavioural syndromes in middle childhood	Journal of the American Academy of Child & Adolescent Psychiatry	Exposure outside age range
Sanson, Ann; Hemphill, Sheryl A.; Smart, Diana	2004	Connections between Temperament and Social Development: A Review	Social Development	Literature review but no specific data to ages of interest
Seeyave, D. M.; Coleman, S.; Appugliese, D.; Corwyn, R. F.; Bradley, R. H.; Davidson, N. S.; Kaciroti, N.; Lumeng, J. C.	2009	Ability to delay gratification at age 4 years and risk of overweight at age 11 years	Archives of Pediatrics & Adolescent Medicine	Exposure outside scope
Sourander, A.; Helstela, L.	2005	Childhood predictors of externalising and internalising problems in adolescence. A prospective follow-up study from age 8 to 16	European Child & Adolescent Psychiatry	Exposure and Outcome outside age range
Sulik, M. J.; Blair, C.; Mills-Koonce, R.; Berry, D.; Greenberg, M.; Family Life Project, Investigators	2015	Early Parenting and the Development of Externalising Behaviour Problems: Longitudinal Mediation Through Children's Executive Function	Child Development	Outcome outside age range

Authors	Year	Title	Journal	Reason
te Velde, S. J.; van Nassau, F.; Uijtdewilligen, L.; van Stralen, M. M.; Cardon, G.; De Craemer, M.; Manios, Y.; Brug, J.; Chinapaw, M. J.; ToyBox-study, group	2012	Energy balance-related behaviours associated with overweight and obesity in preschool children: a systematic review of prospective studies	Obesity Reviews	Systematic review - relevant studies extracted
Tearne, J. E.; Allen, K. L.; Herbison, C. E.; Lawrence, D.; Whitehouse, A. J.; Sawyer, M. G.; Robinson, M.	2015	The association between prenatal environment and children's mental health trajectories from 2 to 14 years	European Child & Adolescent Psychiatry	Exposure outside age range
Tinsley, B. J.	1992	Multiple influences on the acquisition and socialization of children's health attitudes and behaviour: an integrative review	Child Development	Theory paper but limited relevance to the RQ
Trentacosta, C. J.; Fine, S. E.	2010	Emotion Knowledge, Social Competence, and Behaviour Problems in Childhood and Adolescence: A Meta-Analytic Review	Social Development	Exposure and Outcome outside age range
Troller-Renfree, S. V.; Buzzell, G. A.; Bowers, M. E.; Salo, V. C.; Forman-Alberti, A.; Smith, E.; Papp, L. J.; McDermott, J. M.; Pine, D. S.; Henderson, H. A.; Fox, N. A.	2019	Development of inhibitory control during childhood and its relations to early temperament and later social anxiety: unique insights provided by latent growth modeling and signal detection theory	Journal of Child Psychology & Psychiatry & Allied Disciplines	Exposure outside age range
Uszynska-Jarmoc, Janina	2007	Self-Esteem and Different Forms of Thinking in Seven and Nine Year Olds	Early Child Development and Care	Exposure outside scope
Vazsonyi, A. T.; Huang, L.	2010	Where self-control comes from: on the development of self-control and its relationship to deviance over time	Developmental Psychology	Exposure outside scope
Visser, L.; de Winter, A. F.; Vollebergh, W. A.; Verhulst, F. C.; Reijneveld, S. A.	2015	Do child's psychosocial functioning, and parent and family characteristics predict early alcohol use? The TRAILS Study	European Journal of Public Health	Exposure outside age range
Vlahov, Eric; Baghurst, Timothy M.; Mwavita, Mwarumba	2014	Preschool motor development predicting high school health-related physical fitness: A prospective study	Perceptual and Motor Skills	Outcome outside age range
Wang, Cen; Williams, Kate E.; Shahaeian, Ameneh; Harrison, Linda J.	2018	Early Predictors of Escalating Internalising Problems across Middle Childhood	School Psychology Quarterly	Subset of children
Wang, Yiji; Dix, Theodore	2017	Mothers' Depressive Symptoms in Infancy and Children's Adjustment in Grade School: The Role of Children's Sustained Attention and Executive Function	Developmental Psychology	Exposure outside scope

Authors	Year	Title	Journal	Reason
Warren, A. S.; Goldsmith, K. A.; Rimes, K. A.	2019	Childhood gender-typed behaviour and emotional or peer problems: a prospective birth-cohort study	Journal of Child Psychology & Psychiatry & Allied Disciplines	Exposure outside scope
Watts, Tyler W.; Gandhi, Jill; Ibrahim, Deanna A.; Masucci, Michael D.; Raver, C.	2018	The Chicago School Readiness Project: Examining the long-term impacts of an early childhood intervention	PLoS ONE	Exposure outside scope
Weeks, Murray; Cairney, John; Wild, T.; Ploubidis, George B.; Naicker, Kiyuri; Colman, Ian	2014	Early-life predictors of internalising symptom trajectories in Canadian children	Depression and Anxiety	Exposure outside scope
Weeks, Murray; Ploubidis, George B.; Cairney, John; Wild, T.; Naicker, Kiyuri; Colman, Ian	2016	Developmental pathways linking childhood and adolescent internalising , externalising, academic competence, and adolescent depression	Journal of Adolescence	Outcome outside age range
Wirt, T.; Hundsdorfer, V.; Schreiber, A.; Kesztyus, D.; Steinacker, J. M.; Komm mit in das gesunde Boot - Grundschule" - Research, Group	2014	Associations between inhibitory control and body weight in German primary school children	Eating Behaviours	Study design
Woodward, L. J.; Lu, Z.; Morris, A. R.; Healey, D. M.	2017	Preschool self regulation predicts later mental health and educational achievement in very preterm and typically developing children	Clinical Neuropsychologist	Exposure outside age range
Xue, Y.; Leventhal, T.; Brooks-Gunn, J.; Earls, F. J.	2005	Neighborhood residence and mental health problems of 5- to 11-year-olds	Archives of General Psychiatry	Exposure outside scope
Sabol, T. J.; Pianta, R. C.	2011	Patterns of School Readiness Forecast Achievement and Socioemotional Development at the End of Elementary School	Child Development	Study design

Additional File 5: Study Selection: Data Extraction Form

<table>
<tr>
<td>Authors:

Country:

Study objectives:

Study design :
<table>
<tr><td>Descriptive</td><td></td></tr>
<tr><td>RCT</td><td></td></tr>
<tr><td>Cohort</td><td></td></tr>
<tr><td>Sys. review</td><td></td></tr>
<tr><td>Longitudinal Analysis</td><td>X</td></tr>
<tr><td>Qualitative</td><td></td></tr>
<tr><td colspan="2">Other:</td></tr>
</table>
Study population: (including gender split and year recruited)

Contextual factors:

Data collection methods/sources:</td>
<td>Exposure, age and measurement instrument:

Mediating Variables:

Outcomes, age and measurement instrument:

Association and effect size:

Co-variates/Confounders:

Mechanisms between exposure and outcome:

Moderators of the relationship between exposure and outcome:

Summary of Findings:</td>
<td>Main author conclusions:

Strengths:

Weaknesses:</td>
</tr>
</table>

Additional File 6: Quality Assessment Form

STUDY ID	Main Author and date	EXTRACTED BY		EXTRACTION DATE	DD	MM	YY

METHODOLOGICAL QUALITY APPRAISAL (adapted from previously used assessments in systematic reviews[1,2]

Relationships between child development at school entry and adolescent health: A participatory systematic review

Quality Assessment Criteria	I/V/P	+/-/?
Study Population		
1. Adequate* description of sampling frame[†]	I	
2. Participation rate at baseline at least 80%, or evidence that the non-response is not selective	V	
3. Adequate* description of baseline study sample[†]	I	
Study Attrition		
4. Provision of the number of participants at each follow up	I	
5. Provision of information on follow-up duration	I	
6. Response at follow up was at least 70% of the number of participants at baseline	V	
7. Not selective non-response during follow-up assessments[‡]	V/P	
Data collection		
8. Measurement of exposures using objective or valid and reliable measures[§]	V	
9. Measurement of outcomes using objective or valid and reliable measures[§]	V	
Data Analysis		
10. Appropriate statistical model used	V/P	
11. The majority of known confounders in the model	V/P	
12. Presentation of point estimates and measures of variability (confidence intervals)	I	
Quality Ranking: Low , Moderate , High		

* Adequate = sufficient information to be able to repeat the study.

[†] '+' is given only if adequate information is given in the text on all items.

[‡] '+' is given only if non-selective dropout study sample does not significantly differ from study population on key characteristics or results are adjusted for selective non-response (via appropriate missing data imputation procedures).

[§] (+ = objective or valid/reliable measurements for the relevant measures – author stated validity and reliability and reference)

^ '+' is given if gender, measure of SES such as family income/Maternal education, maternal mental health and baseline outcome measure at age of exposure (for cross domain only). If a major confounder is missing this is a red flag item and the study is rated low.

I/V/P criterion: Informativeness (relates to clarity of study description), Validity and Precision (relate to risk of bias).

Notes: Assigning the quality ranking*: V and P criteria should strongly guide the overall quality ranking and carry a greater weight than I. For example all V and P with minimal I would indicate high quality, whereas all I and minimal V and P would indicate low quality*

Studies with limited reporting of method or results, those with minimal or no confounders and those with high attrition and no adjustment made for non-response or missing data are judged to have a high risk of bias and rated to be of low methodological quality. Those with adequate reporting, most measurement instruments valid, some confounders and adjustments made for non-response and missing data should be rated as moderate. Those with clear reporting, all measurement instruments valid, a comprehensive list of confounders and adjustments made for non-response and missing data are considered to have a low risk of bias/high quality.

[1] Hoogendoorn WE, van Poppel MN, Bongers PM *et al*. Systematic review of psychosocial factors at work and private life as risk factors for back pain. *Spine (Phila Pa 1976)* 2000; 25: 2114–2125.

[2] te Velde, S.J., van Nassau, F., Uijtdewilligen, L *et al*. Energy balance-related behaviours associated with overweight and obesity in preschool children: a systematic review of prospective studies. *Obesity Reviews*, 2012, 13: 56-74.

Additional File 7 – Data Synthesis: SwiM checklist

For: Relationships between child development at school entry and adolescent health – a participatory systematic review (page numbers relate to published paper)

SWiM is intended to complement and be used as an extension to PRISMA			
SWiM reporting item	**Item description**	**Page in manuscript where item is reported**	**Other***
Methods			
1 Grouping studies for synthesis	1a) Provide a description of, and rationale for, the groups used in the synthesis (e.g., groupings of populations, interventions, outcomes, study design)	Page 7	
	1b) Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis	N/A	
2 Describe the standardised metric and transformation methods used	Describe the standardised metric for each outcome. Explain why the metric(s) was chosen, and describe any methods used to transform the intervention effects, as reported in the study, to the standardised metric, citing any methodological guidance consulted	Page 7	
3 Describe the synthesis methods	Describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis of effect estimates	Page 7	
4 Criteria used to prioritise results for summary and synthesis	Where applicable, provide the criteria used, with supporting justification, to select the particular studies, or a particular study, for the main synthesis or to draw conclusions from the synthesis (e.g., based on study design, risk of bias assessments, directness in relation to the review question)	Page 7 & 19	

SWiM reporting item	Item description	Page in manuscript where item is reported	Other*
5 Investigation of heterogeneity in reported effects	State the method(s) used to examine heterogeneity in reported effects when it was not possible to undertake a meta-analysis of effect estimates and its extensions to investigate heterogeneity	Page 7	
6 Certainty of evidence	Describe the methods used to assess certainty of the synthesis findings	Page 6	
7 Data presentation methods	Describe the graphical and tabular methods used to present the effects (e.g., tables, forest plots, harvest plots). Specify key study characteristics (e.g., study design, risk of bias) used to order the studies, in the text and any tables or graphs, clearly referencing the studies included	Page 7	
Results			
8 Reporting results	For each comparison and outcome, provide a description of the synthesised findings, and the certainty of the findings. Describe the result in language that is consistent with the question the synthesis addresses, and indicate which studies contribute to the synthesis	Table 4 and pages 22-26	
Discussion			
9 Limitations of the synthesis	Report the limitations of the synthesis methods used and/or the groupings used in the synthesis, and how these affect the conclusions that can be drawn in relation to the original review question	Page 31	

PRISMA=Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
*If the information is not provided in the systematic review, give details of where this information is available (e.g., protocol, other published papers (provide citation details), or website (provide the URL)).

Additional File 8: Results: Table of included study characteristics

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics)*	Factors which moderate the association
Ashford et al 2008	Longitudinal	Holland	294 children	Behaviour internalising and externalising - age 4	Child Behaviour Checklist (CBCL) - parent and teacher rated.	Internalising behaviours - age 11	CBCL – parent and teacher report.	Externalising and internalising problems both associated with internalising problems with an IRR of 2.81 ($p<0.001$) and 3.83 ($p<0.001$) respectively. Four risk indicators (low SES, parenting stress at age 4-5, internalising at age 4-5 and family psychopathology age 2-3) associated with internalising behaviours and together resulted in a total AF of 57%, implying that with this set of risk indicators, 57% of the future cases of internalising problems can be identified.	-	Low SES and parenting stress also predict the outcome.
Berthelsen et al 2017	Longitudinal	Australia	4819 Children from the Growing up in Australia: The Longitudinal Study of Australian Children.	Child Behaviour at age 4-5 and early ecological risk factors SEP, MMH, Parenting anger, parenting warmth, parenting consistency.	Child behaviour risk index measured as the sum of scores: sleep (parent report), emotional dysregulation (parent report) and inattention/	Executive Function (age 14-15).	A composite score from three Cogstate computerised tasks for assessing cognition and measured visual attention, visual working memory and	Negative association between child behaviour risk index and executive function ($\beta = -0.09$). Full model (all early ecological risk factors): Total effects on EF for child behaviour risk ($\beta=-0.07$) and attentional regulation ($\beta = 0.13$) $p<0.001$ for both. Attentional regulation at 4–5 years ($\beta = 0.10$) and approaches to learning at	Attentional regulation and approaches to learning mediated the relationship between behavioural risk and EF.	Low SEP is an additional risk factor for lower EF. Poorer maternal mental health and parenting also associated indirectly with EF via effect on children's self-regulation skills.

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					hyperactivity symptoms (mother rated)		spatial problem solving.	6–7 years (β = 0.18) were both directly associated with executive function at 14–15 years.		
Bornstein et al 2010	Longitudinal	US east coast	118 European American families with children aged 4	Social competence at age 4	Social competence as a construct, of: the peer acceptance subscale of the Pictorial Scale of Perceived Competence and Social Acceptance Preschool Form, the Friendship Interview, and the socialization domain of the Vineland Adaptive Behaviour Scales (VABS).	Internalising and externalising behaviours at age 10 and 14	At age 10 years - the CBCL and Teacher Report Form. At age 14 years - the CBCL and Youth Self-Report.	Social competence predicted: • Externalising behaviours at age 14 (β =-0.14, p<0.05), mediated by internalising and externalising behaviours at age 10 • Internalising behaviour at age 14 (β= -0.09, p < 0.05) mediated by internalising behaviours at age 10.	Social competence at age 4 predicts externalising and internalising behaviours at age 14. For externalising behaviour this relationship is mediated by internalising and externalising behaviour at age 10. For internalising behaviour the relationship is mediated by internalising behaviours only.	
Bornstein et al 2013	Longitudinal	US east coast	224 European American families - two studies (Study 2	Language – communication skills - at age 4	Two verbal subtests of the Wechsler Preschool and Primary	Internalising and externalising behaviour	At age 10 years - the CBCL and Teacher Report Form. At age 14	Language skills predicted age 14-year internalising behaviour problems (β= –0.12, p < .005), mediated by 10-year internalising behaviour problems.	Age 10-year internalising behaviour problems mediate the relationship between language skills at age	

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
			extracted only - 139 children)		Scale of Intelligence—Revised and the VABS	s at age 10 and 14	years - the CBCL and Youth Self-Report.	Language skills did not predict externalising behaviour problems.	4 and internalising problems at age 14.	
Derks et al 2019	Cohort	The Netherlands	Three population cohort studies: only 1 relevant study: Generation R study, 3794 children aged 6-10 in The Netherlands	Aggressive behaviour - at ages 5-7, 10 and 14	CBCL - mother rated	BMI and body composition (fat mass and fat free mass) - at ages 6 and 10	BMI - the Dutch national reference in the Growth Analyser program. FM and FFM - dual-energy x-ray absorptiometry scanner	Aggressive behaviour at age 6 years was associated with higher BMI at age 10 years (β = 0.02, 95% CI: 0.00 to 0.04) and higher FMI at age 10 years β = 0.03, 95% CI: 0.01 to 0.05). No association found in the opposite direction.	*Eating behaviour (self-regulation) and aggressive behaviour are regulated by the same neurotransmitter pathways. Children with aggressive behaviour may also have deficits in self-regulation leading to over eating and obesity. Other mechanisms proposed: Aggressive behaviour and BMI share genetic vulnerabilities and the mechanism of parenting with parents using food to cope with challenging behaviour of children.*	

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics)*	Factors which moderate the association
Duchesne et al 2010	Longitudinal	Canada	2000 children from the Quebec Longitudinal Study of Kindergarten Children	Behaviour - hyperactivity, inattention, aggressiveness and prosociality - age 6 Maternal warmth and maternal control also studied.	Social Behaviour Questionnaire (SBQ) - teacher rated	Trajectory of anxiety at age 11-12	Rated annually from kindergarten to Grade 6 using the Anxiety Scale from the SBQ – teacher report. Children put into trajectory of anxiety.	Children grouped into trajectory of anxiety. Probability of being in the 'high anxiety' group was greater for children facing adversity (odds ratio = 3.46, $p < .001$) and who were inattentive in the classroom (odds ratio = 6.24, $p < .001$). Probability of belonging to this group was lower for children who were socially competent (odds ratio = 0.66, $p < .05$). Children whose mothers tended to apply rules and control their behaviours had a greater probability of belonging to the high group (odds ratio = 1.07, $p < .05$). The probability of belonging to the high group was higher for hyperactive children interacting with mothers who showed little affective warmth.	-	Hyperactive children less likely to be anxious in grade 6 if there was a warm mother/child relationship – protective mechanism at play. Maternal discipline (rules and efforts to control child behaviours) associated with higher anxiety.
Fine et al 2003	Longitudinal	US	154 children from economically disadvantaged families	Emotional knowledge, internalising and ext behaviours age 7	Emotion knowledge – composite score from two tasks: 1. Emotional labelling – ability to label facial	Internalising behaviours age 11	Child self-report aggregate of the following measures: Depression - Children's Depression Inventory	Teacher reported externalising behaviours at age 7 predicted child anxiety self-report at age 11 ($\beta = .26$, $p < .01$). Internalising behaviours did not. Emotion knowledge at age 7 significantly predicted	*In mid-childhood when connections between emotions and cognition are developing, poor emotional knowledge may lead to negative emotional patterns leading to*	

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics)*	Factors which moderate the association
					expressions 2. Emotion situation knowledge – ability to label a protagonist in a story Internalising and externalising behaviours – CBCL (teacher report)		(CDI) Anxiety - The State-Trait Anxiety Inventory Loneliness. The Loneliness Scale Negative emotions – Differential emotions scale	anxiety self-reports at age 11 (β = −.23, p < .05).	*internalising problems. . Indirect mechanisms may include peer relations and social behaviour.*	
Glaser et al 2011	Longitudinal	UK	5250 children from the ALSPAC study, UK	IQ age 8	Wechsler Intelligence Scale for Children	Depression symptoms - age 11, 13, 14 and 17	Self-reported depressive symptoms were measured with the 13-item Short Mood and Feelings Questionnaire (SMFQ) Moderator: Pubertal stage at 11, 13 and 14 years was measured using a five-point rating scale	An increase in 1 s.d. of baseline IQ was associated with a 7% decrease in depression symptoms [SCR=0.93, 95% (CI) 0.92-0.95]. This association changed direction at ages 13 and 14 years such that an increase in 1 s.d. of baseline IQ was associated with a 4% (SCR=1.04, 95% CI 1.02-1.06) and 3% increase (SCR=1.03, 95% CI 1.02-1.05) in depression symptoms, respectively	*The authors speculate that the reappearance of the protective effect of higher childhood IQ in early adulthood, as observed for females at age 17 years, could reflect the end of pubertal development as, for example, biological stress-management systems improve during puberty.*	Association varies depending on pubertal stage - mimics the relationship by age but weaker for males than females by age 17.

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Gregory et al 2020	Longitudinal	Australia	3906 children - mainly caucasian	School readiness across 5 domains (physical, social, emotional, language and cognitive, communication and general knowledge) - Age 5	Australian version of the Early Development Instrument – teacher rated. Children scored as vulnerable, at risk or on-track.	Age 11: four aspects of student wellbeing (life satisfaction, optimism, sadness and worries)	Middle Years Development Instrument - child self-report	Children classed as vulnerable in physical, social and emotional development had lower levels of life satisfaction and optimism and higher levels of sadness and worries compared to children classed as at risk. For the language and cognitive, communication and general knowledge domains the association was with sadness and worries only (lower levels of development associated with more worries). (For all $p<0.05$ or < 0.01)		In most cases, effect estimates were attenuated after adjusting for child and family level confounders. (SES, gender, Aboriginal and/or Torres Strait Islander status, language background other than English (LBOTE), parental education.
Hay et al 2003	Longitudinal	UK	134 children age 4 from two urban communities in London	Co-operation (one form of prosocial behaviour) at age 4	Tester's rating of cooperativeness during the cognitive test (Tester's Rating of Children's Behaviour) and an observational measure of cooperation with the mother during the	Internalising and externalising behaviour problems – at age 11	SDQ and CAPA (Child and Adolescent Psychiatric Assessment).	Children who were more cooperative with their mothers at age 4 had fewer externalising problems at age 11, r(108)5 – 30, p<.002. There was no association between cooperation at age 4 and internalising problems at age 11	*Authors suggest that active cooperation reflects emotionally regulated, socially competent engagement with the social environment may set the child on a course of successful interactions that promote general psychological adjustment.*	Maternal depression decreased prosocial behaviour in the eyes of adults, but children of depressed mothers saw themselves to be prosocial.

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
					Etch-A-Sketch task.					
Hooper et al 2003	Longitudinal	US	74 African American Children	Language - receptive and expressive language, receptive vocab and working memory - age 5 and 7-8 (kindergarten and second grade)	Receptive and expressive language - The Clinical Evaluation of Language Fundamentals. Receptive vocab (Peabody test) and Working memory (Competing Language Processing Task)	Behaviour problems – externalising problems (conduct and hyperactivity) - kindergarten, first, second, and third grade	Teachers completed assessments of the children's behaviour i using a standardized scale of behaviour - Conners' Teacher Rating Scale-Revised	Language and conduct problems: By the time the children reached 9 years of age, the relationship between receptive language and Conduct Problems was significant, $\beta = -0.47$, $p < .01$ Language and hyperactivity: None of the three language measures was found to be a significant predictor of Hyperactivity at any age studied.	-	
Howard et al 2018	Cohort	Australia	4983 kindergarten children from the Longitudinal Study of Australian	Self-regulation - age 4-5 and 6-7	Self-regulation problems were indexedby combining parent-, teacher-,	Academic and weight, mental health, substance use,	• Academic achievement - children's total scores on the Year 9 National Assessment Program -	• Self-regulation problems at 4 to 5 years and at 6 to 7 years were significantly associated with each adolescent outcome. A 1-unit increase in self-regulation problems at either age was associated	*Social Cognitive Theory*	

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
			Children (LSAC)		and interviewer-report ratings of children's self-regulatory behaviours	crime, self-harm and suicidal ideation - age 15	Literacy and Numeracy • Mental health problems were measured in a private face-to-face interview with the parent/carer who knew the adolescent best • Overweight and obesity status was calculated using height and weight which were converted to body mass index scores and used to calculate overweight and obese categories	with one-fifth of an SD reduction in reading and numeracy scores 1 decade later. • Self-regulation problems were associated with a 1.2- to 1.4-times increase in the risk of being an overweight or obese adolescent. Change in early self-regulation (reduced problems) had no effect on the association. • 1 SD increase in self-regulation problems was associated, in adolescence, with a more than a 2-times increase in the risk of self-harm ideation and behaviour, suicidal ideation, and school truancy; almost a 2-times increase in mental health problems, smoking, and violent and property crime; and more than a 1.5-times risk of alcohol use. Change in self-regulation: the association with earlier self-regulation problems was no longer found.		

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Howes et al 2000	Longitudinal	US	307 pre-school children in a longitudinal study	Preschool social—emotional climate, Peer play, Behaviour problems, Teacher-child relationship quality - Age 4	Preschool social—emotional climate - average of children's scores on selected measures within a classroom. Peer play – peer play scale Behaviour problems – classroom behaviour inventory (CBI) Teacher perceptions of their relationship with the child were assessed with the Pianta Student Teacher Relationship Scale	Social competence - Behaviour with peers at age 8	Teacher reports using the Cassidy and Asher Teacher Assessment of Social behaviour Questionnaire	Children's second grade social competence with peers ratings could be predicted by preschool classroom social-emotional climate, four year-old behaviour problems and child-teacher relationship quality.	*Attachment theory and attention to the social context of the classroom*	

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics)*	Factors which moderate the association
Jaspers et al 2010	Longitudinal (retrospective)	Holland	2139 children aged 11 in the TRacking Adolescents' Individual Lives Survey (TRAILS)	Behavioural features at age 4 - 'sleeping, eating, and enuresis problems' and 'emotional and behaviour problems'	Assessed by Preventative Child Healthcare professionals.	Behavioural and emotional problems at age 10 to 12	CBCL - parent completed.	Behaviour problems and attention problems predicted externalising problems with an adj OR 2.3 (1.2-4.2) and 2.1 (1.3-3.3) respectively. The behaviours did not predict internalising problems.		Low level of education of the father, and being male were identified as significant independent determinants of clinical externalising problems. Sleep problems (at age 4), maternal smoking during pregnancy, being male were independent determinants of clinical internalising problems
Lecompte et al 2014	Longitudinal	Canada	68 children from SE diverse parts of Montreal	Emotional wellbeing - Child-parent attachment at age 3-4	Lab based separation reunion procedure	Anxiety and depressive symptoms and self-esteem (age 11-12)	Dominic Interactive Questionnaire -computerised self-report measure of common mental health disorders in childhood. Self-esteem - self-perception	Disorganized attachment compared to secure: • Higher Anxiety Symptoms: $\beta = -2.88$, $p < .05$ • Higher Depressive symptoms: $\beta = -3.27$, $p < .01$ • Lower Self-esteem $\beta = 2.61$, $p < .05$	Disorganized attachment associated with higher anxiety and depression in pre-adolescence. The effect was partially mediated by self-esteem for depression but not anxiety.	

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							profile for children - self-report			
Lee et al 2017	Longitudinal	US	762 Children from the Fragile Family and Wellbeing Study	Behaviour internalising and externalising - age 5	CBCL - primary caregiver completed	Behaviour internalising and externalising - age 9	CBCL - primary caregiver completed	• Internalising behaviour problems at age 5 were more likely to show higher internalising behaviour problems at age 9, β = .44, p < .001. • Externalising behaviour problems at age were more likely to show higher externalising behaviour problems at age 9. (β = .45, p < .001) • Fathers' greater positive engagement reduced the association between poverty and internalising behaviour problems at age 9, β = –.08, p = .014 and for externalising problems (β = –.08, p = .008) • For families experiencing greater poverty fathers' positive engagement was associated with a reduction in the continuity of internalising problems from 5 to 9 years of age.		Poverty: Greater internalising and externalising probs were seen for children living in poverty but this was buffered by father's positive engagement. In addition continuity of internalising problems is weakened by father's positive engagement for children living below the poverty line- *via secure attachment and development of emotional and behavioural regulation skills.*

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Louise at al 2012	Longitudinal	Western Australia	2900 children of Women in the Western Australian Pregnancy Cohort (Raine) Study - majority caucasian	Behaviour - aggressive - age 5, 8, 10 and 14	CBCL, youth self-report at age 14 and teacher report at age 10 and 14	Weight at age 5, 8,10 and 14	Weight - Wedderburn digital chair scale Height was measured using Holtain Stadiometer. BMI was calculated as weight (kg)/height2 (m2). Blood pressure was measured using a Dinamap electronic blood pressure recorder.	• Girls with higher aggressive behaviour scores throughout childhood had a higher rate of change of their BMI. This association persisted after adjusting for race and family income (βage × agg score = 0.005 kg/m2; 95% CI: 0.002, 0.008; P = 0.001). • Boys with higher aggressive behaviour scores throughout childhood had a lower rate of change in their systolic blood pressure This association persisted after adjusting for BMI (βage × agg score = −0.021 mmHg/year; 95% CI: −0.037,−0.005; P = 0.010). • No associations were detected between aggressive behaviour scores and BMI trajectories in boys, systolic blood pressure trajectories in girls or diastolic blood pressure trajectories in either boys or girls	*Aggression and BMI: mechanism proposed is that aggression and BMI may be linked by a common environmental (e.g. low self-esteem) or biological factor (e.g. leptin)* *Aggression and BP Physical aggressive behaviours such as arguing, attacking and fighting are assessed by CBCL, YSR and TRF in this study. As such, suppressed aggression maybe associated with hypertension, whereas physical expression of aggressive behaviour may be associated with lower systolic blood pressure*	

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McKenzie et al 2002	Longitudinal	USA	207 Mexican American and Anglo-American Children in the San Diego Study of Children's Activity and Nutrition (SCAN) project	Fundamental movement skills - Balance, agility, eye-hand coordination - age 4,5 and 6	Movement skill tests in the child's home	Physical Activity - age 12	Trained assessors administered the 7-day Physical Activity Recall (PAR) in the child's home on two occasions, approximately 6 months apart.	Movement skill performances of the children at ages 4-6 years did not predict physical activity levels at the age of 12 years.	*The authors state that physical activity and movement skills are modifiable through interventions, including school PE and sports. The physical education and sport instruction the children received after the age of 6 years may have reduced the tracking of movement performances and the relationship of early skills to later physical activity engagement.*	
Meagher et al 2009	Longitudinal	USA	56 children from childcare centres in New England - majority socially disadvantaged	Socioemotional behaviours observed in pre-school – age 4	Externalising and internalising symptoms from the CBCL – teacher report Observed negative effect by research assistants	Depression symptoms - age 8	Child depression inventory - self-report	Internalising and externalising symptoms not predictive of depression symptoms (internalising). Rule breaking and observed negative affect in preschool were stronger predictors of later depressive symptoms in girls than in boys	*The authors suggest that the findings that rule breaing and negative affect predicted later depressive symptoms suggest that behaviours that place children at-risk for social isolation and adult disapproval may be a pathway to depressive symptoms*	Sex - Rule breaking at 4 was associated with depression in girls at age 8

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Nelson et al 2018	Longitudinal	US	280 pre-school children and their mothers in a small Midwestern city - oversampled foe socioeconomic risk	Executive control and Foundational Cognitive Abilities at age 5	9-tasks administered to each child during individual sessions in the laboratory. The tasks were designed to cover the major areas that make up EC, including working memory, inhibitory control, and flexible shifting and FCA via the Woodcock-Johnson-III Brief Intellectual Assessment	Depression and Anxiety symptoms - Age 9-10.	Child Depression Inventory – child self-report Anxiety symptoms - Revised Child Manifest Anxiety Scale, - child self-report Externalising symptoms - parents completed the ODD and ADHD-Hyperactivity subscales of the Conners 3rd Edition Parent Ratings Scale	• Preschool EC significantly predicted depression symptoms, with poorer EC associated with greater depression symptoms, b = −2.59, ß = −0.25, SE = 0.10, t = −2.54, p = 0.011. • EC also significantly predicted anxiety symptoms, such that children with poorer EC had greater anxiety symptoms, b = −3.66, ß = −0.28, SE = 0.09, t = −2.98, p = 0.003. • FCA did not significantly predict depression or anxiety symptoms • Preschool EC did not significantly predict at-risk/clinical levels of depression but did significantly predict anxiety (log odds = −0.92, p = 0.048), with lower EC scores associated with greater likelihood of at-risk/clinical levels of anxiety symptoms. • FCA did not significantly predict at-risk/clinical levels of depression or anxiety symptoms	*One potential pathway could be through the "impaired disengagement hypothesis "whereby problems with attentional control lead to disengagement and low mood. The role of EC may be critical in moderating experiences of negative emotions.*	Sex – girls more anxiety than boys

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Pagani et al 2014	Longitudinal	Canada	1145 children from the Quebec Longitudinal Study of Child Development - largely middle class	Cognitive skills, Attention skills - age 5-6	Cognitive skills: Number Knowledge Test (administered to children by trained examiners), Receptive vocabulary skills (The Peabody Picture Vocabulary Test administered to children by trained examiners), Attention skills – teacher assessed from the Social Behaviour Questionnaire (SBQ)	Wellbeing - age 10	Health-related behaviours – parent report on child food intake (soft drinks, sweet snacks, fruit and veg and dairy) and physical effort during free time Academic achievement - Children completed the Canadian Achievement Test of mathematics with a trained examiner. Psychosocial adjustment - Teachers report and child self-report on child classroom behaviour – SBQ.	Receptive vocabulary in kindergarten exclusively predicted fourth-grade dietary habits. Unstandardized coefficients predicted decreases in sweet snack intake (β = −.009, 95% confidence interval [CI] = −.011 to −.006) and dairy product intake (β = .009, 95% CI = .005 to .013). Conversely, higher kindergarten math skills predicted increases in activities requiring physical effort (β = .030, 95% CI = .011 to .056). Although vocabulary and attention skills were found important, kindergarten math skills were stronger and more consistent predictors of later academic outcomes.	*The authors state that 'school readiness represents a means to improve self-efficacy, which mobilizes motivation and resilience in achieving cognitive skills for initiating autonomous healthy behaviour and its maintenance'. This implies that school readiness supports better critical thinking about lifestyle habits and behaviours.*	
Pedersen et al 2007	Longitudinal	Canada	551 French-Canadian children	Behaviour - anxiety/social withdrawal	Social Behaviour Questionnair	Peer rejection (age 8 to	• Peer rejection Children's	Early behaviour was associated with both middle-childhood peer	Peer rejection and Friendedness:	Boys tended to be more disruptive and

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
			from a small community in North West Quebec.	and disruptive behaviour - Age 6	e (SBQ) - mother and teacher rated	11), Friendedness (at age 8 to 11) Depressive symptoms Loneliness Delinquency - at Age 13	sociometric status was assessed through peer nominations. •Friendedness Children were also asked to nominate up to four best friends in the classroom • Depressive symptoms - CDI - child report • Loneliness–social dissatisfaction -self-report measure developed by Asher et al 1984 • Delinquency Involvement - assessed Self-Reported Delinquency Questionnaire (SRDQ)	processes. Early disruptiveness was positively related to peer rejection at ages 8–9 and 10–11 (ages 8–9: estimate = .36, $p < .001$; ages 10–11: estimate = .17, $p < .01$) and negatively related to friendedness at ages 8–9 (estimate =–.16, $p < .01$). Anxiety–social withdrawal, however, was only associated with the number of friends at ages 8–9 (estimate =–.17, $p < .01$). • indirect pathway from disruptiveness to depressive symptoms via peer rejection at ages 8–9 and friendedness at ages 10–11 was statistically significant (estimate = .01, $p < .05$). • indirect path emerged from disruptiveness to loneliness via peer rejection at ages 8–9 and 10–11 (estimate = .03, $p < .01$). • No mediation process found for delinquency but early disruptiveness significantly predicted adolescent delinquency (estimate = .19, $p < .01$).	*In relation to peer rejection not having a mediating role linking disruptive behaviour with externalising outcomes: there are theoretical models which suggest that personal characteristics are the sole predictors of later antisocial behaviours, with peer experiences playing only an incidental role in this process*	report more early-adolescent delinquency. Girls reported more early-adolescent depressive symptoms. Few sex differences, however, were observed in the middle-childhood peer processes after adjusting for early behaviour. Lower occupational status was related to greater childhood disruptiveness and more early-adolescent depression, loneliness, and delinquency.

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Piche et al 2012	Longitudinal	Canada	966 from the Quebec Longitudinal Study of Child Development	Self-regulatory skills: classroom engagement and behavioural regulation (emotional distress, physical aggression, impulsivity) - Age 6	Classroom engagement (teacher rated) and Behavioural regulation using the SBQ (teacher rated) –	Child Sports Participation and BMI - Age 10	Parents reported on their child's weekly involvement in structured sports outside of school during the past school year. BMI was derived from direct height and weight measures made by trained, independent examiners	Kindergarten self-regulation skills, including classroom engagement (β = .438, 95%CI [.031, .844], p = .035) and emotional distress (β = −.108, 95%CI [−.178, −.038], p = .003), were significantly associated with subsequent parent-reported child sports participation A higher score on self-regulation skills significantly predicted lower BMI. Specifically, classroom engagement was significantly associated with fourth grade BMI (β = −.689, 95% CI [−1.132, −.067], p = .030)	*Social Cognitive Theory* *optimal self-regulation may help children sustain involvement in structured sports and maintain a healthy BMI by facilitating the exercise of self-control and delay of gratification in the face of challenges and more immediate rewards.*	Being a boy, higher SES and less television viewing associated with more physical activity. Kindergarten BMI and higher SES also associated with BMI in fourth grade.
Piche et al 2019	Longitudinal	Canada	1516 from the Quebec Longitudinal Study of Child Development	Participation in structured and unstructured physical activity - Age 7	Parents reported on their children's participation in structured and unstructured physical activity	Age 8 Depressive symptoms,	Depression symptoms assessed through the Social Behaviour Questionnaire.	Structured physical activity negatively associated with boys' depressive symptoms one year later (ß = -.09, p =0.009). Unstructured physical activity positively associated with girls' depressive symptoms (β = .07, p = .040)	*It is suggested by the authors that the positive influence of structured physical activity compared to unstructured is linked to the combination of psychosocial components of structured activities (self-regulation, self-efficacy, social competencies) and biological changes brought upon by*	Sex – association between structured physical activity at age 7 and depression at age 8 found in boys but not girls.

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
									being physically active	
Rudasill et al 2014	Longitudinal	USA	1156 children from the National Institute of Child Health and Human Development (NICHD) Study of Early Child Care and Youth Development (SECCYD)	Child temperament (negative emotionality at age 4½ and emotional reactivity at age 7-12) (Student-teacher relationship - teacher perception and child perception tested as mediators)	Negative emotionality: Mothers completed eight subscales from the Children's Behaviour Questionnaire Emotional reactivity: Children's emotional responses to events and environmental stimuli were rated by mothers using a measure designed for use in the NICHD SECCYD.	Depressive symptoms in sixth grade (age 11-12)	Mother report of their children's depressive symptoms was measured in 6th grade with the Diagnostic and Statistical Manual of Mental Disorders oriented Affective Problems subscale of the Child Behaviour Checklist	<u>Student perceptions of teacher support:</u> • Children with higher negative emotionality at age 4½ were rated as more emotionally reactive (β=.439, p < .001) in grades 4–6 and had more depressive symptoms (β=.182, p = .008) in grade 6. In addition, teacher support was associated with less depressive symptoms (−.465, p < .001) in grade 6. • No mediating role <u>Teacher perception of student teacher relationship (conflict)</u> • Children with higher negative emotionality at age 4½ were more likely to be rated as emotionally reactive (.444, p < .001) in grades 4–6 and display more depressive symptoms (.246, p = .002) in grade 6. In addition, children showing more emotional reactivity in grades 4–6 were more likely to be	Mediators: STRs were assessed using teachers' responses on the Student-Teacher Relationship Scale – teacher reported in fourth, fifth and sixth grade Teacher support was measured from student responses on the School Attachment and Environment questionnaire given in sixth grade – child reported. Findings reported here indicate that one mechanism by which individuals with higher levels of emotional reactivity have more depressive symptoms may be more conflict with teachers.	Girls more likely to rate their teachers as supportive. Teachers more likely to rate their relationships with boys as conflictual

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
								rated by teachers as conflictual(.165, p < .001) . • conflict partially mediated the relationship		
Rudolph et al 2011	Longitudinal	USA	433 participating in a longitudinal study of peer victimization	Peer Victimization (static and dynamic) (Age 7-12, 2nd to 5th grade)	Children and teachers completed a revised version of the Social Experiences Questionnaire to assess children's exposure to peer victimization .	Depression symptoms and Aggressive behaviour - Age 11-12 (5th grade)	Depression symptoms - Short Mood and Feelings Questionnaire (Child report) Aggressive behaviour - Children's Social Behaviour Scale (teacher report)	Both early and increasing victimization were significantly associated with fifth-grade depressive symptoms, overt aggression, and relational aggression. Both early and increasing victimization over time more strongly predicted fifth-grade relational aggression in girls than in boys.	*Victimization prompts girls to engage in relational aggression during elementary school, and subsequently relational aggression may elicit negative responses such as peer rejection which heighten girls' risk for depressive symptoms during adolescence.*	Sex - relational aggression stronger in girls
Sandstrom et al 2020	Meta-analysis	Any	8836 children	The mean age at the first BI assessment was 3.61 years	BI: defined as shyness, fear, and avoidance when faced with new stimuli	The mean age at the anxiety assessment was 10.39 years	Anxiety and specific anxiety types searched	BI significantly increased the subsequent risk of anxiety (OR = 2.80, 95% CI 2.03 to 3.86, p < 0.001 Children with BI were significantly more likely to have SAD (OR = 5.84, 95% CI 3.38 to 10.09, p < 0.001; Fig. 3), GAD (OR = 2.04, 95% CI 1.43 to 2.91, p < 0.001), and specific phobia (OR = 1.49, 95% CI 1.03 to 2.14, p = 0.03 but not separation anxiety	-	

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Sasser et al 2017	Longitudinal	USA	356 children enrolled in a Head start programme, all children from low-income families	Intervention targeting social-emotional functioning and language-emergent literacy skills in the first year of pre-school. EF measured before and after preschool and each year to third grade (age 8)	EF assessment by trained examiners. Children assigned to either low, moderate or high EF trajectory	Third grade academic outcomes	Reading fluency, language-arts and maths (all teacher rated), children self-evaluation of reading ability	Significant effect of intervention for children with low EF trajectories, with children in the intervention group showing a more positive slope of growth in EF between preschool and third grade ($d = 0.19$, $p = .004$) and exhibiting significantly higher third-grade EF scores ($d = 0.70$, $p = .002$), compared with children in the control group. Significant intervention effects favouring children in the intervention group emerged for children with low EF trajectories on academic outcomes of: reading fluency, language arts and math performance and children's self-perceptions of their reading ability.	-	EF moderates the effect of intervention (social-emotional functioning and language-emergent literacy skills) on academic outcomes

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Shapero et al 2013	Longitudinal	USA	958 children from the National Institute of Child Health & Human Development Study of Early Child Care and Youth Development (SECCYD)	Emotional - emotional reactivity at age 8. (Household income and household chaos also studied.)	Emotional reactivity – mother report - 10-item questionnaire about their perceptions of how their child expresses emotions in response to events	Emotional and behavioural problems - Age 15	Adolescent Emotional and Behavioural Problems – Youth Self-Report.	Higher levels of emotional reactivity predicted higher levels of emotional and behavioural problems (B = 0.122, p <0.001). Income also predictive of the outcome. Household chaos not predictive. The interaction of household chaos and childhood emotional reactivity significantly predicted increases in adolescent total problems and internalising problems (B=0.104, P<0.01), but not externalising problems Emotional reactivity did not moderate the relationship between income and increases in problem behaviours.	*Detrimental effect of physical and psychological aspects of the home environment leading to internalising problems.*	Household chaos is a moderator of the relationship between Temperament (emotional reactivity) and adolescent internalising behaviour problems but income is not.
Slemming et al 2010	Longitudinal	Denmark	1336 from the Aarhus Birth cohort, Denmark	Behaviour: anxious–fearful, hyperactive–distractible, and hostile–aggressive - Age 3-4	Preschool behaviour questionnaire (PBQ) - parent report	Internalising problems - Age 10-12	Emotional difficulties were measured at age 10–12 years with the parent-administered strength and difficulties questionnaire (SDQ)	Anxious–fearful associated with internalising symptoms: OR 2.1, 95% CI 1.1–4.0) and hostile–aggressive associated with internalising symptoms: OR 2.4, 95% CI 1.3–4.7). Hyperactive–distractible preschool behaviour was not associated with school-age emotional difficulties	*Hostile–aggressive behaviour may lead to internalising disorder due to increased environmental stress, a common precursor for the two dimensions or a longitudinal transformation of one behavioural*	Relationship held regardless of confounders

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
								when confounding factors considered.	*dimension into another in later childhood.*	
Straatman et al 2018	Longitudinal	UK	10262 from the Millennium Cohort Study UK	Five central domains of a health check in England: (1) personal, social and emotional development, (2) communication and language, (3) physical health, (4) learning and cognitive development and (5) physical development and self-care) - at Age 3	Health visitor assessment at routine health check	Language ,weight, socioemotional behaviour - Age 11	Language - British Ability Scale Second Edition (BAS II) Verbal Similarities test. Weight was derived from the body mass index (BMI), using the age and sex-International Obesity Task Force cut-offs. Socioemotional behaviour - SDQ - mother report	Model 1 - routine data only. Model 2 - routine data plus data from the five domains (exposure), model 3 - all from model 1 and 2 plus additional risk factors. Language disability, overweight/obesity and socioemotional problems identified with moderate discrimination in model 2 with (AUROC: 0.73, 95%CI 0.71 to 0.75) (AUROC: 0.73, 95%CI 0.72 to 0.74) and AUROC: 0.77, 95%CI 0.75 to 0.79, respectively. Model 2 resulted in a significant improvement over model 1, for overweight/obesity and socioemotional problems with 8.14% and 6.26% more children being correctly reclassified, respectively	-	

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Sutin et al 2017	Longitudinal	Australia	4153 from the Longitudinal Study of Australian Children	Temperament - sociability, persistence, negative reactivity. Age 4-5	Parents completed a 12-item measure of temperament based on the Childhood Temperament Questionnaire.	Weight and weight attitudes and behaviour - Age 14-15	Weight – BMI and waist circumference at all ages Weight attitudes and behaviour. At ages 14–15 years, study children self-reported on several aspects of their attitudes and behaviours.	Persistence associated with a decreased risk of obesity OR = 0.82, CI = 0.69–0.97), overweight (OR = 0.88, CI = 0.78– 0.98) and W: H⩾0.5 (OR = 0.87, CI = 0.77–0.98). Sociability associated with an increased risk of overweight (OR = 1.10, CI = 1.01–1.20) and W: H⩾ .5 (OR = 1.10, CI = 1.01–1.21) but not with obesity risk (OR = 1.10, CI = 0.96–1.26). Negative reactivity was unrelated to risk of overweight, obesity or elevated W: H. Lower persistence and higher negative reactivity were associated with greater weight concerns, restrained eating and use of unhealthy weight-management strategies at ages 14–15 years.	*Individual differences in psychological functioning make some people more vulnerable and others more resilient and points to the importance of addressing both the individual and the environment in weight gain across the lifespan*	Girls higher on sociability had a greater fear of weight gain

Author (Year)	Study Design	Country	Participants	Exposure (measure of development) and age	Exposure Measurement Instrument	Outcome and age	Outcome Measurement Instrument	Results	Mechanism - in study (normal font) or *theorised (italics*)	Factors which moderate the association
Weeks et al 2014	Longitudinal	Canada	4405 children from the Canadian National Longitudinal Study of Children and Youth (NLSCY)	Verbal ability (age 4-5) and Math skills - age 7-11	Verbal Ability: Peabody Picture Vocabulary Test-Revised (PPVT-R) Math skills - children completed a Mathematics Computation Test (MCT).	Internalising symptoms of anxiety and depression - Age 12-13 and 14-15	Questionnaire that included 7 items from the Ontario Child Health Study (OCHS-R), assessing symptoms of anxiety and depression - self-report.	Greater verbal ability at age 4–5 decreased the odds of moderate (Adj OR=0.83; CI: 0.75, 0.93) and severe (Adj OR=0.80; CI: 0.70, 0.92) internalising symptoms at age 12-13 and decreased the odds of mild symptoms (OR=0.84; CI: 0.76, 0.92) at age 14-15. Higher maths ability at age 6–7 increased the odds of mild symptoms (Adj OR=1.21; CI: 1.05, 1.39) at age 12-13 and increased the odds of mild (Adj OR=1.44; CI: 1.21, 1.72) and severe (Adj OR=1.50; CI: 1.18, 1.92) internalising symptoms at age 14-15.	*Hormonal changes to explain the loss of the protective effect of cognitive ability on internalising symptoms. Children with greater cognitive ability in childhood may be better at coping with the stress of family dysfunction and chronic illness in childhood, perhaps because they are more capable of problem-solving and adapting to more stressful environments.*	Gender and family stress: Some of the effects of childhood cognitive ability varied with child gender. Also, childhood cognitive ability attenuated the effects of family dysfunction and chronic illness throughout childhood on subsequent internalising symptoms.
Yan et al 2018	Longitudinal	USA	695 from the NICHD SECCYD study.	Emotional Wellbeing - child parent relationship - Age 6	Both fathers and mothers rated their relationships (conflict and closeness) with the child at Grade 1, 3, 4 and 5. Using the short form of the Child-Parent Relationship Scale	Loneliness at grades 1, 3 and 5 (age 10-11)	Loneliness and Social Dissatisfaction Questionnaire - child self-report	As parent child closeness increases, loneliness reduces The slope of father-daughter closeness was negatively associated with the slope of loneliness for girls $\beta = -0.46$, $p = .03$). When father-daughter closeness declined more slowly, girls' perceived loneliness declined more quickly.	*Attachment theory.*	Gender: father-child closeness has a stronger association with girls loneliness

Additional File 9: Quality Assessment: Results of quality assessment of studies

Author and Year	Recruitment	Participation*	Description of baseline characteristics	Participants at follow up	Duration of follow up	Response at follow up*	Not selective non-response*	Exposure measurement*	Outcome measurement*	Analytical model*	Adjustment for confounders*	Measures of variability	Methodological Quality
Ashford et al 2008	+	+	+	+	+	+	+	-	+	?	-	+	Moderate
Berthelsen et al 2017	+	+	+	+	+	-	+	-	+	+	+	+	High
Bornstein et al 2010	-	?	+	-	+	+	+	+	+	?	-	+	Moderate
Bornstein et al 2013	-	-	+	-	+	+	+	+	+	?	+	+	Moderate
Derks et al 2019	+	?	+	+	+	+	+	+	+	+	+	+	High
Duchesne et al 2010	+	+	+	+	-	-	+	+	+	+	+	+	High
Fine et al 2003	?	+	+	+	+	+	+	+	+	+	-	-	High
Glaser et al 2011	+	+	+	+	+	+	+	+	+	+	+	+	High
Gregory et al 2020	+	+	+	+	+	-	+	+	+	+	-	+	Moderate
Hay et al 2003	+	-	+	+	+	+	-	+	+	+	-	+	Low
Hooper et al 2003	+	?	+	-	+	?	?	-	+	+	-	+	Low
Howard et al 2018	+	+	+	+	+	-	+	+	+	+	+	+	High
Howes et al 2000	+	+	+	-	-	-	-	+	+	+	-	+	Low
Jaspers et al 2010	+	+	+	+	+	+	+	-	+	+	-	+	Moderate
Lecompte et al 2014	-	-	-	+	+	+	-	+	+	?	-	+	Low
Lee et al 2017	+	+	+	+	+	?	-	-	+	+	+	+	Moderate
Louise at al 2012	+	-	+	+	+	+	-	+	+	+	-	+	Moderate
McKenzie et al 2002	-	+	+	+	+	-	?	-	+	+	-	+	Low

Author and Year	Recruitment	Participation*	Description of baseline characteristics	Participants at follow up	Duration of follow up	Response at follow up*	Not selective non-response*	Exposure measurement*	Outcome measurement*	Analytical model*	Adjustment for confounders*	Measures of variability	Methodological Quality
Meagher et al 2009	-	?	+	+	+	+	-	-	+	?	-	+	Low
Nelson et al 2018	+	?	+	+	+	+	-	+	+	+	+	+	Moderate
Pagani et al 2014	+	-	+	+	+	-	+	+	?	+	-	+	Moderate
Pedersen et al 2007	+	+	+	+	+	-	+	-	+	+	-	-	Low
Piche et al 2012	+	-	-	+	+	+	+	+	-	+	-	+	Moderate
Piche et al 2019	+	-	-	+	+	?	+	-	+	+	+	+	Low
Rudasill et al 2014	+	+	+	+	+	-	+	-	+	+	-	+	Moderate
Rudolph et al 2011	-	+	+	-	+	+	-	-	+	+	-	-	Low
Sandstrom et al 2020	*Study design is Meta-Analysis: AMSTAR used as quality assessment tool*												Low
Sasser et al 2017	+	+	+	+	+	+	+	-	+	+	-	-	Moderate
Shapero et al 2013	+	-	+	-	+	+	-	+	+	+	-	+	Moderate
Slemming et al 2010	+	-	+	+	+	+	-	-	-	+	+	+	Moderate
Straatmann et al 2018	+	-	-	-	+	+	+	+	+	+	+	+	High
Sutin et al 2017	+	+	+	+	+	+	+	-	+	+	-	+	High
Weeks et al 2014	+	-	+	+	+	+	?	-	+	+	+	+	Moderate
Yan et al 2018	+	+	+	-	+	?	+	-	+	+	+	+	Moderate

Appendix 5: Supplementary files for Paper 3 (Longitudinal Analysis)

Additional file 1: Number of families, cohort members and attrition at each wave

Number of single cohort members interviewed at wave 1 to 7 (twins removed).

Wave	Age	Sample Size (Number of families issued to the field)*	Number of responding families	Number of cohort members (multiple births removed)	Attrition from previous wave	Cumulative attrition of cohort members
MCS 1	9 months	24180	18552	18296	-	
MCS 2	3 years	19870**	15590	15382	2914	2914
MCS 3	5 years	19244 (18528)	15246	15042	340	3254
MCS 4	7 years	19244 (17031)	13857	13682	1360	4614
MCS 5	11 years	19244 (16393)	13287	13112	570	5184
MCS 6	14 years	19243 (15415)	11726	11564	1548	6732
MCS 7	17 years	19243 (14496)	10625	10500	1064	7796

*Reasons for not issuing to the field include death, emigration, permanent refusal, untraceability and sensitive situation.
**Sample size at MCS2 was the number of productive families at MCS1 (18481) and 1389 new families. Sample size for MCS 3 onwards is those who had responded at least once to MCS 1 or 2. This dropped by 1 in MCS6 onwards as on family was identified as having duplicate records.

References for this table: Millennium Cohort Study User Guides: https://cls.ucl.ac.uk/wp-content/uploads/2017/07/Technical-Report-on-Sampling-4th-Edition-August-2007.pdf, http://doc.ukdataservice.ac.uk/doc/5795/mrdoc/pdf/mcs1-5_user_guide_ed9_2020-08-07.pdf, https://cls.ucl.ac.uk/wp-content/uploads/2018/10/mcs6_user_guide_28march2017.pdf, https://cls.ucl.ac.uk/wp-content/uploads/2022/05/MCS7-user-guide-Age-17-ed2.pdf

Additional File 2: Cognitive assessments at each wave

Cognitive assessments used at each MCS wave, ages 3-14 years:

- **MCS2 (Age 3) and MCS3 (Age 5),** BAS Naming Vocabulary: measures expressive verbal ability
- **MCS4 (Age 7),** BAS Word Reading: measures reading ability
- **MCS5 (Age 11),** BAS Verbal Similarities: measures verbal reasoning and verbal knowledge
- **MCS6 (Age 14),** Word Activity Test (subset of the vocab assessment in the 1970 British cohort study survey): measures verbal vocabulary

Additional File 3a: Equations for Group based multi-trajectory model

The key features of the GBTM technique used in our study are trajectory shapes, defined by a cubic or quadratic function of age, and the individual's probability of trajectory group membership. We used Stata Traj to run the models and logistic regression to model the conditional probabilities of individuals' states for binary outcomes of cognitive problems and socioemotional behaviour problems over time (from age 3 to 14 years).

The model yields a probability for each individual of being in each trajectory group, as follows.

For each individual *i*, let

$\boldsymbol{Y}_i^1$ denote the vector of binary state of Cognitive problems at ages, 3, 5, 7, 11 and 14 years

$\boldsymbol{Y}_i^2$ denote the vector of binary state of Socioemotional behaviour problems at ages, 3, 5, 7, 11 and 14 years,

$j_i \in (1, \dots, 4)$ denotes the latent trajectory groups identified for our final model.

The group-based multi-trajectory model assumes that subjects belong to a trajectory group, *j*, with the following likelihood function for each individual *i*

$$\Pr(\boldsymbol{Y}_i^1 = \boldsymbol{y}_i^1, \dots, \boldsymbol{Y}_i^2 = \boldsymbol{y}_i^2) =$$

$$\sum_{j=1}^{4} \Pr(J_i = j) \Pr(\boldsymbol{Y}_i^1 = \boldsymbol{y}_i^1, \dots, \boldsymbol{Y}_i^2 = \boldsymbol{y}_i^2 | J_i = j)$$

Where the latter factor is the probability of the longitudinal data for subject i given that this subject belongs to trajectory group j. This probability is given by

$$\Pr(\boldsymbol{Y}_i^1 = \boldsymbol{y}_i^1, \dots, \boldsymbol{Y}_i^2 = \boldsymbol{y}_i^2 | J_i = j) =$$

$$\Pr(\boldsymbol{Y}_i^1 = \boldsymbol{y}_i^1 | J_i = j) Pr(\boldsymbol{Y}_i^2 = \boldsymbol{y}_i^2 | J_i = j)$$

Following from the equations above, which define conditional independence of the indicators $\boldsymbol{Y}^1$ to $\boldsymbol{Y}^2$ once the trajectory groups are identified, the model is developed as follows. Let our unobservable discrete variable J_i indicate the latent trajectory of the *i-th* individual. J_i is assumed to take on *J* values, 4 in our case, each corresponding to a distinct expected trajectory *j*. Our model follows a finite mixture distribution of order J with *K* outcome components where the likelihood for each individual conditional on number of groups *J* may be written as

$$P\left(Y_i^1, \ldots, Y_i^k | Age_i\right) = \sum_{j=1}^{J} \Pr(J_i = \mathrm{j}) \prod_{k=1}^{K} P_k\left(Y_i^k \middle| Age_i, j;\ \beta_j^k\right)$$

With

$$P_k\left(Y_i^k \middle| Age_i, j;\ \beta_j^k\right) = \prod_{t=1}^{T^k} p_k\left(y_{it}^k \middle|\ age_{it}, j;\ \beta_j^k\right)$$

where each of the *k* indicators can be measured at different time points *T = t*. Here the conditional distribution of Y_i^k, given membership in *j* is indexed by the unknown parameter vector β_j which determines the shape of the group-specific trajectory. We estimated $p_k(*)$ using a logistic regression model with a cubic or quadratic function of age for all *k*.

The equations highlight the assumed independence between measurements at different time points within individuals conditional on group membership.

(Multi-trajectory Groups for socioemotional behaviour and cognitive problems from age 3 to 14 years in the UK Millennium Cohort Study)

Model Selection Results

Number of groups and trajectory shapes*	BIC**	AIC***	Entropy
1 (2) (2)	-29279	-29257	-
2 (22) (22)	-26561	-26513	0.71
3 (223) (222)	-25954	-25877	0.80
4 (2233) (2222)	-25898	-25791	0.72
5 (22333) (22222)	-25856	-25720	0.64

Highlighted group: indicates selected model
*Trajectory shapes of the best fit model for a given number of groups; 2 = quadratic and 3 =cubic
**Bayesian Information Criterion
***Akaike information criterion
Note: In STATA TRAJ. BIC and AIC is calculated using the Schwarz criterion = log(L) - 0.5 k log(n) which is (-1/2 * usual BIC). Therefore, using STATA TRAJ, the larger the BIC and AIC the better the model fit.

Estimated probability and the proportion of cohort members classified to each group according to the maximum posterior probability assignment rule:

- Trajectory of 'No problems' (8844), 69.1% (estimate based on Ave Prob), 76.5% (Group assignment)
- Trajectory of 'Late socioemotional problems' (1175), 14.8%, 10.1%
- Trajectory of 'Early cognitive and socioemotional problems' (990), 10.9%, 8.6%
- Trajectory of 'Persistent cognitive and socioemotional problems (555), 5.2%, 4.8%

Model Adequacy Results – Multi-trajectory Groups

- Trajectory of 'No problems' (8844, 76.5%), AvePP* 0.89, OCC** 2
- Trajectory of 'Late socioemotional problems' (1175, 10.1%), AvePP 0.83, OCC 44
- Trajectory of 'Early cognitive and socioemotional problems' (990, 8.6%), AvePP 0.79, OCC 41
- Trajectory of 'Persistent cognitive and socioemotional problems (555, 4.8%), AveP* 0.81, OCC 87

Notes:

*AvePP: average posterior probability
**OCC: Odds of Correct Classification
Note: AvePP >0.7 and OCC>5 represent a good model fit
Notes on OCC:
OCCj, , the numerator represents the OCC based on the maximum probability rule, and the denominator represents the OCC based on a random assignment. So, if the maximum probability rule is not better than random guessing, the OCC would equal 1 for a given trajectory group. http://www.rehabilomics.pitt.edu/publications/GroupBased_biomarker.pdf

Additional File 4: STROBE Checklist

For: Trajectories of child cognitive and socioemotional development and associations with adolescent health in the UK Millennium Cohort Study (page numbers relate to published paper).

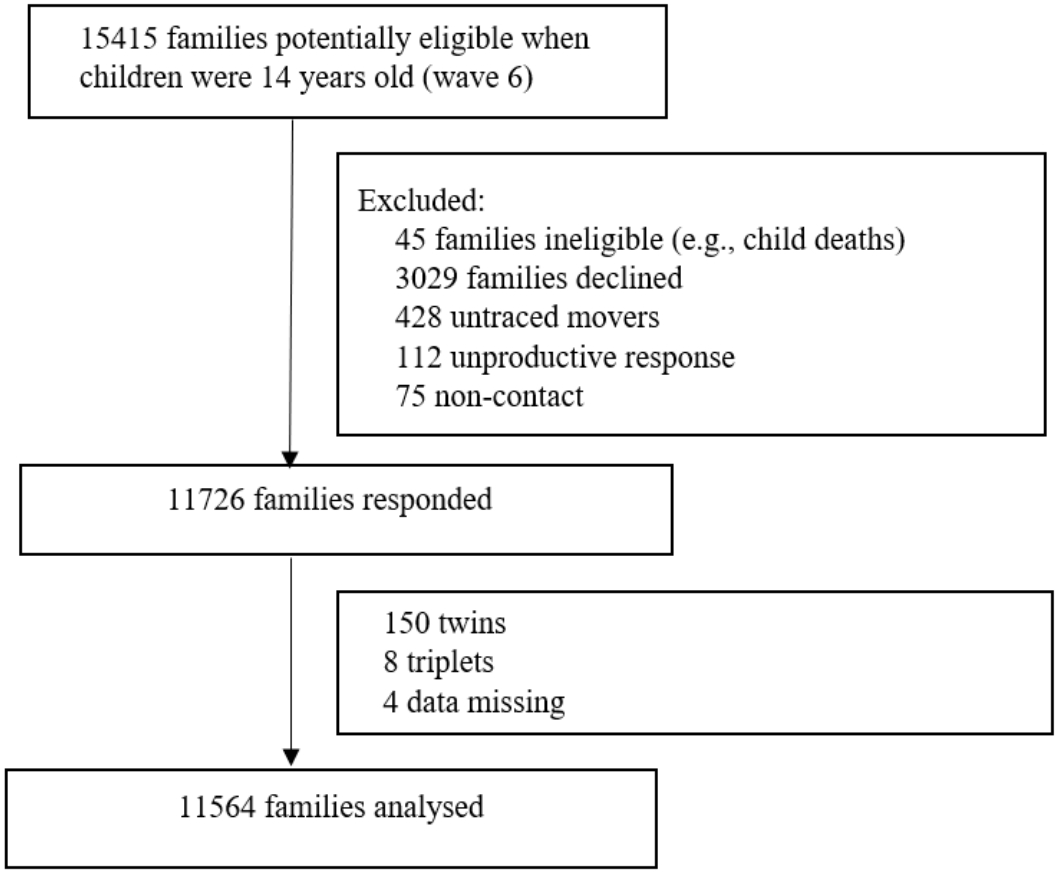
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods – pp 3, line 122-131
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Methods – pp 3, line 132-136, Supplementary File 1
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods – pp 3-5, line 137-195,
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods – pp 3-5, line 137-195
Bias	9	Describe any efforts to address potential sources of bias	Methods –pp 5, line 213-215
Study size	10	Explain how the study size was arrived at	Methods -pp 3, line 132-136
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods -pp 3-5, line 137-195
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Methods – pp 5, line 196-222
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	Methods - pp 5, line 213-214
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Methods - pp 3, line 122-131
		(*e*) Describe any sensitivity analyses	Methods - pp 5, line 196-222
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results – pp 6, line 227-228 Supplementary file 1
		(b) Give reasons for non-participation at each stage	Supplementary file 1

		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results – pp 7 Table 3
		(b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	Table 3
Outcome data	15*	Report numbers of outcome events or summary measures	Table 4 and 5
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 4 and 5
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	Discussion – pp 11, line 311-321
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion – pp 13-12, line 382-401
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion – pp 11-13 line 322-381
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion – pp 13 line 382-385
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	pp 14, line 436

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Additional File 5: Study Flow Diagram



Additional File 6: Cross-sectional Pevalence of socioemotional behaviour and cognitive problems

Cross-sectional Prevalence of socioemotional behaviour problems and cognitive problems in the UK millennium cohort study, weighted sample

Development	**Age 3 years** n=15382 (%)	**Age 5 years** n=15042 (%)	**Age 7 years** n=13682 (%)	**Age 11 years** n=13112 (%)	**Age 14 years** n=11564 (%)
Socioemotional Behaviour Problems	9.9 (9.4-10.4)	5.6 (5.2,5.9)	7.6 (7.2-8.1)	10.0 (9.5,10.5)	12.1 (11.5,12.7)
Cognitive Problems	7.2 (6.8-7.6)	7.8 (7.3,8.2)	9.1 (8.6,9.6)	7.6 (7.2,8.1)	7.3 (6.8,7.7)
Either	14.0 (13.5,14.5)	11.4 (10.9,11.9)	12.8 (12.2,13.4)	13.9 (13.3,14.5)	16.0 (15.3,16.7)
Both	1.6 (1.4,1.8)	0.9 (0.8,1.1)	2.0 (1.8,2.2)	1.9 (1.6,2.1)	1.7 (1.5,2.0)

Note: 95% Confidence Interval, Clopper-Pearson. Weighting variables: pttype2 (strata variable), sptn00 (Primary Sampling Unit: clustered at ward level), nh2 (finite population correction factor), survey weight ((bovwt2 (age 3), (covwt2 (age 5), (dovwt2 (age 7), (eovwt2 (age 11), (fovwt2 (age 14))

Appendix 6: Additional files for the trajectories of single domains of development

Simple Trajectories - Socioemotional behaviour problems from age 3-5 years, UK MCS

Table a: Model Selection Results based on trajectory shape, BIC, AIC, entropy and size of smallest group

Number of Groups	Trajectory Shapes*	BIC** (N=11551)	AIC***	Entropy	% of the smallest group
2	3 3	-12550	-12517	0.861	-
3	3 3 3	-12730	-12678	0.328	-
3	2 3 3	-12533	-12485	0.694	5.4
3	2 2 3	-12524	-12480	0.730	4.6
3	2 2 2	-12647	-12606	0.875	4.2
4	2 2 2 2	-12532	-12476	0.767	4.0
4	2 2 3 3	-12485	-12422	0.724	4.1
4	2 2 2 3	-12502	-12443	0.704	1.4
4	2 3 3 3	-12539	-12472	0.740	3.9
4	3 3 3 3	-12535	-12465	0.734	2.9

*Trajectory shapes of the best fit model for a given number of groups; 2 = quadratic and 3 =cubic
**Bayesian Information Criterion
***Akaike information criterion Highlighted group: 2233 indicates selected model

Table b: Estimated probability and the proportion of cohort members classified to each group according to the maximum posterior probability assignment rule

Trajectory Group	Population estimate based on average probabilities (%)	Group assignment based on predicted probabilities (%)	Number of cohort members per group
No problems	74.9	82.6	9544
Late socioemotional problems	10.3	6.8	789
Early socioemotional problems	10.6	6.5	754
Persistent socioemotional problems	4.1	4.1	477

Table c: Model Adequacy Results

Trajectory Group	N	AvePP*	OCC**
No problems	9544 (82.6%)	0.91	2
Late socioemotional problems	789 (6.8%)	0.76	43
Early socioemotional problems	754 (6.5%)	0.78	51
Persistent socioemotional problems	477 (4.1%)	0.78	84

*AvePP: average posterior probability **OCC: Odds of Correct Classification
Note: AvePP >0.7 and OCC>5 represent a good model fit
OCCj, , the numerator represents the OCC based on the maximum probability rule, and the denominator represents the OCC based on a random assignment. So, if the maximum probability rule is not better than random guessing, the OCC would equal 1 for a given trajectory group. http://www.rehabilomics.pitt.edu/publications/GroupBased_biomarker.pdf

Simple Trajectories - Cognitive problems from age 3-5 years, UK MCS

Table d: Model Selection Results based on trajectory shape, BIC, entropy and size of smallest group

Number of Groups	Trajectory Shapes*	BIC** (N=11529)	AIC***	Entropy	% of the smallest group
2	22	-11563	-11537	0.74	8.7
3	333	-11528	-11476	0.54	9.4
3	233	-11510	-11462	0.73	4.5
3	222	-11560	-11520	0.56	6.5
4	2 2 2 2	-13697	-13642	0.63	4.3
4	2 2 3 3	-13681	-13618	0.48	3.8
4	3 3 3 3	-13672	-13603	0.63	1.1
4	2 3 3 3	-13706	-13640	0.64	2.3
4	2 3 3 2	-13762	-13700	0.38	3.1
4	2 3 2 2	-13735	-13676	0.58	2.0
4	2 3 2 3	-13719	-13656	0.55	5.9
4	3 3 2 3	-13846	-13780	0.21	-
4	3 2 2 3	-13727	-13665	0.76	3.4
4	3 2 2 2	-13701	-13642	0.55	4.3
4	3 2 3 2	-13772	-13710	0.36	2.3

*Trajectory shapes of the best fit model for a given number of groups; 2 = quadratic and 3 =cubic
**Bayesian Information Criterion ***Akaike information criterion
Highlighted group: 2222 indicates selected model

Table e: Estimated probability and the proportion of cohort members classified to each group according to the maximum posterior probability assignment rule

Trajectory Group	Population estimate based on average probabilities (%)	Group assignment based on predicted probabilities (%)	Number of cohort members per group
No problems	65.6	80.1	9263
Late cognitive problems	23.7	9.4	1084
Early cognitive problems	4.2	6.2	719
Persistent cognitive problems	6.5	4.3	498

Table f: Model Adequacy Results

Trajectory Group	N	AvePP*	OCC**
No problems	9263 (80.1)	0.81	1
Late cognitive problems	1084 (9.4)	0.83	48
Early cognitive problems	719 (6.2)	0.63	25
Persistent cognitive problems	498 (4.3)	0.81	93

*AvePP: average posterior probability **OCC: Odds of Correct Classification
Note: AvePP >0.7 and OCC>5 represent a good model fit