# Understanding moderating factors of stress-induced eating behaviours in emerging adulthood

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The candidate confirms that the work submitted is his/her own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

In this thesis, chapter 2 outlines two meta-analyses. The meta-analysis in adolescents stems from a jointly published paper (full reference: Hill, D. C., Moss, R. H., Sykes-Muskett, B., Conner, M., & O'Connor, D. B. (2018). Stress and eating behaviors in children and adolescents: Systematic review and meta-analysis. Appetite, 123, 14-22). In this jointly authored publication, Rachael Moss and I contributed equally to the all aspects of the paper (i.e., database searching, screening, data extraction, analyses and write-up). Bianca Sykes-Muskett was involved with double coding the data file prior to analyses, whilst Mark Conner and Daryl O'Connor formed the supervision team for the project. In my thesis, I have focused on papers exclusively based on adolescents (and not children) and have updated the search since the paper was published to include additional papers in the analyses. Chapter 2 combines the findings from stress-related eating habits in adolescents, with a new meta-analysis in adult populations.

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## Abstract

This thesis aimed to investigate stress-induced eating behaviours across emerging adulthood and identify moderating variables on this relationship. Firstly, the findings of two meta-analyses highlighted that stress is associated with changes in the amount, and type, of foods consumed in adults and adolescents. The meta-analyses identified gaps in the literature including limited research using samples of adolescents and a paucity of objective measures of stress.

A daily diary study was conducted to determine stress-eating associations in adolescents (*N* = 78) and young adults (*N* = 98). Results identified that daily stress was associated with increased consumption of between-meal snacks but was not associated with a change in healthy food consumption. Conscientiousness moderated stress-eating associations in young adults, where stress-eating associations were greatest in individuals high in conscientiousness compared to lower levels of this personality trait.

Secondly, an experimental study combined objective (saliva and hair cortisol) and subjective measures of stress to determine the role of cortisol reactivity (to a stress-induction task) on daily stress-eating associations. In a sample of 123 participants (59 adolescents and 64 young adults), the study found that days with low levels of stress were associated with significant differences in total snacks consumed across AUC (i.e., cortisol reactivity) groups. However, on high stress days, there were no differences in total snack intake across the AUC groups. Chronically occurring stress (measured via hair sampling) was not associated with changes to stress-related eating habits across emerging adulthood. Eating style and emotion regulation differentially influenced stress-eating associations between adolescents and young adults.

Combined with previous research, the findings of this thesis indicate that stress-eating associations are present in adolescents and may continue into adulthood. Moderating variables (such as cortisol reactivity, conscientiousness and eating style) should be considered in future research to understand the complex associations between stress and health.

## Publications and Conference Submissions

Hill, D., Coats, R. O., Halstead, A., & Burke, M. R. F. (2015). A systematic research review assessing the effectiveness of pursuit interventions in spatial neglect following stroke. *Translational Stroke Research*, *6*(6), 410-420.

Hill, D., Moss, R., Sykes-Muskett, B., Connor, M., & O'Connor, D. (2018). Stress and eating behaviours in 8-18 year old children: A systematic review and meta-analysis. *Appetite, 123,* 14-22*.*

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Hill, D., Conner, M., Clancy, F., Moss, R., Bristow, M., & O'Connor, D. *(under review)*. Stress and eating behaviours in adults: A Systematic review and meta-analysis.

Prudenzi, A., Graham, C., Clancy, F., Hill, D., O' Driscoll, R., Day, F., & O' Connor, D. *(under review).* Acceptance and Commitment Therapy-Based Interventions to Improve Wellbeing and Reduce Burnout in Healthcare Professionals: A Systematic Review and Meta-Analysis.

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# Abbreviations

ACTH: Adrenocorticotrophic Hormone

ANOVA: Analysis of Variance

AUC: Area under the Curve

AUCg: Area under the Curve with Respect to Ground

AUCi: Area under the Curve with Respect to Increase

CRF: Corticotropin-Releasing Factor

BMI: Body Mass Index

CSS: Chernyshenko Conscientiousness Scale

DEBQ: Dutch Eating Behavior Questionnaire

ELISA: Enzyme-linked Immunosorbent Assay

EPHPP: Effective Public Health Practice Project

ERQ: Emotion Regulation Questionnaire

HCCs: Hair Cortisol Concentrations

HELN: High Energy Low Nutrient

HPA: Hypothalamic Pituitary Adrenal

LEHN: Low Energy High Nutrient

MANOVA: Multivariate Analysis of Variance

MAST: Maastricht Acute Stress Task

MCAR: Missing Completely at Random

RCTs: Randomised Controlled Trials

SAM: Sympathetic Adrenal Medullary

TSST-G: Trier Social Stress Task (group)

# Chapter 1
# Mechanisms, Moderators and Outcomes of Stress-related Eating Behaviours

## 1.1 Introduction

The increasing prevalence of overweight (defined as having a body mass index of 25 to 29.9kg/$m^2$) and obesity (body mass index of 30kg/$m^2$ or greater) has been an ongoing issue for public health over the last 50 years (Davis & Wansink, 2015). In 2015, it was estimated that 604 million adults and 108 million children globally were classified as having obesity, and, in the same year, 4 million deaths occurred as a result of high BMI (Afshin et al., 2017). Similarly, obesity rates in adolescents have tripled in the last 30 years to approximately 17% (International Food Information Council, 2006; Centres for Disease Control, 2007). Although these rates have plateaued in some countries, levels of obesity and overweight in children and adolescents in the UK remains high (Bauman, Rutter, & Baur, 2019).

Obesity in adolescence is directly associated with long term ill health (Reinehr, 2018), including poorer mental health (Sutaria, Devakumar, Yasuda, Das, & Saxena, 2019) and cardiovascular disease (Bjerregaard, Adelborg, & Baker, In Press). Worryingly, overweight and obesity during adolescence can increase the risk of premature mortality and physical illness as a consequence of obesity continuing into adulthood (Reilly & Kelly, 2011).

Understanding the factors which influence the engagement in health behaviours in adolescence is vital in improving long term health outcomes. Both adolescence (13-18 years old) and emerging adulthood (18 to 25 years old) are key age periods for the formation of health promoting behaviours, particularly dietary habits (Albani, Butler, Traill, & Kennedy, 2018; Todd, Street, Ziviani, Byrne, & Hills, 2015). Poorer dietary habits formed during these younger years can continue throughout adulthood (Mikkilä, Räsänen, Raitakari, Pietinen, &

Viikari, 2005), increasing the risk of ill health in later life (Ebbeling, Pawlak, & Ludwig, 2002).

One mechanism thought to contribute to obesity is stress. Stress can directly influence health outcomes through biological mechanisms; prolonged activation of physiological and cardiovascular systems in response to chronically occurring stress can increase wear and tear on internal systems (Aschbacher et al., 2013; McEwen, 2004), leading to poorer cardiovascular health in later life (for a meta-analysis see Chida & Steptoe, 2010). More interestingly, stress can negatively influence health indirectly, through changes to normal eating behaviours (Cartwright et al., 2003). For example, increased perceived stress has been associated with increased intake of foods (Wallis & Hetherington, 2009), particularly unhealthy or snack foods (O'Connor & O'Connor, 2004), an increased desire to eat (Groesz et al., 2012) and greater disturbed eating attitudes (Gerke et al., 2013). These changes in normal eating behaviours have been linked to increases in body weight, adiposity (Steptoe & Wardle, 2005) and obesity (Berridge, Ho, Richard, & DiFeliceantonio, 2010). However, it is important to note that excess weight gain only occurs when positive energy balance is chronic, while both the experience of stress and other moderating factors (such as emotional eating) may be transient and situation specific. As such, changes to eating behaviours under conditions of stress would need to occur chronically to result in disparities between energy intake and expenditure needed to result in weight change.

Previous literature reviews have identified that stress is associated with changes in normal dietary behaviours, where individuals increase their food intake when experiencing stress (Adam & Epel, 2007; Araiza & Lobel, 2018), particularly for unhealthy foods, whilst intake of healthy foods decreases (Lyzwinski, Caffery, Bambling, & Edirippulige, 2018; Torres & Nowson, 2007). However, the strength of these associations has not been quantified. Furthermore, there is limited research currently on stress and eating habits throughout emerging adulthood. Therefore, this thesis aimed to highlight current trends in stress-related eating habits in adolescents and young adults (i.e., across emerging adulthood).

Understanding the influence of stress on health presents an ongoing challenge due to the complex nature of stress and the behavioural, endocrine and neural systems it involves (Finch, Tiongco-Hofschneider, & Tomiyama, 2019). Furthermore, individual differences in potential moderating variables (such as eating style and personality traits) can differentially influence stress-related eating behaviours (Greeno & Wing, 1994). This thesis aims to further current understanding of stress-related eating habits in adolescents and young adults by identifying potential moderating variables on this relationship.

## 1.2 Defining Stress

Operationalising definitions of stress is problematic due to the subjective nature of stress and the multitude of behavioural and psychological factors it may incorporate. Many definitions within the literature identify four key elements which underpin the experience of stress; surprise, uncertainty (Peters, McEwen, & Friston, 2017), predictability and controllability (Koolhaas et al., 2011). Combined, or in isolation, these four factors determine the perceived experience of stress, as well as the severity and duration. Definitions posit that stress is more likely to occur when the source of the stressor is unexpected (Morrison & Bennett, 2009) and/or unpredictable, leading to an absence of anticipation of the stressor (Koolhaas et al., 2011). Similarly, stress may occur where there are uncertainties, either relating directly to the stressor (Koolhaas et al., 2011) or uncertainties regarding availability of resources (physical, psychological or material) needed to alleviate the source of the stress (Folkman, 2013). Finally, definitions of stress include elements of controllability, where a loss of control may be experienced over a particular situation or stimuli resulting in stress (Koolhaas et al., 2011).

Definitions of stress become more variable when behavioural and psychological factors are also considered. Generally, stress is conceptualised as a multidimensional concept involving a combination of endocrine, autonomic and subjective responses (Day, 2005; Levine & Ursin, 1991) to a situation, event or thought which can in turn produce negative emotions (Segerstrom & O'Connor, 2012). The experience of stress is subjective (Sapolsky, 1994) meaning that, although stress is more likely to occur under certain conditions (where there is

unpredictability, uncertainty and/or uncontrollability), whether stress is experienced is largely dependent on a person's perception, appraisal and evaluation of a situation, event or thought (Lazarus & Folkman, 1984).

Stress may be further defined by cognitive, behavioural and environmental aspects. For example, stressors may be identified as being interpersonal (involving interactions with others), work related or financial (Folkman, 2013). Stress may also be physical in nature (such as an illness) or may pose a threat to one's ego when faced with potential failure, such as a job interview or public speaking task (O'Connor, Jones, Conner, McMillan, & Ferguson, 2008). Finally, stress can be defined by its duration, as being either acute or chronic.

### 1.2.1 Acute and Chronic Stress

Definitions of acute and chronic stress are poorly described in the literature and often subject to interpretation (Epel et al., 2018), however the two types of stress have distinct effects on physiological responses. Acute stressors are brief experiences which commonly occur in everyday life and can be resolved within a short period of time (Epel et al., 2018). Manipulations of acute stress within laboratory environments most commonly utilise an unexpected task combined with elements of social evaluation (such as a public speaking task) to induce acute stress (for a meta-analysis see Dickerson & Kemeny, 2004). Similarly, acute stress can be induced using unsolvable puzzles (e.g., Royal & Kurtz, 2010), challenging mental arithmetic tasks (Kirschbaum, Pirke, & Hellhammer, 1993) and physical tasks, such as a cold-water stimulus (Smeets et al., 2012).

In contrast, chronic stressors are longer lasting, continuing over many days, months or years depending on the nature of the stressor. For example, adversity in early life can have lasting effects on the experience of stress throughout adulthood (Yam, Naninck, Schmidt, Lucassen, & Korosi, 2015). Chronic stress may occur from a single life event such as bereavement or divorce (Lantz, House, Mero, & Williams, 2005). Chronic stress may also occur when numerous stressors are experienced and are not resolved, creating an additive effect from acute stressors to chronically experienced stress (Epel et al., 2018). The experience of stress triggers a cascade of physiological responses in the

body; however, the physiological impact of stress can differ depending on whether the stressors are acute or chronic.

### 1.2.2 Physiology of Stress

Experiencing a stressor elicits activation of two systems: The Sympathetic Adrenal Medullary (SAM) and the Hypothalamic Pituitary Adrenal (HPA) axis. The SAM system is activated quickly via the hypothalamus to release adrenaline and noradrenaline. In contrast, the HPA axis takes longer to respond, however, once activated, the physiological response of the HPA axis can have long lasting effects on health (Abraham, Conner, Jones, & O'Connor, 2016).

When a stressor is experienced, the limbic system (formed of the hippocampus, amygdala and prefrontal cortex) is activated and initiates the hypothalamus to release corticotropin-releasing factor (CRF) from the paraventricular nucleus. The CRF then stimulates the release of adrenocorticotrophic hormone (ACTH) from the pituitary gland. Finally, ACTH is transported via the blood to the adrenal cortex, signalling the release of the glucocorticoid, cortisol (McEwen, 1998; Nieuwenhuizen & Rutters, 2008). Circulating cortisol can be used as a biomarker to investigate individual differences in reactivity to a stressor (DeRijk & de Kloet, 2008) and its associations with health (Feder, Nestler, & Charney, 2009).

Once active, the HPA axis relies on negative feedback from ACTH and CRF to reduce signalling within the system to ultimately return to homeostasis (Chen & Miller, 2007; Meijer, 2006). When experiencing acute stressors, the HPA axis is activated and ‘turned off’ once the stressor has been resolved. However, prolonged activation of physiological and cardiovascular systems in response to chronically occurring stress can increase wear and tear on internal systems (Aschbacher et al., 2013; McEwen, 2004) and lead to poorer cardiovascular health in later life (for a meta-analysis see Chida & Steptoe, 2010). For example, short term circulation of CRF suppresses appetite, however extended stress exposure (and subsequently prolonged activation of the HPA axis) triggers the release of adrenocorticotropic hormones and glucocorticoids such as cortisol (Ulrich-Lai & Herman, 2009).

Research has found that when combined with cortisol, CRF creates an immunosuppressing effect which increases inflammation, directly influencing health (Elenkov, Webster, Torpy, & Chrousos, 1999; Tsigos & Chrousos, 2002). Aside from the physiological effects on the body, a more complex association between stress and health exists via an indirect, behavioural pathway; the impact on health due to changes in eating behaviours when experiencing stress. Prior to discussing these differences, it is important to note that cortisol secretion is diurnal and, as such, different physiological patterns are investigated when using measures of basal cortisol secretion (i.e., naturally occurring, unstimulated cortisol) opposed to stimulated cortisol secretion (i.e., changes in cortisol as a result of experiencing an acute stressor).

## 1.3 Stress and Eating Behaviours

The relationship between stress and eating behaviours has received increasing attention within health psychology. There is a growing body of research indicating that the experience of stress can lead to deviations in normal eating behaviours (see Chapter 2 for a review and meta-analysis of the literature on stress-related eating behaviours in adolescents and adults). Studies using self-report questionnaires have found that adults typically consume more food when they experience stress compared to periods with fewer stressors (Kandiah, Yake, Jones, & Meyer, 2006; Oliver & Wardle, 1999; Wardle, Steptoe, Oliver, & Lipsey, 2000).

Similarly, studies using daily measures of stress and eating behaviours have also found that stress is positively associated with food consumption, where increased daily stress is associated with greater consumption of between meal snacks (Conner, Fitter, & Fletcher, 1999; Newman, O'Connor, & Conner, 2007). Daily diary studies are a particularly useful method as, unlike single use questionnaires, they can document day-to-day individual variability of both stress and eating behaviours (O'Connor et al., 2008).

Eating behaviours have also been found to change in experimental studies where stress has been induced to compare food intake under acute stress with food intake when under no stress. For example, Habhab, Sheldon, and Loeb

(2009) used solvable and unsolvable puzzles to induce stress in females and found that those in the unsolvable puzzle (high stress) condition consumed more food ad-libitum compared to those in the solvable (low stress) condition. Stress induction studies can be especially useful as they allow direct comparisons of eating behaviours in both stress and control conditions.

Although research has indicated that stress is associated with an increase in food consumption (Greeno & Wing, 1994), an inverse relationship may be present when considering the type of foods being consumed. Several studies have found that consumption of healthy foods (defined as being low in energy and high in nutrients; LEHN) such as fruit and vegetables, decreases as stress increases (O'Connor et al., 2008; Wallis & Hetherington, 2009). In contrast, intake of unhealthy foods (i.e., high energy low nutrient foods; HELN) appears to increase as a function of stress in some individuals. This has been demonstrated both cross-sectionally and longitudinally in large scale projects. For example, in a sample of 12,110 men and women Ng and Jeffery (2003) found that individuals ate more fat in their diet when experiencing stress compared to stress free periods.

There are several theories as to why food consumption changes when we experience stress, such as neurological reward pathways and enhanced salience of palatable foods when experiencing stress (Nieuwenhuizen & Rutters, 2008; Sominsky & Spencer, 2014). As stress is more likely to occur when resources available to cope with the stressors are perceived to be limited (Folkman, 2013), maladaptive coping strategies may be employed as an alternative coping method (Wethington, Glanz, & Schwartz, 2015). One such maladaptive method for coping with a stressor is changing the amount of food consumed as a result of stress.

Dallman et al. (2003) suggest that, in animal-based research, glucocorticoids increase the salience of pleasurable activities, such as eating, which can be a motivator for comfort eating when stressed. In humans, the combination of high stress and increased levels of circulating glucocorticoids can result in one of two patterns, termed hyperphagia and hypophagia. Hyperphagia occurs when an individual increases their food intake in response to stress, which in turn leads to weight gain through chronic, positive energy balance (Torres &

Nowson, 2007). In contrast hypophagia occurs when an individual decreases their food intake, subsequently leading to weight loss through chronic, negative energy balance. It is estimated that 35-40% of people increase their food intake when experiencing stress (Oliver & Wardle, 1999; Sproesser, Schupp & Renner, 2014), which may be used as a method of avoidance coping (Dallman et al., 2003). Other animal studies have also suggested that consumption of palatable foods can reduce the experience of stress through activation of the basolateral amygdala, often referred to as the reward pathway (Ulrich-Lai et al., 2010). This dysregulation of bio-behavioural responses may overtime result in weight gain (Ulrich-Lai et al., 2010).

Stress experienced over longer periods of time can have reinforcing effects on these eating behaviours. Tryon, Carter, DeCant, and Laugero (2013) suggest that chronic stress can lead to alterations which then predispose individuals to respond more favourably towards foods which are HELN, where they are seen as being more rewarding, leading to a tendency to seek HELN foods as a method of coping with stress compared to LEHN foods. This theory is consistent with studies which have found that stress increases intake of foods either high in fat and/or foods which are carbohydrate based (Roberts, Campbell, & Troop, 2014). Other research has indicated that wanting for foods increases when experiencing stress (Groesz et al., 2012), even in the absence of hunger (Lemmens, Rutters, Born, & Westerterp-Plantenga, 2011), supporting the theory that eating behaviours may be used as a maladaptive coping mechanism.

Deviations in normal eating behaviours in response to stress can have long lasting impacts on health, both directly and indirectly. Furthermore, poorer health behaviours may persist over many years if these maladaptive habits are formed during adolescence, as they can continue into adulthood (Mikkilä et al., 2005). Similarly, overweight and obesity during adolescence can result in long term health issues and ultimately premature mortality (Reilly & Kelly, 2011).

## 1.4 Impact of Stress-related Eating Behaviours on Health Outcomes

Stress is thought to influence health by two differing pathways; a direct, biological pathway and an indirect, behavioural pathway (see Figure 1-1 for a schematic diagram).

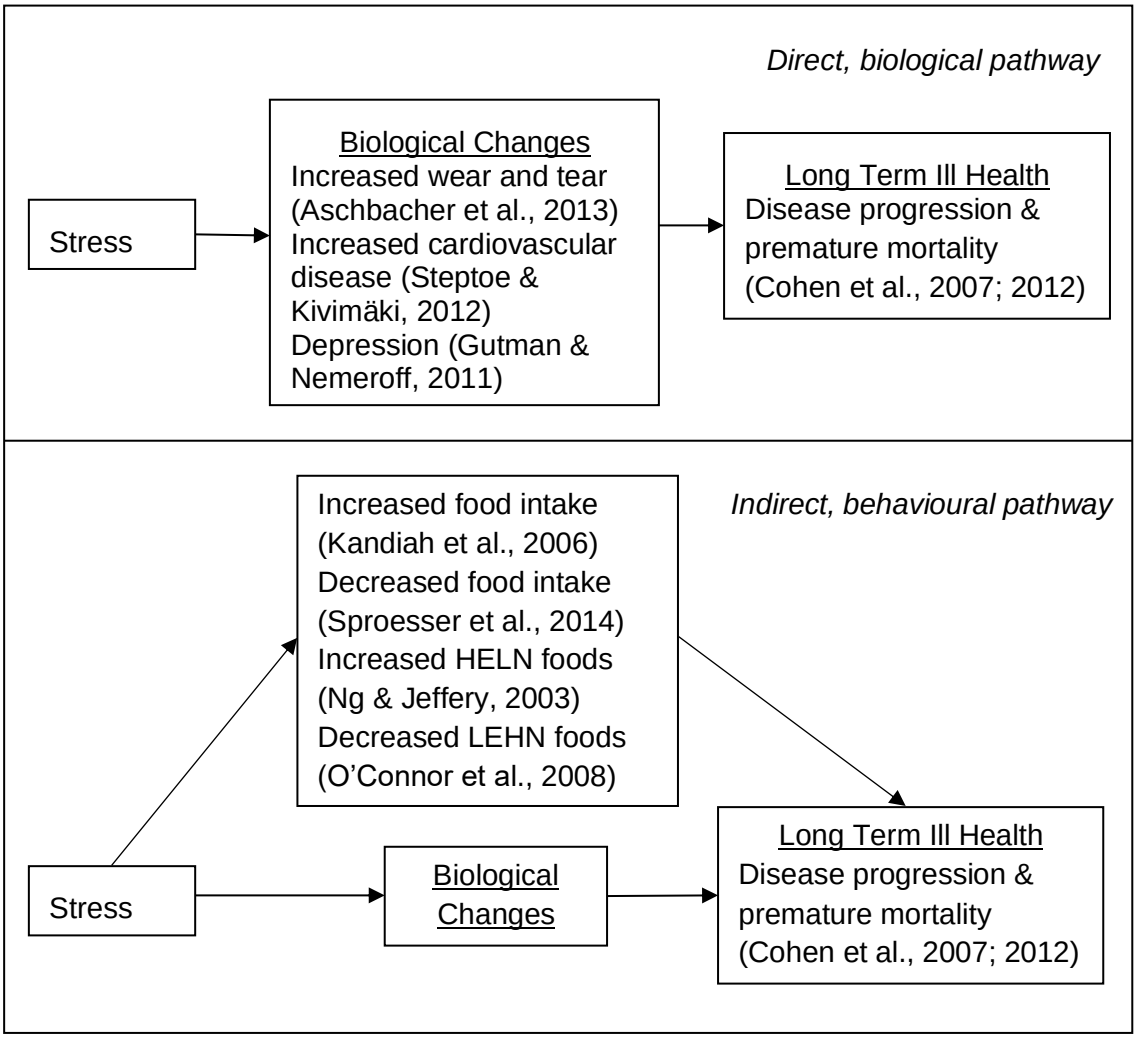


**Figure 1-1. Schematic of the direct (top diagram) and indirect (bottom diagram) influences of stress on health outcomes.**

Previous research has suggested that stress can directly influence health through physiological and biological mechanisms. For example, stress has been associated with increased risk of cardiovascular disease (Steptoe & Kivimäki, 2012), poorer sleep behaviours (Mezick et al., 2009), increased alcohol/drug use

(Schwabe, Dickinson, & Wolf, 2011) and reduced physical activity (Stults-Kolehmainen & Sinha, 2014). More generally, high levels of stress have been associated with an increased risk of developing physical diseases as well as an accelerated rate of disease progression (Cohen et al., 2012; Cohen, Janicki-Deverts, & Miller, 2007).

More interestingly, stress has been found to negatively influence health indirectly through changes to health behaviours (such as eating habits) which consequently lead to ill health (see section 1.3 and Chapter 2 for literature on stress-related eating behaviours). Changes in normal eating behaviours, such as increased consumption of HELN foods, have been linked to weight gain and increased body adiposity (Steptoe & Wardle, 2005). This weight gain through altered eating habits consequently raises the risk of overweight and obesity (Berridge, Ho, Richard & DiFeliceantonio, 2010). Finally, the indirect impact of stress-related eating behaviours can extend to negative health outcomes which develop as a result of weight gain and obesity. For example, a meta-analysis by Hartemink, Boshuizen, Nagelkerke, Jacobs, and van Houwelingen (2006) found that, amongst other health outcomes, the risk of developing type 2 diabetes was a direct function of BMI, where risk of Type 2 diabetes increased by approximately 20% for every 1kg/$m^2$ increase in BMI. Understanding the factors involved with weight gain is necessary to reduce obesity rates and associated poor health across emerging adulthood.

The prevalence of obesity in children and adolescents has rapidly increased over the last few decades (Ebbeling et al., 2002; Lobstein, Baur, & Uauy, 2004), although this trend is now plateauing in developed countries (Olds et al., 2011; Rokholm, Baker, & Sørensen, 2010; Wabitsch, Moss, & Kromeyer-Hauschild, 2014). The development of obesity in childhood has been associated with an increased risk of metabolic illnesses (Pervanidou, Charmandari, & Chrousos, 2013) and cardiovascular disease (Rosende, Pellegrini, & Iglesias, 2012) within this young age group. This detrimental effect on health can transfer into adulthood, as children with obesity are more likely to be overweight as adults (Biro & Wien, 2010; Freedman et al., 2005). Increased sedentary behaviours (Rey-López, Vicente-Rodríguez, Biosca, & Moreno, 2008), reduced physical

activity and poorer dietary behaviours, particularly showing a liking towards HELN foods (Lobstein et al., 2015), have all been identified as contributory factors to the increasing obesity rates in children and adolescents, however the mechanisms facilitating these behaviours are less clear.

Stress-induced changes in normal eating habits (i.e., the indirect pathway) is one suggested mechanism which has been associated with paediatric and adolescent obesity prevalence. Obesity and overweight in children and adolescents are estimated at 110 million worldwide and presents a global problem for health and wellbeing (Cali & Caprio, 2008). Previous research has found that stress-related eating behaviours are present in both young children and adolescents (Hill, Moss, Sykes-Muskett, Conner, & O'Connor, 2018). Eating behaviours are established in early childhood and, like personality traits, remain stable throughout childhood (Ashcroft, Semmler, Carnell, Van Jaarsveld, & Wardle, 2008). Deviations in normal eating behaviours during adolescence can continue into adulthood (Mikkilä et al., 2005) and consequently increase the risk of weight related illnesses later in life (Ebbeling et al., 2002). Furthermore, Pervanidou and Chrousos (2016) suggest that stress may work in a bidirectional manner, by increasing and maintaining obesity rates in children and adolescents through increased food consumption. Higher paediatric obesity rates are also thought to be compounded by increased food intake in response to stress as well as decreased physical activity within this age group (Tajik, Zulkefli, Baharom, Minhat, & Latiff, 2014). It is therefore essential that healthy eating habits are promoted within the adolescent years in order to foster good health throughout adulthood (Todd et al., 2015).

Although adolescence is a key period to research due to changes in development and formation of health behaviours, research on stress-related eating habits have mainly focused on adult populations. This thesis aimed to address this gap in the literature to investigate whether stress-related eating behaviours in adolescents were comparable to findings previously outlined in the literature.

## 1.5 Stress-Related Eating Behaviours in Adolescents

The experience of stress has been reported to be particularly high during the teenage years (Hankin, Mermelstein, & Roesch, 2007) due to increased social and academic demands. Stressors during this age can manifest in several ways, as adolescents experience pressures in their academic (Jayanthi, Thirunavukarasu, & Rajkumar, 2015), digital (Weinstein et al., 2016) and social lives (Spear, 2000) which are challenging to balance effectively (De Vriendt et al., 2012). For example, in a survey of 1,206 American 13-17 year olds, achievement at school was reported as one of the top stressors in this age group (American Psychological Association, 2009).

Previous research has found that high levels of stress in adolescents can lead to poorer health outcomes, including depression (Agoston & Rudolph, 2011; Low et al., 2012), anxiety (Michl, McLaughlin, Shepherd, & Nolen-Hoeksema, 2013) and obesity through a combination of increased food intake and decreased physical activity (Tajik et al., 2014). Perceived stress in adolescence may also change perceptions of the self, as some research has found that increased stress is correlated with greater body dissatisfaction (Johnson & Wardle, 2005). Additionally, high levels of stress during the adolescent years can predispose some individuals to disordered eating in later life (Rasmus, Anna-Lisa, Mauri, Riittakerttu, & Kaj, 2010). In contrast, having lower levels of stress may be protective against negative health outcomes. In a study of 135 college students (mean age 20 years), Fogle and Pettijohn (2013) found that young adults who reported having lower levels of perceived stress exhibited more health promoting behaviours including maintaining good levels of exercise and nutritional behaviours.

Aside from differences in perceived stress, changes in eating behaviours are also thought to be present in adolescents, in a similar manner to stress-eating behaviours reported in populations of adults. A recent meta-analysis found that stress-related eating habits may be present in children as young as 8 years old (Hill et al., 2018) and these maladaptive behaviours can continue throughout adulthood (see Chapter 2 for a meta-analysis of the literature). Moreover, the

experience of stress in early life can have long lasting effects on food choices and eating patterns in later life (Maniam & Morris, 2012).

However, age may have a differential effect on stress-eating associations in children and young adults. In a meta-analysis, Hill et al., (2018) found that stress was associated with increased consumption of unhealthy foods in children (8-12 years), however, healthy food intake remained unchanged. Furthermore, the review found that, in adolescents aged 13 to 18 years old, there was a negative association between stress and reduced intake of LEHN foods, like that found in adult populations (for example Wallis & Hetherington, 2009). However, the effect of stress on eating habits has not been consistently reported in adolescents. Contrary to the meta-analysis findings, in a daily diary study, Debeuf, Verbeken, Van Beveren, Michels, and Braet (2018) found that intensity of daily stress was not associated with daily snack intake in adolescents aged 13 years old. However, the authors suggest that this may be a result of the limited autonomy these young people had over their eating habits.

The conflicting findings of stress-related eating behaviours in adolescents may be partly explained by the onset of puberty, as research has suggested that onset of puberty alone may be associated with differences in the engagement of health behaviours. For example, Simon, Wardle, Jarvis, Steggles, and Cartwright (2003) reported that in a sample of 4,320 children aged 11-12 years, the onset of puberty was associated with greater engagement in unhealthy behaviours, such as smoking, food intake and increased experience of stress. Furthermore, Pervanidou and Chrousos (2011) suggest that chronic stress can be especially detrimental to developing adolescents regarding the risk of obesity, and that stress experienced over long periods of time may alter their emotional and cognitive development.

However, it is important to note that the boundary between the periods defining adolescence and young adulthood is not clearly defined. Nelson, Story, Larson, Neumark-Sztainer, and Lytle (2008) suggest that, when considering health behaviours there may not be clear boundaries between adolescence and adulthood. For example, Sawyer, Azzopardi, Wickremarathne, and Patton (2018) argue that the period which typically defines adolescence (i.e., 10-19 years old)

may no longer capture changes in development, due to earlier puberty onset and later age of transitioning to jobs. Instead, they suggest that adolescence should cover 10 to 24-year olds which can better capture changes experienced within this phase of development. This is in line with Arnett (2000) who suggests that emerging adulthood should cover a broader age range from 18 to 25 years old. Establishment of key health behaviours during adolescence and emerging adulthood are vital for disease prevention as it is a unique stage of human development where behaviours such as stress-related eating can become habitual and so impact on later life (Nelson et al., 2008).

## 1.6 Moderators of Stress and Eating Behaviours

Although stress has been found to influence normal eating behaviours, additional variables can moderate this relationship by either enhancing the salience of stress-related eating behaviours or reducing the impact of stress on eating behaviours (see Figure 1-2 for an example of moderating variables on stress-related eating behaviours and health outcomes). The individual

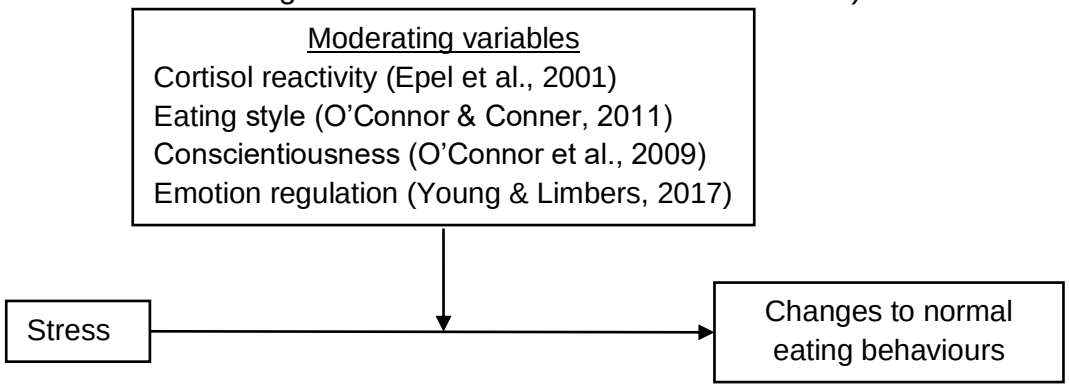


**Figure 1-2. Schematic diagram illustrating the role of moderating variables on the indirect, behavioural pathway between stress and health behaviours.**

differences model posits that changes in stress responses and eating habits are due to a combination of additional psychological and physiological factors (Greeno & Wing, 1994). For example, dietary restraint may moderate this relationship, where level of restraint (being high or low) can result in increased or decreased stress-induced eating behaviours (Newman et al., 2007).

The relationship between stress and eating behaviours is complex due to additional variables thought to moderate this relationship (Finch et al., 2019). Both individual and environmental factors can influence the strength of stress-induced eating behaviours. For example, research has indicated that females are more likely to change their normal eating behaviours when experiencing stress compared to males (Mikolajczyk et al., 2009; Sims et al., 2008; Stone & Brownell, 1994; Weinstein, Shide, & Rolls, 1997). Similarly, body weight has also been found to moderate stress-related food consumption, where individuals with greater body weight are more susceptible to increased food consumption when stressed than those lower in weight (Cotter & Kelly, 2018; Greeno & Wing, 1994). Finally, environmental factors such as socioeconomic status can influence health outcomes. Studies have found that stress experienced chronically can lead to poorer health, particularly for individuals in low socioeconomic environments (Ball, Schoenaker, & Mishra, 2017; Spinosa, Christiansen, Dickson, Lorenzetti, & Hardman, 2019). However, there are several moderating variables which are necessary to consider regarding stress, eating behaviours and subsequent health outcomes. The following section will discuss research findings on four variables which are reported to influence stress-related eating behaviours.

### 1.6.1 Physiological Markers of Stress

Experience of a stressor elicits the release of cortisol through activation of the HPA axis (see section 1.2.2 for a background on the physiology of stress). Cortisol is used as a biological indicator of stress and has been suggested to influence health through the physiological reaction elicited when experiencing stress, in addition to moderating stress-eating associations.

In a review of the literature, Björntorp (2001) suggested that physiological responses to stress through activation of the HPA axis may increase risk of obesity through increased food intake, which may partly be due to higher levels of circulating leptin. Activation of the HPA axis has also been associated with perturbations in the neuropeptide Y system, which is associated with regulation of food intake. Changes to the neuropeptide Y system can result in increased deposition of visceral fat, particularly in abdominal areas. From an evolutionary perspective, this increase in food intake and fat deposition was necessary to

maintain energy availability to respond to physical stressors (i.e., predators) throughout periods when food may be scarce.

Research has indicated that physiological activity can differentially influence health outcomes. The following sections will summarise these effects by the type of physiological marker of stress, as outcomes are quantitatively different depending on whether cortisol is investigated through diurnal, chronic or acute (i.e., reactivity to a stressor) measures.

*Diurnal cortisol*

In a meta-analysis of 80 studies, Adam et al. (2017) found that flatter, diurnal cortisol profiles were associated with poorer health outcomes (including physical and emotional) compared to more leptokurtic (i.e., heightened) profiles. Changes in diurnal cortisol have also been linked to differences in the experience of stress. For example, in a sample of female undergraduate students, Lovell, Moss, and Wetherell (2011) found that individuals who reported greater perceived stress had on average flatter diurnal cortisol profiles compared to individuals who reported lower perceived stress.

Diurnal cortisol patterns have also been investigated on their association with eating behaviours. In a sample of 323 children aged 5 to 10 years old Michels et al. (2013) found that children who had elevated cortisol (both overall and cortisol awakening response) consumed sweet foods more frequently than those with lower cortisol levels. Furthermore, children with a steeper decline in diurnal cortisol were reported to consume more snack and fatty foods, suggesting that higher levels of cortisol in pre-pubescent children is associated with greater unhealthy (but not healthy) dietary habits.

*Chronic activation of the HPA axis*

Chronic activation of the HPA axis can be measured through hair cortisol which can indicate average cortisol levels retrospectively for up to three months. Currently, there is limited research using hair cortisol to investigate individual differences in stress-eating associations, however, a study by Steptoe, Easterlin, and Kirschbaum (2017) indicated that individual differences in hair cortisol may predict eating behaviours. In their study of over 2000 older men and women

(mean age 66 years), Steptoe et al., (2017) found a negative association between hair cortisol concentrations and fruit and vegetable intake, where lower cortisol was associated with greater consumption of fruit and vegetables. Similar to diurnal cortisol, differences in chronic activation of the HPA axis may provide insights into changes to normal eating habits under conditions of stress.

*Acute cortisol reactivity*

In contrast with chronic activation of the HPA axis, measures of acute cortisol reactivity have received increased attention in the literature.

Research has identified two patterns of cortisol reactivity in response to an acute stressor (heightened and blunted) which may influence associations between stress and eating behaviours. A heightened response is identified by a sharp rise in circulating cortisol following a stressor which gradually decreases through a negative feedback loop from the hypothalamus to the pituitary glands (Tsigos & Chrousos, 2002). In contrast, individuals with a blunted cortisol reactivity (i.e., low reactors) will experience only a slight increase in cortisol concentrations, which recover back to normal levels much quicker than those with a heightened cortisol response. Blunted cortisol reactivity is also referred to as a flattened response due to the platykurtic pattern in data when plotted.

Previous research has identified that both patterns of cortisol reactivity can influence normal eating behaviours. Epel, Lapidus, McEwen, and Brownell (2001) found that women consumed a greater amount of food following a stressor if they had a heightened stress response compared to those who had a blunted cortisol response. Similarly, Newman et al. (2007) found that the association between daily stress and snack intake was only present in individuals who were high reactors (i.e., had a heightened cortisol response), and stress was not associated with snack intake in individuals who were low in cortisol reactivity. Furthermore, cortisol reactivity fully mediated food intake following a stress-induction task. Appelhans, Pagoto, Peters, and Spring (2010) also found that heightened cortisol reactivity was associated with greater snack intake following a stressful task, however only in women with obesity. No effect was found on cortisol and snack intake in women with healthy weight. In contrast, in a sample of adult women, Tryon et al. (2013) found that those who reported high chronic stress but had low

reactivity to a stress induction task consumed more energy from high energy density, palatable foods than those who reported having low chronic stress.

Finally, the difference in cortisol reactivity in response to a stressor has also been found in children aged 8-9 years old. Francis, Granger, and Susman (2013) found that higher cortisol reactivity was associated with increased food intake in the absence of hunger following a stress induction task.

One theory for this association is that the heightened cortisol response increases the likelihood of a loss of control when eating, particularly for HELN foods (Maier, Makwana, & Hare, 2015). This may be because foods are perceived as more rewarding when experiencing stress (Adam & Epel, 2007) and are used as a maladaptive method of coping with the stressor (Dallman et al., 2003), although this has been researched predominately in women (Tomiyama, Dallman, & Epel, 2011). However, Pool, Delplanque, Coppin, and Sander (2015) theorizes that increased food consumption as a response to stress may result from the formation of habits, rather than an intrinsic seeking for reward from foods.

The relationship between stress and activation of the HPA axis is complex and highly variable depending on an individual's experience of a stressor (Miller, Chen, & Zhou, 2007). These individual differences in reactivity to a stressor develop from differences in psychological appraisal of the stressor itself (Gaab, Rohleder, Nater, & Ehlert, 2005). For example, Miller et al. (2007) suggest that the type of stressor experienced can lead to variations in the HPA axis response. They suggest that the physiological reaction is largely dependent on not only the perceived distress caused by a stressor but also the type of stressor experienced. For example, stressors which are uncontrollable, involve some form of trauma or a potential violation to physical integrity have been found to produce an elevated but flat profile for diurnal cortisol levels. Miller et al. (2007) suggest that a combination of objective and subjective measure of stress should be used to better capture an individual's reactivity to a stressor.

Taken together, these findings provide evidence that physiological markers of stress can influence and moderate the stress-eating relationship. Furthermore, individual differences seem to be particularly evident for cortisol

reactivity to acute stressors. However, previous research has almost exclusively used samples of adults, with currently limited research on cortisol reactivity in adolescents. This thesis aims to address the current gap in the literature by investigating the moderating role of cortisol on stress and eating behaviours in adolescents and young adults. Furthermore, variations in cortisol reactivity may be due to individual variability on factors surrounding stress (such as the type of stressor experienced). Combining objective and subjective measures of stress may allow greater insights into the mixed findings on cortisol reactivity and eating behaviours. Therefore, this thesis aimed to combine objective measures of stress (i.e., cortisol measured via saliva and hair samples) with subjective measures to understand the role of cortisol reactivity in daily stress and eating habits of adolescents and young adults.

### 1.6.2 Eating Style

Individual variability in stress-related eating behaviours may, in part, be explained by differences in eating styles (Greeno & Wing, 1994; O'Connor & Conner, 2011). Research has identified three key eating styles which have been found to moderate stress-related eating behaviours.

#### *Dietary Restraint*

The moderating effect of dietary restraint on the relationship between stress and eating behaviours is well established. Dietary restraint reflects the ability to exert self-control over one's eating behaviours (Van Strien, Frijters, Bergers, & Defares, 1986). An early theory by Polivy and Herman (1985) suggested that overconsumption is due to dietary restraint, where perceived hunger increases due to prolonged restrictions in food intake as a method of controlling body weight (Herman & Mack, 1975). Under normal conditions, individuals higher in dietary restraint maintain healthier eating habits than those low in restraint who do not restrict their eating behaviours as closely (Contento, Zybert, & Williams, 2005; Mitchell & Epstein, 1996; Rideout, Linden, & Barr, 2006; Rideout, McLean, & Barr, 2004). However, this pattern is reversed in periods of stress. Studies in samples of adults have consistently found a hyperphagic response (i.e., eating more when experiencing greater stress) in individuals who are high in dietary restraint, compared to those low in restraint (Levine & Marcus,

1997; Newman et al., 2007; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007; Zellner et al., 2006).

There has been some research to suggest that dietary restraint moderates stress-related eating behaviours in young children. For example, in a sample of 40 pre-adolescents (mean age 9 years old), Roemmich, Wright, and Epstein (2002) found that children higher in dietary restraint consumed a greater number of snacks following a stressor compared to children who were lower in dietary restraint. This was also found in a later study (Roemmich, Smith, Epstein & Lambiase, 2007).

However, there have been some inconsistencies in the literature regarding the role of dietary restraint in stress-related eating behaviours. For example, in a study on daily stress and eating habits, O'Connor and O'Connor (2004) did not find any moderating effect of dietary restraint on the association between exam stress and food intake in female university students. Similarly, in a sample of Chinese female students (mean age 19 years), Lai, Why, Koh, Ng, and Lim (2012) found that changes in body weight were observed during periods of academic stress in high restrained eaters only. Furthermore, this change in body weight was not attributed to changes in food intake during the stress period, it was instead associated with reduced engagement in physical activity in these highly restrained eaters, resulting in an imbalance between energy intake and energy expenditure. These studies show some differences to the overall literature; however, both used exclusively female samples and are specific to university aged students. Tice, Bratslavsky, and Baumeister (2001) reported that dietary restraint was not associated with changes in food intake when experiencing emotional distress (lab study). In a stress induction paradigm, Oliver and Wardle (1999) did not find an effect of dietary restraint on stress-related eating in their study.

There is a gap in the literature for understanding how dietary restraint may influence stress-related eating behaviours in adolescents. Although there is evidence to suggest that dietary restraint may moderate stress-related eating in children as young as 8 years (Roemmich et al., 2007; Roemmich et al., 2002), findings in samples of adults have been mixed. Investigating the role of dietary

restraint in stress-induced eating behaviours will advance current understanding of stress and health in adolescents and young adults. Furthermore, moderating variables such as dietary restraint can be used to identify those most susceptible to maladaptive eating behaviours when experiencing stress.

### *External Eating*

External eating style is characterised by eating behaviours which are driven by environmental cues rather than internal cues, such as hunger (Schachter, Goldman, & Gordon, 1968). Similar to dietary restraint, external eating has been found to change eating habits (Greeno & Wing, 1994), where individuals high in external eating style consume more food compared to those scoring low in external eating (Oliver, Wardle, & Gibson, 2000), and in children (aged 8-10 years old) are less likely to adhere to a specific diet (Bawaked et al., 2018).

When considering stress, the moderating effect of external eating on stress-related eating behaviours is mixed. There are studies which have found that external eating behaviours moderate stress-related eating. For example, in daily diary studies, external eating moderated associations between daily stress and daily snack intake, where individuals higher in external eating behaviours consumed more snacks when experiencing stress than those lower in external eating (Conner et al., 1999; O'Connor et al., 2008).

However, Van Strien, Herman, and Verheijden (2009) did not find any moderating effect of external eating on overconsumption or weight (specifically being overweight). Newman et al. (2007) found that although external eating was associated with greater snack intake, it did not moderate the interaction between cortisol reactivity and snack intake. Similarly, Royal and Kurtz (2010) did not find any moderating effect of external eating style on stress and food intake in adults.

The moderating effect of eating style on stress and eating behaviours seems to be complex with contradictory findings. Whilst Conner et al. (1999) found that external eating significantly moderated the association between daily stress and snack intake, dietary restraint and emotional eating were not found to moderate this association. Similarly, van Strien, Herman, Anschutz, Engels, and de Weerth (2012) found no moderating effect of emotional eating scores on stress

condition and food intake when external eating was removed from the statistical model. This is interesting as it suggests that eating styles can independently have different effects on stress and food intake in samples of adults. Therefore, these differences in moderating effects of eating style on stress and eating behaviours are also likely to be present in adolescents and young adults.

***Emotional eating***

Finally, emotional eating (defined as eating in response to any strong emotion) has been found to moderate the association between stress and eating behaviours. An early theory by Kaplan and Kaplan (1957) suggested that food may be used as a method to overcome negative emotional arousal. Interestingly, emotional eating behaviours were initially thought to result from a combination of genetic susceptibility and environmental factors (van Strien, van der Zwaluw, & Engels, 2010), however a twin study by Herle, Fildes, and Llewellyn (2018) suggests that emotional eating is a learnt behaviour. This is consistent with some previous research in adolescents which has associated the emergence of emotional eating with situational factors such as depression (Ouwens, van Strien, & van Leeuwe, 2009) and parenting style (Snoek, Engels, Janssens, & van Strien, 2007). Emotions have been associated with changes to food intake, particularly negative emotions (such as sadness or frustration), with people increasing, decreasing or seeing no change in their food intake (Macht, 2008). Similarly, emotional eating has been found to moderate stress-related eating behaviours in adults.

In lab-based studies using stress induction paradigms, higher levels of emotional eating have been associated with greater intake of food following a stressor, particularly for foods high in sugar and fat (Oliver & Wardle, 1999; Oliver et al., 2000; Wallis & Hetherington, 2004). The association is also thought to be greater in women than men, although some studies have used female only samples (Tomiyama et al., 2011). Consequently, increased emotional eating when stressed can result in overweight and obesity (Richardson, Arsenault, Cates, & Muth, 2015). While emotional eating may influence the susceptibility to stress-related eating habits, it is important to note that this relationship may only result in weight gain when positive energy balance is chronic. In contrast, both

stress and emotional eating behaviours may be transient and situation specific, and so changes to eating habits would need to be sustained to influence weight related outcomes.

Research on emotional eating and stress appears to be consistent across a range of age groups. For example, in a sample of 437 children aged 5-12 years old, Michels et al. (2012) found that negative emotions were positively associated with stress and food intake. Similarly, in a study of 501 preadolescent children (mean age 12 years) Nguyen-Rodriguez, Chou, Unger, and Spruijt-Metz (2008) found that perceived stress was significantly, positively correlated with emotional eating. The study found that children who reported having higher perceived stress were more likely to engage in emotional eating behaviours.

This change in eating habits has also been found in young adults (aged 18-23 years old) where events which were evaluated as being more stressful lead to greater emotional eating behaviours (Wilson, Darling, Fahrenkamp, D'Auria, & Sato, 2015). Concurrent with recent evidence (Herle et al., 2018), Tan and Chow (2014) suggest that eating is a learned response within preadolescent children which can be problematic in later adolescence into adulthood as these emotional eating behaviours increase the risk of becoming overweight or obese. However, there is limited research on the moderating effects of emotional eating on stress and food intake in adolescents. Of the three eating styles considered, emotional eating has been suggested to be the pre-eminent eating style in stress-induced eating (O'Connor et al., 2008). It is therefore vital that emotional eating should be considered when understanding individual differences in stress-related eating behaviours, and ultimately the formation of maladaptive eating habits in emerging adulthood.

Emotional eating as an eating style links closely to how one regulates emotions. However, facets within emotional eating have been found to influence the amount and type of food consumed when experiencing stress.

### 1.6.3 Emotion Regulation

Aside from emotions generally influencing stress-related eating habits, strategies used to regulate our emotions have been suggested to differentially

influence eating behaviours. Macht (2008) suggested that there are five facets within the broader scope of emotional eating. However, two facets in particular have received greater interest regarding their interactions with stress and eating behaviours; cognitive reappraisal and expressive suppression.

Cognitive reappraisal is a strategy where emotionally relevant events/situations are reinterpreted in order to change current emotional state and reduce emotional impact (Gross & John, 2003). Cognitive reappraisal is considered as an adaptive coping strategy to regulate emotions, and has been associated with decreased negative and increased positive mood (Garnefski, Kraaij, & Spinhoven, 2001; Gross & John, 2003), and can moderate symptoms of depression in periods of stress (Troy, Wilhelm, Shallcross, & Mauss, 2010).

In contrast, expressive suppression involves inhibiting the behavioural expression of emotions (such as controlling one's facial expressions) when experiencing a strong emotion (Gross & John, 2003). Expressive suppression is considered to be a maladaptive strategy of emotion regulation when used over long periods (John & Gross, 2004) and can have negative effects on mood and health (Gross & John, 2003), for example contributing to risk of cardiovascular disease (Mauss & Gross, 2004). In adolescents, expressive suppression may be used as an emotional avoidance strategy, which has been linked to greater stress-related eating behaviours (Young & Limbers, 2017). In contrast, using cognitive reappraisal as an emotion regulation strategy can improve resilience against stress and has been negatively associated with cortisol reactivity (Carlson, Dikecligil, Greenberg, & Mujica-Parodi, 2012).

These strategies of emotion regulation have been found to influence eating behaviours differently. For example, Evers, Marijn, and de Ridder (2010) looked at cognitive reappraisal and expressive suppression on eating when experiencing emotions (emotion-induction task – recalling a sad event). They found that individuals who were higher in suppression consumed more food than individuals lower in suppression when experiencing emotions. Differences in level of cognitive reappraisal were not associated with any changes to food consumption. Based on these findings, Evers et al. (2010) argue that strategies

of emotion regulation are more important when considering eating behaviours compared to individual differences in emotional eating style more broadly.

There is limited research on the moderating role of emotion regulation, particularly in relation to stress and eating behaviours in adolescents and young adults. In addition to different styles of eating, understanding the cognitive factors in emotional eating in adolescents and young adults will help to determine which factors moderate stress-related eating behaviours in this age group.

### 1.6.4 Conscientiousness

Conscientiousness is one of five dimensions used to describe personality (Costa & McCrae, 1992) and has received increasing interest regarding its association with health. Conscientiousness is the tendency to be organised, goal-directed and to follow rules and norms (Roberts, Jackson, Fayard, Edmonds, & Meints, 2009). Individuals who score highly in conscientiousness tend to be rule abiding, practical and strive for achievement, whereas individuals low in conscientiousness tend to be more irresponsible, spontaneous and less motivated to accomplish their goals (Costa & McCrae, 1992). Conscientiousness has a vital role in health psychology as a powerful and important construct for research as highly conscientious individuals tend to live longer and have a lower mortality risk than those lower in this trait (Terracciano, Löckenhoff, Zonderman, Ferrucci, & Costa Jr, 2008).

Compared to other personality traits, conscientiousness is unique in its application to health as it can predict longevity (Friedman et al., 1993; Kern & Friedman, 2008) even after controlling for factors such as cognitive ability (Hill, Turiano, Hurd, Mroczek, & Roberts, 2011), socioeconomic status and level of education (Roberts et al., 2007). Conscientiousness has also been used to predict relative risk of mortality in both children (Taylor et al., 2009) and older adults aged ≥ 65 years old (Weiss & Costa Jr, 2005). Similarly, Goodwin and Friedman (2006) found that lower levels of conscientiousness were associated with poor physical health, including diabetes, strokes and elevated blood pressure. This may, in part, be due to low conscientious individuals having higher BMI's on average compared to individuals high in conscientiousness (Sutin, Ferrucci, Zonderman, & Terracciano, 2011). In contrast, a meta-analysis of over

75,000 adults concluded that being high in conscientiousness is protective against poor health including risk of obesity (Jokela et al., 2013). Furthermore, these highly conscientious individuals have a reduced risk of experiencing psychiatric and psychological conditions (Goodwin & Friedman, 2006). In contrast, individuals low in conscientiousness tend to have fewer health promoting behaviours and instead engage in more high-risk behaviours such as drug use and excessive alcohol consumption, which in turn damages physical and psychological health (Bogg & Roberts, 2004).

It is possible that conscientiousness influences health outcomes through changes in both attitudes and intentions towards general health promoting behaviours (Conner & Abraham, 2001). For example, O'Connor, Conner, Jones, McMillan, and Ferguson (2009) found that individuals high in conscientiousness reported consuming more fruit and less high fat snacks when experiencing stress. This may be because individuals low in conscientiousness have fewer, and/or less strong intentions to consume healthy foods such as fruit and vegetables, than those high in conscientiousness (Wilson, O'Connor, Lawton, Hill, & Roberts, 2016).

Furthermore, changes in conscientiousness may be associated with individual differences on other factors, such as eating style, which consequently influence the engagement in health behaviours. Heaven, Mulligan, Merrilees, Woods, and Fairooz (2001) found that conscientiousness is associated with differences in eating style, where individuals scoring more highly on external and emotional eating tend to be less conscientious. Restraint was also influenced by this personality trait, where individuals higher in conscientiousness were more restrained in their eating habits. This research suggests that conscientiousness may differentially influence eating behaviours.

Conscientiousness can also influence health outcomes indirectly by moderating the experience of stress and eating behaviours. Vollrath (2000) found that highly conscientious individuals experience fewer stressors than those lower in this trait. This has also been found in studies using objective measures of stress, such as hair cortisol concentrations (Steptoe et al., 2017). Furthermore, these highly conscientious individuals also reported experiencing fewer stress-

related health problems than those low in conscientiousness (Ferguson, 2013). This may be because individuals higher in conscientiousness cope better with stressors (Penley & Tomaka, 2002) by responding more positively towards them (Gartland, O'Connor, & Lawton, 2012) and/or adopting a more problem focused response to cope with the stress (Bartley & Roesch, 2011; Watson & Hubbard, 1996).

Studies have found that when experiencing stress, individuals low in conscientiousness tend to consume more between-meal snacks (particularly high fat snacks) and less fruit than individuals higher in conscientious (O'Connor et al., 2009; O'Connor & O'Connor, 2004). Conscientiousness is thought to moderate not only the number of stressors experienced but also the engagement in more health promoting behaviours like healthy eating and exercising (O'Connor et al., 2009).

It is likely that this moderating effect on stress-related eating behaviours is also present in adolescents and young adults. In a sample of adolescents (aged 14-18 years old) Macchi, MacKew, and Davis (2017) found that impulsivity (a factor within conscientiousness where high impulsivity represents low conscientiousness) in decision making was associated with more unhealthy eating habits compared to lower impulsivity (higher levels of conscientiousness).

Conscientiousness is an important variable to consider in health research as it can be used to explain individual variability in the stress and eating relationship. Although this trait is well researched in adults, there is limited research on how conscientiousness may influence stress-related eating behaviours in adolescents and young adults. Given the direct and indirect effects conscientiousness is thought to have on health outcomes, it is a key variable to include in research on eating behaviours in emerging adulthood.

## 1.7 Summary and Thesis Aims

The relationship between stress and health outcomes is complex. Stress can have a detrimental effect on health both directly and indirectly, through changes to our normal health behaviours. Stress has been found to influence the amount and type of food consumed, where food is used as a maladaptive coping

mechanism. However, there is limited research on this association in adolescents and young adults.

Adolescence is a key age group to research as there is increased autonomy over food choices as adolescents and young adults become less dependent on the family home environment. Furthermore, persistent lifestyle behaviours are established during this age period which can have long term effects on health (Nelson et al., 2008), particularly eating behaviours. Changes to the amount and type of food consumed when experiencing stress has been well documented in adult samples, however the effect is under researched in emerging adulthood. Therefore, it is vital to identify the extent of stress-related behaviours in emerging adulthood to prevent the formation of maladaptive eating habits due to stress.

However, the association between stress and eating behaviours is complex and research has highlighted several variables moderate stress-related eating behaviours in adults, including conscientiousness, dietary restraint and emotional eating (Murphy, Miller, & Wrosch, 2013; O'Connor & Conner, 2011; Royal & Kurtz, 2010; van Strien et al., 2012). Furthermore, physiological responses to stress have also been found to moderate stress-related food intake, with emphasis on cortisol reactivity to a stressor (Appelhans et al., 2010; Epel et al., 2001; Steptoe et al., 2017). Although under-researched in younger samples, these variables may have similar moderating effects in adolescents and young adults.

Understanding associations between stress and eating habits is essential as stress-related eating behaviours are a modifiable and learnt behaviour. Eating habits are an easily modifiable health behaviour which can directly reduce the likelihood of weight gain and detrimental health outcomes throughout adulthood. Gaining insights into how stress may influence health behaviours in adolescents, and understanding the role of moderating variables, can inform future research to develop targeted interventions to reduce stress-related eating in emerging adulthood.

This thesis aimed to further current understanding of the indirect effects of stress on health in samples of adolescents aged 13 to 18 years old and young

adults. Firstly, this thesis aimed to synthesize previous research on stress and food consumption in adolescents and adults separately. Two meta-analyses (Chapter 2) were conducted to identify the strength of associations between stress and food intake, as well as identify potential moderating variables. The meta-analyses also highlight limitations with previous research and gaps in the literature.

Secondly, this thesis aimed to conduct a large-scale, daily diary study of stress and food intake in adolescents and young adults (Chapter 3). This study aimed to determine whether stress-related eating habits are present in adolescents, as well as in young adults. Furthermore, this study aimed to investigate potential moderating variables on this relationship.

Thirdly, this thesis aimed to investigate the interactions between perceived stress and physiological reactivity through cortisol sampling. Chapter 4 reports an experimental, daily diary study which combined subjective (self-reported) stress with objective stress (cortisol) measured using a stress induction paradigm and hair samples.

Finally, this thesis will discuss the findings from the meta-analyses and the two studies in the context of previous literature (Chapter 5). The discussion will outline the novelty of this research and address potential limitations in this research. Furthermore, the discussion will address the relative importance of moderating variables in understanding stress-related eating behaviours. Finally, this thesis will discuss applications of the findings to both research practice and to policy decisions to reduce eating in response to stress within adolescents and young adults.

# Chapter 2
# Stress-related Eating Behaviours in Adults and Adolescents: Combined Findings from Two Meta-Analyses

## 2.1 Introduction

Chapter 1 outlined the influence of stress on health outcomes through two pathways. The direct pathway posits that prolonged activation of physiological and cardiovascular systems in response to chronically occurring stress can increase wear and tear on internal systems (Aschbacher et al., 2013; McEwen, 2004), leading to poorer cardiovascular health in later life (for a meta-analysis see Chida & Steptoe, 2010). In contrast, stress can influence health outcomes indirectly through deviations in health behaviours, particularly eating behaviours (O'Connor & Conner, 2011; Tomiyama, 2019), where individuals increase their food intake when experiencing stress (Pool et al., 2015).

More specifically, higher levels of stress have been associated with increased consumption of unhealthy foods (Lyzwinski et al., 2018), particularly those high in fat and sugar (Newman et al., 2007; Roberts et al., 2014). In contrast, higher levels of stress are also associated with decreased consumption of healthy foods (Mikolajczyk, El Ansari, & Maxwell, 2009; O'Connor et al., 2008; Wallis & Hetherington, 2009).

Previous literature reviews are in accordance with these findings, where emphasis is placed on changes to eating habits as a result of experiencing stress (Adam & Epel, 2007; Araiza & Lobel, 2018), particularly increased intake of unhealthy foods and decreased intake of healthy foods (Lyzwinski et al., 2018; Torres & Nowson, 2007). Worryingly, a recent meta-analysis indicated that stress-related eating behaviours may be present in children as young as 8 years old and can continue throughout childhood into adolescence (Hill et al., 2018). Reviews have also identified theories for stress-induced eating behaviours, including neurological reward pathways and enhanced salience of palatable foods when experiencing stress (Nieuwenhuizen & Rutters, 2008; Sominsky &

Spencer, 2014). Although the results are generally in agreement, the existing literature reviews all highlight the complex interactions between biological and behavioural components of stress-related food intake. However, the strength of reported associations between stress and eating behaviours have not been quantified.

Additionally, there has been less focus in the literature on how stress may influence the eating behaviours of healthy adolescents. Investigations of dietary behaviours in this cohort have typically focused on the effect of stress on disordered eating (for a review see Ball & Lee, 2000; Stice, 2002). Previous studies have indicated a similar effect of stress-induced eating behaviours in children and adolescents (Hill et al., 2018), however the strength of this effect has not been determined in adolescents only.

Therefore, the primary aim of this systematic review and meta-analysis was to first determine the strength of the association between stress and food consumption in adults. Furthermore, the meta-analysis also aimed to determine whether the strength of association between stress and food consumption varied as a function of type of food consumed (i.e., unhealthy and healthy). Following this, a second meta-analysis aimed to synthesize previous findings on stress-related food consumption (both overall and on type of food) in adolescents and compare the strength of associations with those found in adults.

**Moderators of stress and eating**

The individual differences model of stress and eating posits that changes in stress responses and eating habits are due to a combination of psychological and physiological factors (Greeno & Wing, 1994; Sapolsky, 1994). Interactions between stress and health form part of a complex interaction between biological, psychological and social aspects. Research has highlighted some variables thought to moderate stress-related eating behaviours (for a review see Araiza & Lobel, 2018; Gibson, 2012; O'Connor & Conner, 2011; Tomiyama, 2019), although findings have not been consistent.

The effect of stress on eating behaviours is thought to influence men and women differently. Research has indicated that females are more likely to change their normal eating behaviours when experiencing stress compared to males

(Mikolajczyk et al., 2009; Sims et al., 2008; Stone & Brownell, 1994; Weinstein et al., 1997), however this difference between genders has not been consistently found in previous research (Barrington, Beresford, McGregor, & White, 2014; Conner et al., 1999; El Ansari & Berg-Beckhoff, 2015; Reichenberger et al., 2018). Furthermore, some studies have used exclusively female samples (for example Epel et al., 2001; Habhab et al., 2009; Wallis & Hetherington, 2009), making it difficult to interpret the strength of stress-related eating in males and females separately. Therefore, this review also aimed to investigate the moderating effect of gender on the relationship between stress and eating behaviours.

Similarly, eating style is thought to moderate food consumption when experiencing stress (see section 1.6.2 for a summary of previous literature), particularly dietary restraint (Adam & Epel, 2007; Greeno & Wing, 1994; Wardle et al., 2000). Research has found that individuals higher in dietary restraint are more likely to engage in stress-related eating behaviours compared to those lower in restraint (Adriaanse, de Ridder, & Evers, 2011; O'Connor et al., 2008; Torres & Nowson, 2007; Wallis & Hetherington, 2004). Restrained eaters are assumed to restrict their food intake through self-control processes. When these self-control processes are undermined, disinhibition of eating occurs, and excessive food intake takes place. It has been suggested that the intake of unhealthy food increases as a response to stress when disinhibition occurs (Lattimore & Maxwell, 2004; Ward & Mann, 2000). Stress is expected to affect restrained eaters through disrupting the control normally exerted over their eating behaviours. Thus, individuals with high restraint scores are more likely to respond to stress by eating, while those low in restraint should show no change to their eating behaviours. Therefore, the moderating effects of dietary restraint on stress-eating relations will be investigated in the current meta-analysis. Further eating style variables (e.g., external and emotional eating) were not considered in the current meta-analyses due to the limited number of studies investigating these moderating variables on stress-eating behaviours.

Previous research has indicated that, once established, dietary patterns remain relatively consistent throughout adulthood (Mikkilä et al., 2005). For

example, a recent meta-analysis highlighted that stress-related eating may occur in children as young as 8 years old (Hill et al., 2018). Similarly, studies have reported interactions between stress and eating across a range of ages in adults, particularly in longitudinal studies (Barrington, Ceballos, Bishop, McGregor, & Beresford, 2012; Mouchacca, Abbott, & Ball, 2013). However, in studies using adult samples, there is a bias towards samples recruited from higher education environments (particularly universities) in psychology research generally, but also in stress and health research (Ball & Lee, 2000; Henrich, Heine, & Norenzayan, 2010) which may result in data which is not representative of wider populations (Hanel & Vione, 2016). Therefore, in addition to mean age, the meta-analysis in adults investigated the moderating effect of sample source to compare associations between stress and food intake from samples recruited from higher education environments (i.e., university students and staff) compared to samples obtained from wider populations (i.e., general population). Furthermore, the findings of the two meta-analyses will be compared to determine whether stress-induced eating habits are similar across adolescents and adults.

Associations between stress and eating habits have been found using different types of study design, including stress induction paradigms (e.g., Oliver et al., 2000), objectively measured stress (e.g., Newman et al., 2007), daily diary studies (e.g., Conner et al., 1999) and surveys of perceived stress at single time points (e.g., Vidal et al., 2018). These meta-analyses aimed to determine whether the type of study design, and overall study quality, moderated associations between stress and food consumption. It was predicted that study quality (weak, moderate or strong), and study design would influence the strength of the association between stress and food intake overall.

Finally, weight has been found to moderate stress-related food consumption in samples of adults. Previous studies have found that weight is positively associated with stress-related eating behaviours, where heavier individuals are more susceptible to increased food consumption when stressed than those lower in weight (Cotter & Kelly, 2018; Greeno & Wing, 1994). Therefore, weight (mean BMI and proportion of healthy/overweight individuals) was included as a moderating variable in the meta-analyses.

## 2.2 Aims

Firstly, the meta-analyses aimed to determine the strength of stress-related eating behaviours in adults and adolescents. Two methods of analysis were used to calculate effect sizes using Comprehensive Meta-Analysis version 3 (see section 2.3.5 for details). Secondly, the meta-analyses aimed to determine the association between stress and type of food consumption (healthy and unhealthy) in adults and adolescents.

Finally, where there is sufficient data available, the meta-analyses aimed to investigate moderating variables on stress and food consumption. Given the hypothesized differences between unhealthy and healthy eating, the moderator analyses were first performed across all outcomes (i.e., stress and food intake overall) and then within studies measuring unhealthy or healthy eating. The combined findings of the two reviews will address gaps in the literature and offer directions for future research.

## 2.3 Meta-Analysis in Adults

### 2.3.1 Search Terms and Selection Criteria

The systematic review and meta-analysis was registered on PROSPERO on the 12th December 2017 (record number CRD42017082646). Online databases were searched on the 16th of May 2017 using key terms which were combined using Boolean operators. Email alerts from the initial search were established to include any recently published studies up until 1st January 2019. Key terms were searched in PsycINFO (1806 to Present) and Ovid databases (Ovid Medline 1946 to Present; Ovid Medline Epub Ahead of Print, In-Process & Other Non-Indexed Citations; Ovid MEDLINE Daily; and Ovid Versions 1946 to present). The database search was limited to human studies, English language, journal articles and restricted by age (≥ 18 years old). Search terms were based on those used in a previous meta-analysis (Hill et al., 2018) and were developed regarding stress measurement and eating behaviours (see Appendix Item 1 for a full list of search terms in an example search strategy). Additionally, reference

lists of papers included at full text level were hand searched to include relevant studies which were not initially identified via the online database search.

#### 2.3.1.1 Inclusion and Exclusion Criteria

Papers were screened for their inclusion in the meta-analysis based on the study population, stress measurement used and the type of eating behaviour outcome. Papers were included in the review if participants were aged 18 years or older. Studies which were partially within the age range (for example 16 to 25 years old) were retained in the screening process to determine whether data were available on the adult participants within the study. Studies which reported a mean age of at least 18 years old were retained in the meta-analysis. The review included any healthy populations of adults, which was defined as individuals without any pre-existing physical or psychological illnesses. Only healthy adults were included due to the comorbidities between psychological wellbeing and poorer health generally (Scott et al., 2016). Similarly, studies which focused exclusively on clinical patients or individuals with disordered eating behaviours (e.g., bulimia) were excluded from the review.

In addition to participant demographics, studies were retained in the review if they had used a measurement of stress. This included objective measures (such as cortisol sampling or blood pressure), subjective measures (such as self-report questionnaires) or stress induction paradigms (for example the Trier Social Stress Task; Kirschbaum et al.,1993). Studies which measured constructs other than stress, such as emotional distress, or those which focused on early life trauma as an indicator of stress were excluded from the review, due to comorbidities between these constructs, ill health and changes to normal health behaviours (Agorastos, Pervanidou, Chrousos, & Baker, 2019; Kalmakis & Chandler, 2015; Steptoe, 2019).

Finally, studies were retained in the review if they included some form of food intake as an eating behaviour. Eating behaviours included dietary habits, snack consumption, food frequency measures and/or macronutrient intake. Studies were excluded from the review if they focused on body weight as an outcome measure (such as BMI or adiposity). Similarly, studies which measured

behaviours around eating without the inclusion of any food intake (such as dietary restraint) were also excluded from the review.

### 2.3.2 Data and Variable Coding

Studies were coded based on the type of stress measure and the type of eating outcome assessed, as previously outlined in Hill et al. (2018). Stress measures were categorised into perceived stress (which included daily diary studies), objective (for example cortisol or blood pressure measures) or induced stress (such as a stress induction paradigm or stress and no stress periods). Eating outcomes were categorised into three types of food intake; healthy, unhealthy and other foods. Healthy foods were identified as those which are health promoting, such as intake of low energy high nutrient (LEHN) foods like fruit and vegetables. Unhealthy foods were identified as high energy, low nutrient (HELN) foods which may be health limiting. Foods which did not fall into either healthy or unhealthy categories, such as macronutrients (like protein, carbohydrates), or food groups (for example cereals, meat products and seafood) were categorised as being other foods.

To determine the initial differences between stress and the type of foods consumed, studies with more than one type of eating outcome could appear more than once across the eating categories (e.g., healthy and unhealthy food intake). In these instances, sample sizes were reduced to account for a study appearing in more than one eating category (for example, samples were halved for studies which included both a healthy and unhealthy eating outcome). The method was used only when comparing the three eating categories to avoid the creation of a ‘combined’ eating behaviour category.

### 2.3.3 Quality Assessment

A quality assessment tool was developed based on the Effective Public Health Practice Project (EPHPP) assessment tool for quantitative studies (Thomas, Ciliska, Dobbins, & Micucci, 2004). The EPHPP was developed for assessing the quality of randomised controlled trials (RCTs) and includes six component scoring sections; Selection Bias, Study Design, Confounders, Blinding, Data Collection Methods and Withdrawals / Dropouts. One section

(Blinding) was specific to RCTs and was removed from the EPHPP for use in this review. Studies were assessed on the remaining 5 sections (See Appendix Item 2 for the full assessment tool and with scoring instructions).

Two component scoring sections (Study Design and Data Collection Methods) were adapted to better reflect the type of studies retained in this review. In the Study Design component section, a rating of strong was given to studies which had used either a longitudinal design or had adopted a stress induction paradigm (using either independent groups or repeated measures). A moderate quality rating was given to studies which had either used an objective measure (of either stress or eating behaviour) at one time point, had adopted a daily diary methodology, or had investigated subjective stress at more than one time point. Finally, a weak Study Design rating was given to studies which had used subjective stress and subjective eating measures, at only one time point. Similarly, if the study design could not be determined, it was coded as weak in this component section.

The Data Collection Methods component section was adapted to assess the reliability and validity of stress and eating measures, independent to one another. A study was rated as strong in quality when both the stress and eating measures were valid and reliable. A moderate rating was given to studies where both measures are shown to be valid, and one or both measures were either not reliable, or reliability for the measure was not reported. Similarly, if one measure was both valid and reliable, a moderate rating was given. Finally, a weak study quality rating was given in this component section where both the stress and eating measures were neither valid nor reliable, or where validity and reliability could not be determined.

After the completion of component sections, studies were assigned a global quality rating following the method outlined by Thomas et al. (2004). Where no weak ratings were given on any of the component scales (i.e., all sections were either strong or moderate), studies were identified as being strong in study quality overall. A moderate global rating was given for studies which included one weak rating out of the 5 component rating sections. Finally, studies were coded

as being weak in quality where they scored weak on two or more of the component scales.

### 2.3.4 Data Synthesis

All studies retrieved from the initial database search and those subsequently retrieved via email alerts were screened at title, abstract and full text level by a reviewer. A minimum of 10% of studies were independently coded by a second reviewer at title (*N* = 1,700), abstract (*N* = 34) and at full text levels (*N* = 9). Cohen's kappa (Cohen, 1960) value was found to be good overall for the screening process ($\kappa$ = .84), with high agreement levels across title ($\kappa$ = .80) and abstract levels ($\kappa$ = .72), and perfect agreement at full text screening ($\kappa$ = 1.0). Study quality was assessed on all papers included in the review using the modified EPHPP tool. At least 10% of studies included in the review (*N* = 6) were assessed by an independent reviewer and agreement levels were calculated. Agreement levels across the five component scales ranged from some disagreements (60%) to agreement accepted in most situations at 80% (Neuendorf, 2016). Disagreements were discussed and resolved, resulting in perfect agreement ($\kappa$ = 1.0) on study quality ratings for the studies.

### 2.3.5 Method of Analysis

Prior to analysis, all extracted data were checked by an independent reviewer. Data was synthesized using Comprehensive Meta-Analysis version 3 (Borenstein, Hedges, Higgins, & Rothstein, 2005) and effect sizes were calculated using Hedges' G to account for any small sample sizes included in the review (Orwin, 1983). In order to account for dependence from multiple outcomes (i.e., where studies had more than one outcome measure), effect sizes were calculated using two methods (Scammacca, Roberts & Stuebing, 2014). Analyses were first conducted assuming independence between outcomes (i.e., assuming a correlation of 0), where each outcome contributes independent information to the analyses. In contrast, analyses were also conducted when independence was not assumed between outcomes (i.e., a correlation of 1) which generates effect sizes adjusted for the assumption that outcomes are related to one another. Overestimations of effect size data can occur when independence is assumed between outcomes, raising the risk of a Type II error. Conversely,

underestimations can occur when independence between outcomes are not assumed, increasing the risk of a Type I error (Scammacca et al., 2014; Borenstein, Hedges, Higgins & Rothstein, 2009). Therefore, using both methods of analysis provides more precise results by calculating a plausible range of effect size data from the two methods (Borenstein, Hedges, Higgins, & Rothstein, 2011).

Effect sizes up to 0.49 were considered to be small, between 0.5 and ≤ 0.79 medium effect sizes and ≥ 0.80 were considered large (Cohen, 1988). Publication bias was assessed across all studies using a funnel plot of observed and imputed effect sizes, with additional analyses used to determine the severity of potential publication bias in this review.

Standardised residuals were used to assess potential outliers in computed effect sizes. Any studies with a standardised residual > 3 or < -3 were further investigated using sensitivity analyses. Four studies (Boggiano et al., 2015; Kandiah et al., 2006; Peker & Bermek, 2011; Conner et al., 1999) were identified as potential outliers, with standardized residual values of 6.46, 4.28, -3.50 and 3.18 respectively. To determine the impact of potential outliers in the analysis, each study was systematically removed from the overall analysis to determine their individual contribution. Removal of each study in turn resulted in a change to the overall effect size by -0.020, -0.017, -0.014 and +0.009 for each study respectively. Due to the minimal impact overall to the findings, the studies were retained in analyses.

A random effects meta-analysis was used to investigate assumed heterogeneity across studies (Riley, Higgins, & Deeks, 2011). Initial analyses aimed to investigate the relationship between stress and eating behaviours overall across all studies. Further analyses were carried out to investigate the moderating effect of type of eating behaviour on stress, where moderator analyses were first investigated across the whole sample and then (where effects were found) within studies measuring unhealthy and healthy eating. The relationship between stress and type of eating behaviour (unhealthy and healthy) was carried out independently. Heterogeneity was assessed for main analyses and moderating variables using Cochran Q tests and $I^2$ (Higgins, Thompson,

Deeks, & Altman, 2003; Lipsey & Wilson, 2001), where $I^2$ (reported as a percentage) indicates the degree of heterogeneity across studies, opposed to variance occurring due to chance (Higgins & Thompson, 2002).

Additional moderating variables were investigated on the relationship between stress and eating behaviours. Pearson's correlations were used to determine the independence between the moderating variables used in analyses. Stress measurement, study quality, gender (where data was available for females and males separately), mean age, mean dietary restraint, mean BMI, proportion healthy / overweight and sample source (i.e., participants recruited via higher education environments or from wider populations) were included as moderating variables on the relationship between stress and eating behaviours overall. Where reported, mean values for dietary restraint were standardized into z-scores to control for the use of different questionnaires.

### 2.3.6 Results

A total of 16,889 unique articles were retrieved from searching electronic databases and hand searching of reference lists (see Figure 2-1 for a PRISMA flow diagram; Moher, Liberati, Tetzlaff, & Altman, 2009). The main reason for exclusion from the review at title level was due to articles not being relevant to the topic area ($k$ = 16,222). Of the 309 studies screened at abstract level, 100 were retained for full text screening. The main reason for exclusion at abstract level was studies not including a measure of food consumption ($k$ = 96). From full text screening, 67 studies were identified for inclusion in the review. During quantitative synthesis, two studies were excluded due to using the same data set as another included paper (O'Connor et al., 2009; van Strien et al., 2012). A further 11 studies were excluded from the review due to insufficient data, leaving 58 studies included in this review (see Appendix Item 3 for a summary of study characteristics).

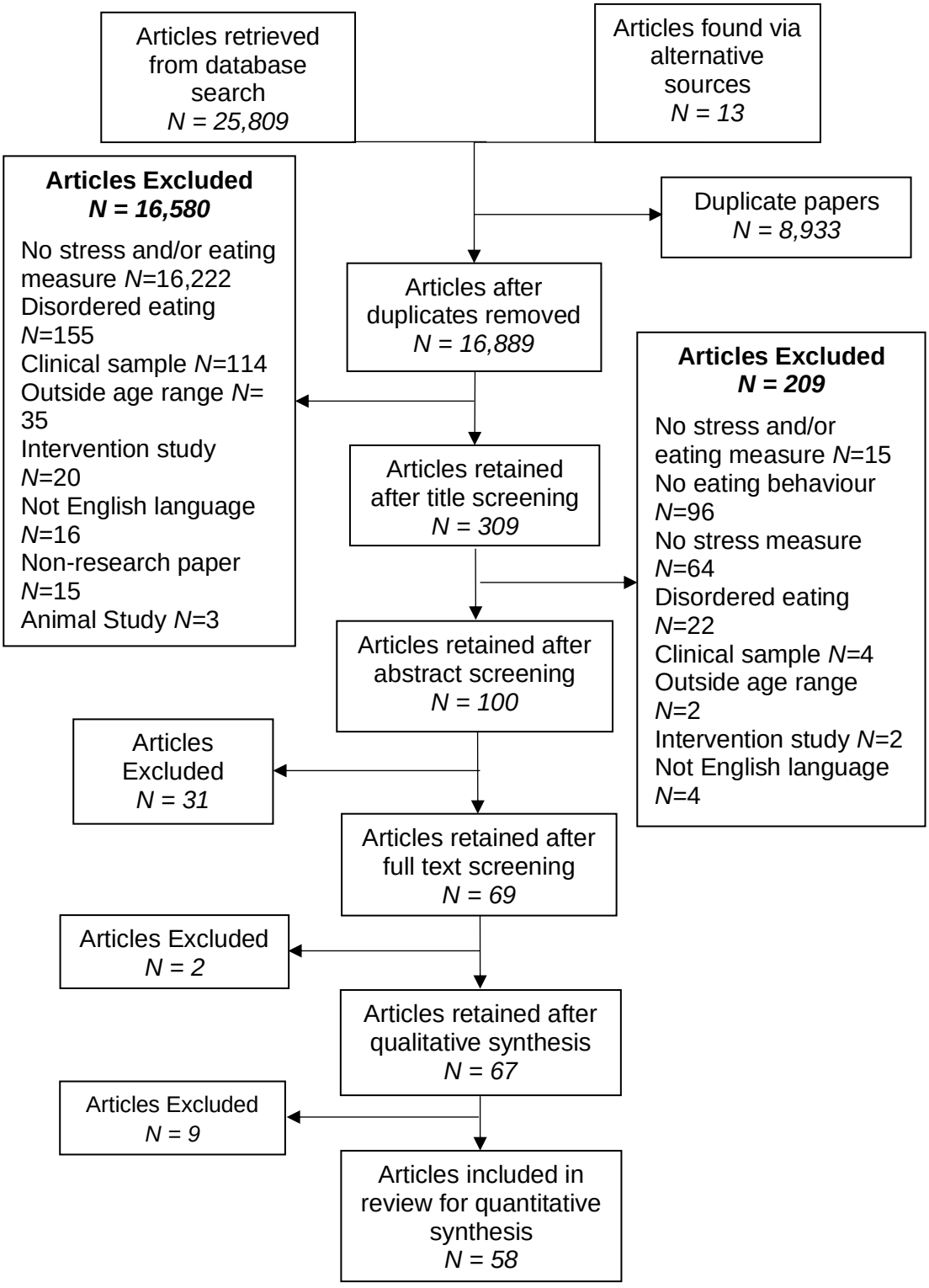


**Figure 2-1. PRISMA flow diagram of articles retained and excluded at each stage of the screening process for the meta-analysis in adults (Moher, Liberati, Tetzlaff & Altman, 2009).**

#### 2.3.6.1 Study Characteristics

The combined sample size from the 58 included studies was 105,049 (range 9 to 65,235 in individual studies), of which 56,982 were female (54.24%) and 47,655 were male (45.54%). Of the 58 studies, 28 used exclusively female participants (comprising of 4,216 participants) and two studies used exclusively male participants (total of 56 participants). Gender was not reported for 412 participants (<1%). Mean age for the total sample was 28.89 years (range 18 to >90 years where reported). Mean age was not reported in three studies. Additionally, 29 studies used samples recruited exclusively from higher education environments (e.g., universities; *N* = 13,579). The mean BMI was 25.83 kg/m$^2$ with a range of 20.2 kg/m$^2$ to 38.9 kg/m$^2$. Where reported, studies were categorised by weight status; 15 studies reported the proportion of participants who were a healthy weight (defined as a BMI from 18.5 to 24.9 kg/m$^2$) and 14 studies reported the proportion of participants with overweight/ obesity (i.e., with a BMI over 25 kg/m$^2$). BMI was not reported in 27 studies.

Studies were categorised based on the type of stress measurement and type of eating outcome (for details on coding, see section 2.3.2). Studies which included multiple stress measures and / or eating outcomes were included within each relevant category. Most studies used a measure of perceived stress ($k$ = 35) or a stress induction methodology ($k$ = 21). Four studies included an objective measure of stress. Similarly, studies were categorised based on the type of eating outcome. Of the 58 studies included in the review, 37 included a measure of unhealthy food consumption, 19 used healthy food consumption and 36 used a measure of other food intake. Eleven studies reported mean restraint.

Finally, studies were categorised based on overall study quality. Most of the studies included in the review were identified as being weak in study quality ($k$ = 31), with fewer being categorised as moderate in study quality ($k$ = 19) and only 8 identified as being strong in study quality. A breakdown of study quality across the five component ratings is presented in Figure 2-2. Over half of the studies included in the review were identified as at risk of selection bias, where samples may not accurately reflect the wider population (for example undergraduate university students enrolled on a Psychology course). However,

35 studies were identified as being strong in their data collection methods (for example, where studies had used valid and reliable scales to measure stress).

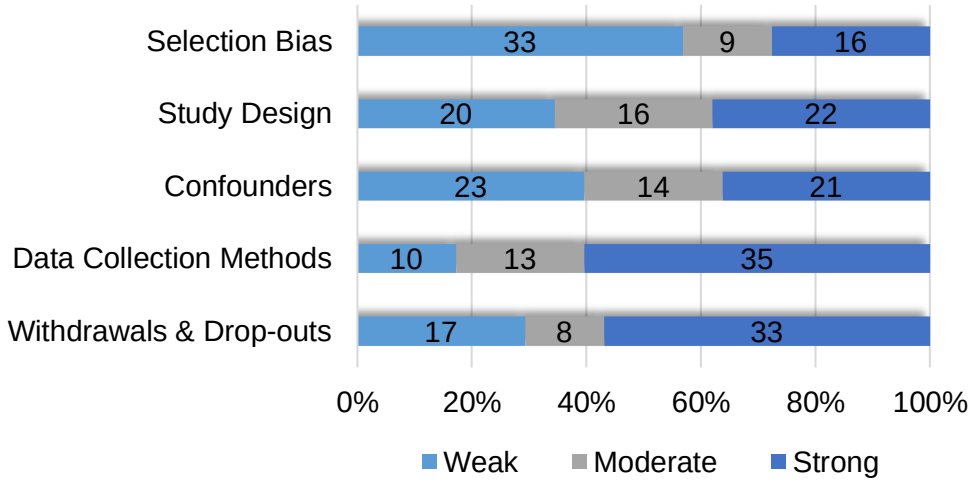


**Figure 2-2. Number of studies (adult meta-analysis) scoring across 5 quality assessment sections from weak to strong (left to right).**

### 2.3.6.2 Main Findings

The relationship between stress and food intake overall was initially investigated. A significant positive association was found between stress and food intake, *Hedges' g* = 0.102, *95% CIs* [0.050, 0.154], $Z = 3.847$, $p < .001$, where higher levels of stress was associated with more food intake compared to lower levels of stress. A proportional forest plot of stress and food consumption overall is presented in Figure 2-3 (see Appendix Item 4 for individual study findings).

There was considerable heterogeneity across subgroup analyses (see Table 2-1) and considerable heterogeneity across the 58 studies overall, $Q_{(57)} = 671.619$, $p < .001$, $I^2 = 91.513$. Therefore, further analyses were conducted to investigate potential moderating variables contributing to the high level of heterogeneity (Higgins & Green, 2011).

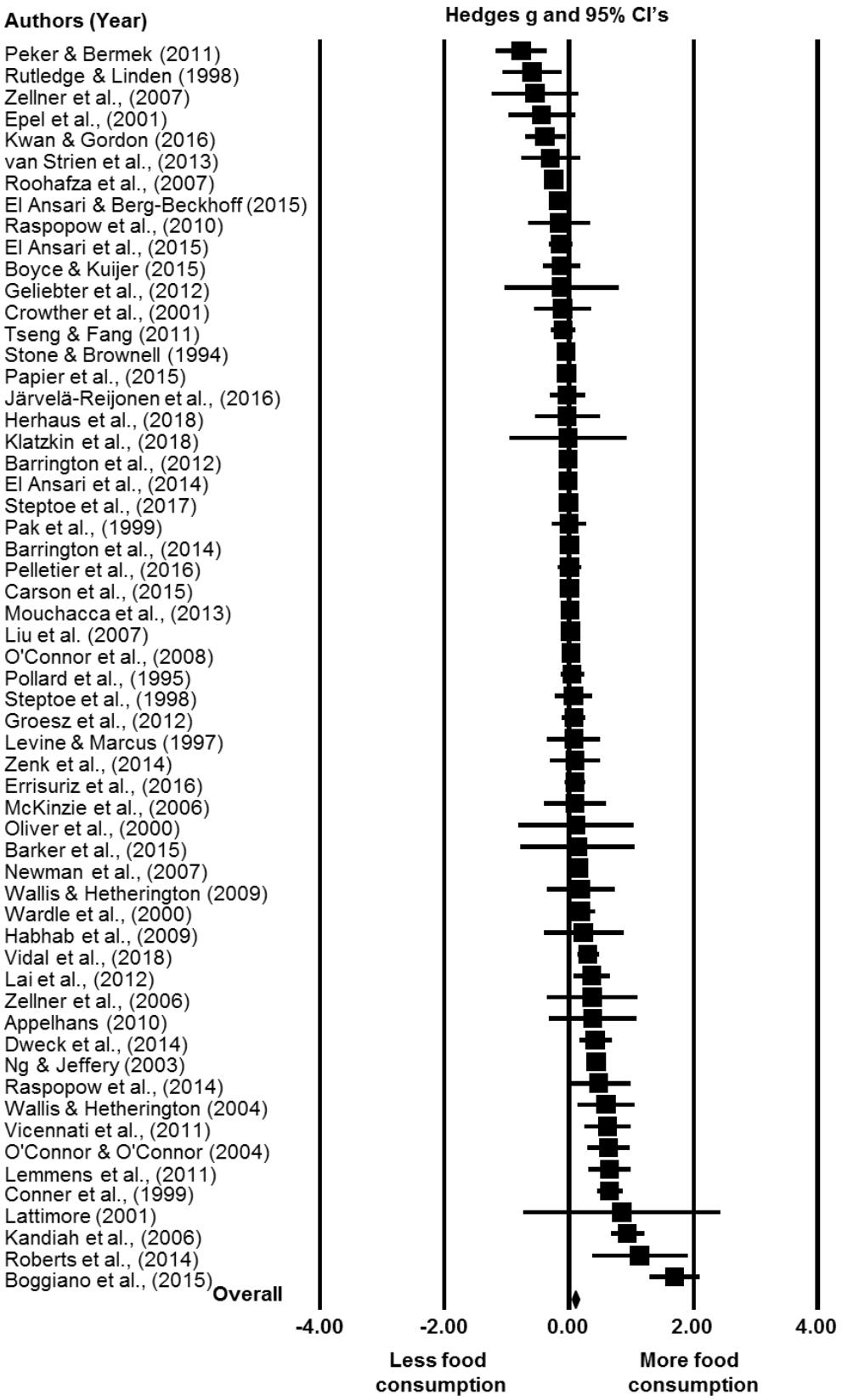


**Figure 2-3. Proportional distribution plot of stress and eating behaviours overall across all studies (*k* = 58).**

**Table 2-1. Summary of heterogeneity within and between variable analyses in the meta-analysis in adults (*k* = 58).**

| Sub-group | Variables | Number of study outcomes (*k*) & sample size (*n*) | Effect size [95% CIs] Mixed Effects Model | $I^2$% | Q and p value (Within studies) | Q & p value (Between studies) |
|---|---|---|---|---|---|---|
| Eating category | Unhealthy | *k=37* *n*=54,447 | 0.153 [0.068, 0.238] | 91.042% | 401.865 (<.001) | 42.106 (<.001) ** |
| | Healthy | *k=19* *n*=45,753 | -0.134 [-0.205 -0.064] | 86.068% | 129.199 (<.001) | |
| | Other | *k=36* *n*=4,849 | 0.191 [0.106, 0.277] | 81.461% | 188.794 (<.001) | |
| Stress Measure | Perceived [1] | *k=35* *n*=101,438 | 0.099 [0.040, 0.159] | 94.317% | 598.263 (<.001) | 0.006 (.939) |
| | Induced | *k=21* *n*=1,056 | 0.093 [-0.053, 0.239] | 61.384% | 51.793 (<.001) | |
| Study quality | Strong | *k*=8 *n*=5,190 | 0.021 [-0.017, 0.060] | 13.891% | 8.129 (.321) | 7.506 (.023)* |
| | Moderate | *k*=16 *n*=85,211 | 0.129 [-0.006, 0.264] | 96.155% | 390.071 (<.001) | |
| | Weak | *k*=34 *n*=14,648 | 0.141 [0.053, 0.229] | 87.897% | 272.661 (<.001) | |
| Gender | Female | *k*=35 *n*=16,233 | 0.157 [0.049, 0.266] | 88.791% | 303.334 (<.001) | 1.223 (.269) |
| | Male | *k*=9 *n*=8,337 | -0.014 [-0.297, 0.270] | 95.923% | 196.205 (<.001) | |
| Sample source | Higher Education Settings | *k*=31 *n*=13,668 | 0.112 [0.003, 0.220] | 85.443% | 206.083 (<.001) | 0.041 (.839) |
| | Wider population | *k*=27 *n*=91,381 | 0.098 [0.030, 0.167] | 94.379% | 462.544 (<.001) | |

*Note*: * Significant at p <.05; ** Significant at p <.001

[1] As a sub-group within perceived stress, analyses indicated that use of a daily diary methodology yielded a strong, significant effect on stress and food intake overall, *Hedges' g* = 0.735, *95% CIs* [0.128, 1.342], *Z* = 2.373, *p* = .018.

### 2.3.6.3 Stress and Type of Food Intake

The relationship between stress and food consumption was further investigated using the three eating behaviour categories. Overall, there was a significant difference between stress and type of food intake, $Q_{(2)}$ = 42.106, $p$ <.001. Analyses indicated a significant difference between unhealthy and healthy eating, $Q_{(1)}$ = 26.055, $p$ <.001, and unhealthy and other food intake, $Q_{(1)}$ = 32.998, $p$ <.001. No differences were found between healthy and other food consumption, $Q_{(1)}$ = 0.378, $p$ = .538. Further analyses were conducted to investigate the association between stress and type of food intake.

### 2.3.6.4 Publication Bias

The presence of publication bias was investigated across the 58 studies included in the review. Egger's regression analyses (Egger, Smith, Schneider, & Minder, 1997) indicated that there was not significant publication bias within the review (intercept = 0.818, *df* = 56, $p$ = .099). In contrast, a funnel plot of observed and imputed standard error values (see Figure 2-4) indicated that there may be three missing studies to the right of the mean. Duval and Tweedie's Trim and Fill analysis (Duval & Tweedie, 2000) indicated that inclusion of the missing studies would result in a small increase to the overall effect size (observed *Hedges' g* = 0.102, *95% CIs* [0.050, 0.154]; computed *Hedges' g* = 0.123, *95% CIs* [0.071, 0.175]).

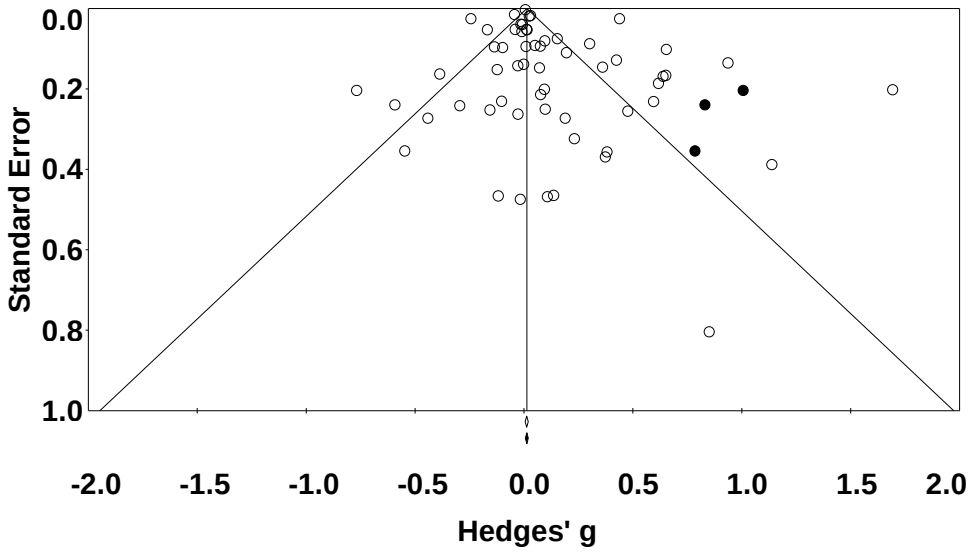


**Figure 2-4. Funnel plot of publication bias for meta-analysis in adults with observed (white) and imputed (shaded) studies.**

Sensitivity analysis was conducted to investigate the relative influence of each study on the main findings. Through the systematic removal of each study in turn, the analysis indicated that changes to the overall study findings of stress and food consumption were minimal, with the largest effect size change of -0.023 to +0.013 about the calculated Hedges' g (resulting in the overall effect size ranging from 0.079 to 0.115).

#### 2.3.6.5 Independence of Moderating Variables

Pearson's correlations were used to assess the independence between categorical moderating variables (sample source, study quality, stress measure and eating behaviour). A significant correlation was found between sample source and study quality ($r$ = -.584, $p$ < .001) where studies were judged lower in quality when participants had originated from higher education environments. This correlation was expected as the sample source influenced ratings of study quality within the *Selection Bias* component. No other associations were found between these categorical moderating variables.

#### 2.3.6.6 Moderating Variables on Stress and Eating Behaviours Overall

The moderating effect of study quality, gender, stress measurement and sample source were used via subgroup analyses. For gender, studies were included where the effect of stress on eating behaviour had been reported for males and females separately. The moderating effect of mean age, sample size, mean BMI, proportion of healthy / overweight individuals and dietary restraint on stress and eating overall was investigated using meta-regressions (maximum likelihood).

The moderating effect of study quality was assessed across all studies included in the review. Analyses indicated that study quality (strong, moderate, weak) moderated the association between stress and food intake overall, $Q_{(2)}$ = 6.903, $p$ = .032. Effect sizes were largest and significant in the weak quality studies (*Hedges' g* = 0.138, *95% CIs* [0.050, 0.226], $Z$ = 3.079, $p$ = .002), smaller and non-significant in the moderate study quality studies (*Hedges' g* = 0.129, *95% CIs* [-0.006, 0.264], $Z$ = 1.873, $p$ = .062) and smallest and also non-significant in the high quality studies (*Hedges' g* = 0.027, *95% CIs* [-0.006, 0.060],

$Z$ = 1.618, $p$ = .106). There was only a significant difference in effect size between the high- and low-quality studies, $Q_{(1)}$ = 5.352, $p$ = .021. The other two comparisons were not significant (strong versus moderate, $Q_{(1)}$ = 2.058, $p$ = .151; moderate versus weak, $Q_{(1)}$ = 0.012, $p$ = .912).

Thirty-nine studies included data on females only, with 9 studies including data on males only. No moderating effect of gender was found on stress and eating overall, $Q_{(1)}$ = 1.223, $p$ = .269.

The moderating effect of type of stress measurement was investigated using subgroup analyses. Overall, the type of stress measurement used did not moderate the association between stress and eating behaviours, $Q_{(1)}$ = 0.006, $p$ = .939. Studies using perceived stress were significantly associated with stress and eating overall (*Hedges' g* = 0.099, *95% CIs* [0.040, 0.159], $Z$ = 3.274, $p$ = .001) and studies using induced stress were not (*Hedges' g* = 0.093, *95% CIs* [-0.053, 0.239], $Z$ = 1.245, $p$ = .213). As a sub-group within perceived stress, analyses indicated that use of a daily diary methodology yielded a strong, significant effect, *Hedges' g* = 0.735, *95% CIs* [0.128, 1.342], $Z$ = 2.373, $p$ = .018. In contrast, studies using an objective measure of stress were not associated with eating behaviours overall (*Hedges' g* = 0.050, *95% CIs* [-0.377, 0.477], $Z$ = 0.230, $p$ = .818).

Subgroup analysis for the source of samples (i.e., recruited exclusively from Higher Education environments, or from the wider population) were investigated. Analysis indicated that there was no difference between the source of samples on stress and food intake overall, $Q_{(1)}$ = 0.041, $p$ = .839.

Fifty-four studies were included in moderation analyses to investigate the effect of mean age on stress and eating overall. The meta-regression indicated that mean age did not moderate the association between stress and food consumption, *coefficient* = -0.0018, *standard error* = 0.0049, $Z$ = -0.41, $p$ = .685.

The moderating effect of total sample size was assessed for all studies included in the review. The meta-regression indicated that total sample size did not moderate the association between stress and food intake overall, *coefficient* < -0.001, *standard error* < 0.001, $Z$ = -0.37, $p$ = .712.

Twenty-eight studies were included in moderation analyses to investigate the effect of mean BMI on stress and eating overall. Mean BMI was not found to moderate the relationship between stress and eating behaviours, *coefficient* = 0.0054, *standard error* = 0.0167, $Z$ = 0.32, $p$ = .747. Further analyses investigated the proportion of people with healthy weight and overweight on stress and eating overall. No moderating effect was found for the proportion of people with healthy weight, *coefficient* = -0.0026, *standard error* = 0.0034, $Z$ = -0.75, $p$ = .451, nor the proportion of people with overweight on the association between stress and eating overall, *coefficient* = -0.0008, *standard error* = 0.0036, $Z$ = -0.22, $p$ = .829.

Finally, eleven studies were included in moderation analyses to investigate the effect of dietary restraint on stress and eating overall. Standardised mean restraint scores were not found to moderate stress and eating overall, *coefficient* = 0.0589, *standard error* = 0.0944, $Z$ = 0.62, $p$ = .533.

#### 2.3.6.7 Stress and Unhealthy Eating Outcomes

Analyses indicated a significant, positive association between stress and consumption of unhealthy foods, where higher levels of stress was associated with greater intake of unhealthy foods, *Hedges' g* = 0.128, *95% CIs* [0.064, 0.192], $Z$ = 3.929, $p$ < .001 (see Figure 2-5 for proportional forest plot of stress and unhealthy food consumption). There was significant heterogeneity between studies with measures of unhealthy food intake, $Q_{(36)}$ = 448.682, $p$ < .001, $I^2$ = 91.977.

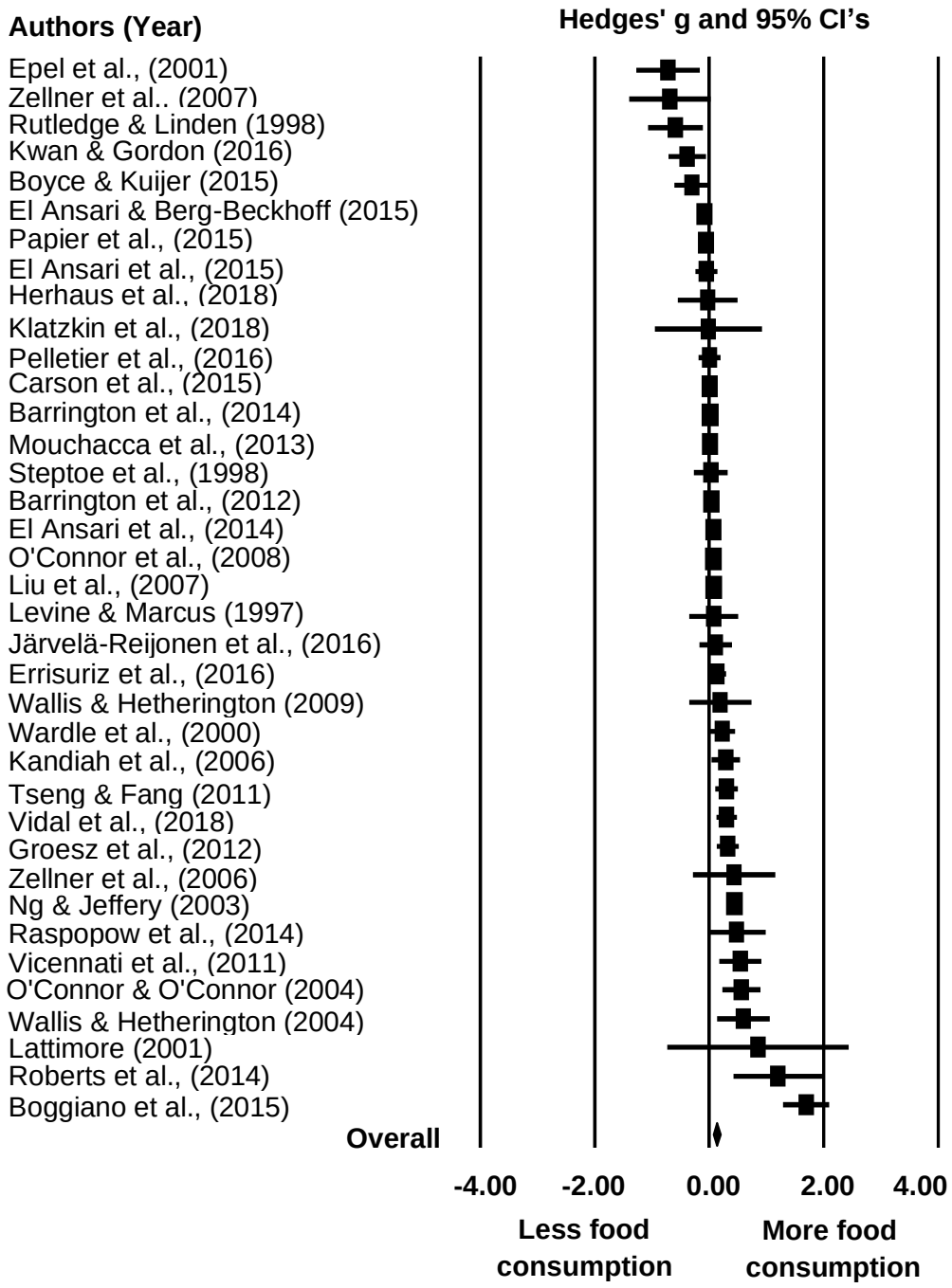


**Figure 2-5. Proportional forest plot of stress and consumption of unhealthy foods (*k* = 37).**

The effect of stress and unhealthy eating behaviours was investigated using moderating variables (see Table 2 for a summary of heterogeneity for categorical subgroups). Analyses indicated no moderating effect of study quality on stress unhealthy eating, $Q_{(2)}$ = 3.082, $p$ = .214. There were no moderating effects of gender on stress and unhealthy food consumption, $Q_{(1)}$ = 0.672, $p$ = .412. The type of stress measurement used was not found to moderate stress and unhealthy eating, $Q_{(1)}$ = 1.376, $p$ = .241. Finally, the moderating effect of sample source was investigated on stress and unhealthy eating outcomes. Analyses indicated that sample source did not moderate stress and unhealthy eating outcomes, $Q_{(1)}$ = 0.114, $p$ = .735.

#### 2.3.6.8 Stress and Healthy Eating Outcomes

In contrast, a significant, negative association was found between stress and healthy food consumption where higher levels of stress was associated with decreased intake of healthy foods, *Hedges' g* = -0.112, *95% CIs* [-0.165, -0.060], $Z$ = -4.189, $p$ < .001 (see Figure 2-6 for a proportional forest plot).

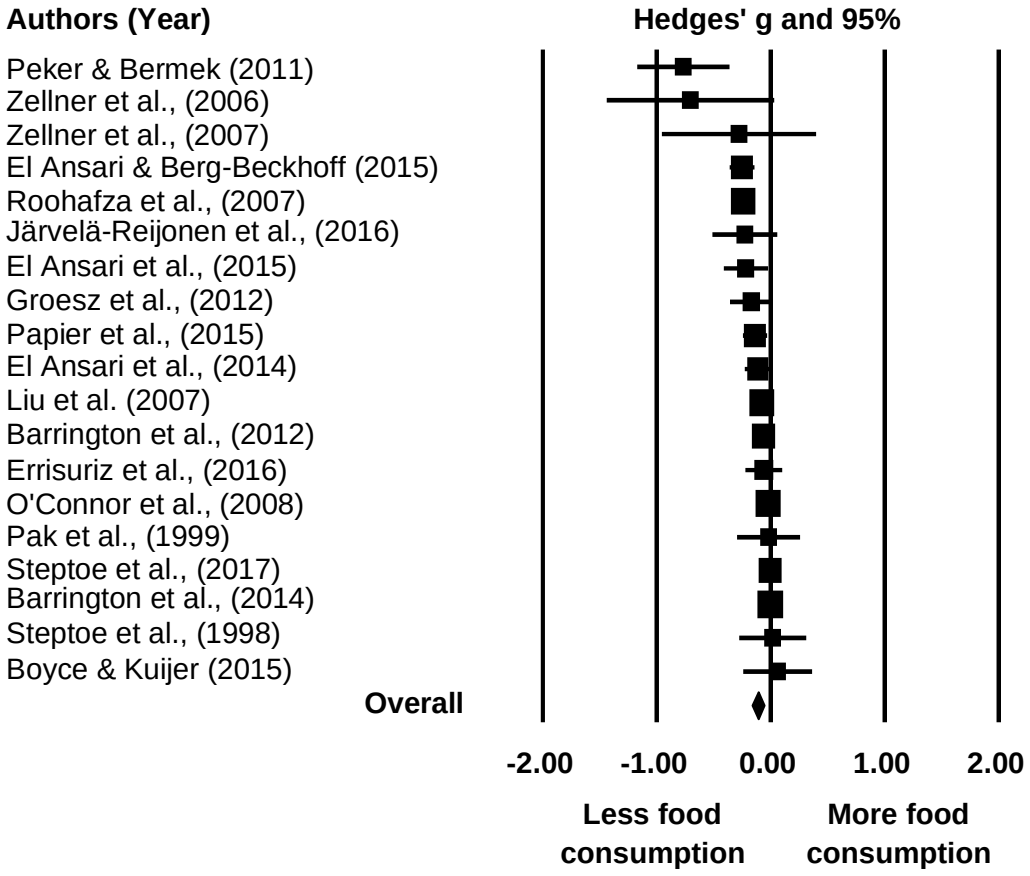


**Figure 2-6. Proportional forest plot of stress and consumption of healthy foods in adults (*k* = 19).**

Analyses indicated significant heterogeneity between studies with measures of healthy food intake, $Q_{(18)} = 149.701$, $p < .001$, $I^2 = 87.976$.

Moderating analyses were conducted to further investigate the effect of stress and healthy food consumption (see Table 2-2 for a summary of heterogeneity across categorical subgroups). Study quality moderated stress and healthy eating outcomes, $Q_{(2)} = 9.896$, $p < .001$, specifically between studies weak and strong in study quality $Q_{(1)} = 8.344$, $p = .004$. No differences were found between studies rated as weak or moderate in study quality, $Q_{(1)} = 0.021$, $p = .886$, nor strong and moderate in study quality, $Q_{(1)} = 2.324$, $p = .127$.

Similar to the effects in unhealthy eating outcomes, gender was not found to moderate stress and healthy eating outcomes $Q_{(1)} = 2.318$, $p = .128$. The type of stress measurement used was not found to moderate stress and healthy eating, $Q_{(1)} = 1.964$, $p = .161$. Finally, analyses indicated that sample source did not moderate the association between stress and healthy eating outcomes, $Q_{(1)} = 2.173$, $p = .140$.

**Table 2-2. Summary of heterogeneity within and between studies on stress and unhealthy (*k* = 37) and healthy eating behaviours (*k* = 19).**

| | | Unhealthy eating outcomes (*k* = 37) | | | | | Healthy eating outcomes (*k* = 19) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Subgroup | Variables | Number of study outcomes (*k*) & sample size (*n*) | Effect size [95% CIs] Mixed Effects Model | $I^2$% | Q and p value (Within studies) | Q & p value (Between studies) | Number of study outcomes (*k*) & sample size (*n*) | Effect size [95% CIs] Mixed Effects Model | $I^2$% | Q and p value (Within studies) | Q & p value (Between studies) |
| Stress Measure | Perceived | *k=25* *n*=94,712 | 0.145 [0.078, 0.213] | 94.075% | 405.076 (<.001) | 1.376 (.241) | *k=16* *n*=84,935 | -0.18 [-0.174, -0.062] | 89.701% | 145.644 (<.001) | 1.964 (.161) |
| | Induced | *k=11* *n*=577 | -0.036 [-0.322, 0.259] | 70.697% | 34.126 (<.001) | | *k=2* *n*=70 | -0.474 [-0.970, 0.021] | 0% | 0.705 (.401) | |
| Study quality | Strong | *k=5* *n*=2,644 | 0.053 [-0.052, 0.158] | 75.036% | 16.023 (.003) | 3.082 (0.214) | *k=2* *n*=2,850 | -0.021 [-0.054, 0.013] | 0% | 0.171 (.679) | 9.896 (.007)** |
| | Moderate | *k=9* *n*=78,962 | 0.240 [0.053, 0.426] | 97.150% | 280.726 (<.001) | | *k=5* *n*=72,502 | -0.129 [-0.264, 0.006] | 95.435% | 87.629 (<.001) | |
| | Weak | *k=23* *n*=13,810 | 0.126 [0.019, 0.233] | 84.116% | 138.506 (<.001) | | *k=12* *n*=12,081 | -0.140 [-0.214, -0.066] | 59.253% | 26.996 (.005) | |
| Gender | Female | *k=23* *n*=15,692 | 0.142 [0.016, 0.268] | 91.176% | 249.331 (<.001) | 0.672 (.412) | *k=6* *n*=5,832 | -0.116 [-0.203, -0.030] | 61.790% | 13.085 (0.023) | 2.318 (.128) |
| | Male | *k=6* *n*=8,263 | 0.013 [-0.267, 0.294] | 96.693% | 151.173 (<.001) | | *k=5* *n*=2,773 | -0.258 [-0.418, -0.097] | 78.448% | 18.560 (.001) | |
| Sample source | HE environments | *k=19* *n*=12,966 | 0.121 [-0.002, 0.244] | 86.202% | 130.451 (<.001) | 0.114 (.735) | *k=10* *n*=11,830 | -0.158 [-0.239, -0.077] | 65.244% | 25.895 (.002) | 2.173 (.140) |
| | Wider population | *k=18* *n*=82,450 | 0.147 [0.056, 0.238] | 94.565% | 312.762 (<.001) | | *k=9* *n*=73,333 | -0.077 [-0.147, -0.007] | 90.934% | 88.242 (<.001) | |

## 2.4 Meta-Analysis in Adolescents

The same method was used in the meta-analysis on adolescents as that used in the meta-analysis in adults (see Section 2.3 for full details). The following sections outline the differences in methodology employed for the meta-analysis in adolescents.

### 2.4.1 Search Terms and Selection Criteria

Electronic databases were searched using combinations of key terms and Boolean operators on the 28th January 2016. Key terms were also mapped onto appropriate subject headings such as 'Child Health'. Selected databases from Web of Science (Core Collection; 1990-present; BIOSIS Citation Index 1969-present; Data Citation Index 1900-present), Ovid (AMED, Global Health 1973-2016, Ovid Medline 1946-2016, Ovid Medline In-Process and Non-Indexed Citations, PsycInfo (1806-2016) and Food Science and Technology Abstracts (1969-2016) were searched, in combination with Scopus, Science Direct and the Cochrane Library. The key terms used for the search were categorised by population, stress measurement and eating behaviour or eating outcome (see Appendix Item 5 for full list of search terms and an example search strategy). Email alerts were established at the time of the initial search to notify any recently published articles. Additional studies were included in the review until 1st December 2018. Finally, studies were identified using a descendancy approach by hand searching reference lists.

#### 2.4.1.1 Population

Research papers were included in the review if they contained a sample of adolescents aged 13 to 18 years old of either sex. If an age range was not specified in the study, the mean reported age was used as an indicator during the screening process. Similarly, studies which included a wider age range, for example 16 to 21 years old, the mean age of the sample was used to determine the studies eligibility for inclusion in the review. Studies were retained in the screening process if data were available for the target age range. Studies were excluded from the review if the sample were aged <13 years old or > 18 years old. Studies were also excluded if the sample exclusively consisted of clinically

identified individuals with disordered eating (i.e., those with anorexia and/or bulimia), without the inclusion of a healthy comparison group. Additionally, studies were excluded if the sample consisted of medical patients or individuals with psychological illnesses such as anxiety or depression. Finally, studies were excluded from the review if the population was specially trained (e.g., elite athletes).

The same selection criteria were used as outlined above for the type of stress measurement and type of food intake (see section 2.3.1 for details on these criteria). Similarly, stress measures and eating behaviours were coded using the same method outlined in section 2.3.2. Inter-rater reliability was assessed on at least 10% of articles screened by two independent reviewers (*N* = 2,800). Reliability was considered to be good for the overall screening process ($\kappa$ = .74), with moderate agreement at title level ($\kappa$ = .64) and good agreement at abstract ($\kappa$ = .71) and full text levels ($\kappa$ = .87). Disagreements between reviewers were discussed and agreements reached.

### 2.4.2 Quality Assessment

Study quality was assessed using the same quality assessment tool as outlined in section 2.3.3. Due to the small number of studies included in this meta-analysis, studies identified as being 'Moderate' or 'Strong' in overall quality were combined into one category for moderation analyses (i.e., 'Moderate-to-Strong'). Inter-rater reliability was good across study quality assessment of studies included in the review, with Cohen's kappa ranging from $\kappa$ = .81 to $\kappa$ = 1 (perfect agreement).

### 2.4.3 Method of Analysis

The method of analysis was the same as that described in section 2.3.5 with the following differences. Standardised residuals were used to assess potential outliers in computed effect sizes. Any studies with a standardised residual > 3 were further investigated using sensitivity analyses. No studies were found to have a standardized residual value greater than 3 when using the mean of selected outcome (range = -2.08, 2.10) or when assuming independence

between outcomes (range = -2.04, 2.14). In both analyses, De Vriendt et al. (2012) and Jeong and Kim (2007) had the largest residuals respectively.

Gender (% female), study quality, mean age and sample size were included as moderating variables on stress and eating behaviours overall. Due to the small number of studies included in the review, two categories were used for study quality; weak and moderate-to-strong.

### 2.4.4 Results

A total of 32,497 unique articles were retrieved from key search terms of electronic databases and hand searching of reference lists (see Figure 2-7 for a PRISMA flow diagram of the screening process). A large proportion of studies initially identified from database searching were excluded at title level ($\kappa$ = 27,865), predominately due to the article focusing on an irrelevant topic ($\kappa$ = 20,375). At abstract level, the main reason for exclusion of studies was due to studies using clinical samples ($\kappa$ = 134). A total of 11 papers were assessed for their eligibility at full text level.

During quantitative synthesis, 3 studies were excluded from the meta-analysis. One study (De Vriendt et al., 2011) was excluded due to using the same dataset as a second paper (De Vriendt et al., 2012). A further two studies were excluded due to eating behaviours not measuring an intake of food; Richards and Smith (2015) focused on caffeine consumption whilst Feld and Shusterman (2015) measured the frequency and skipping of meals.

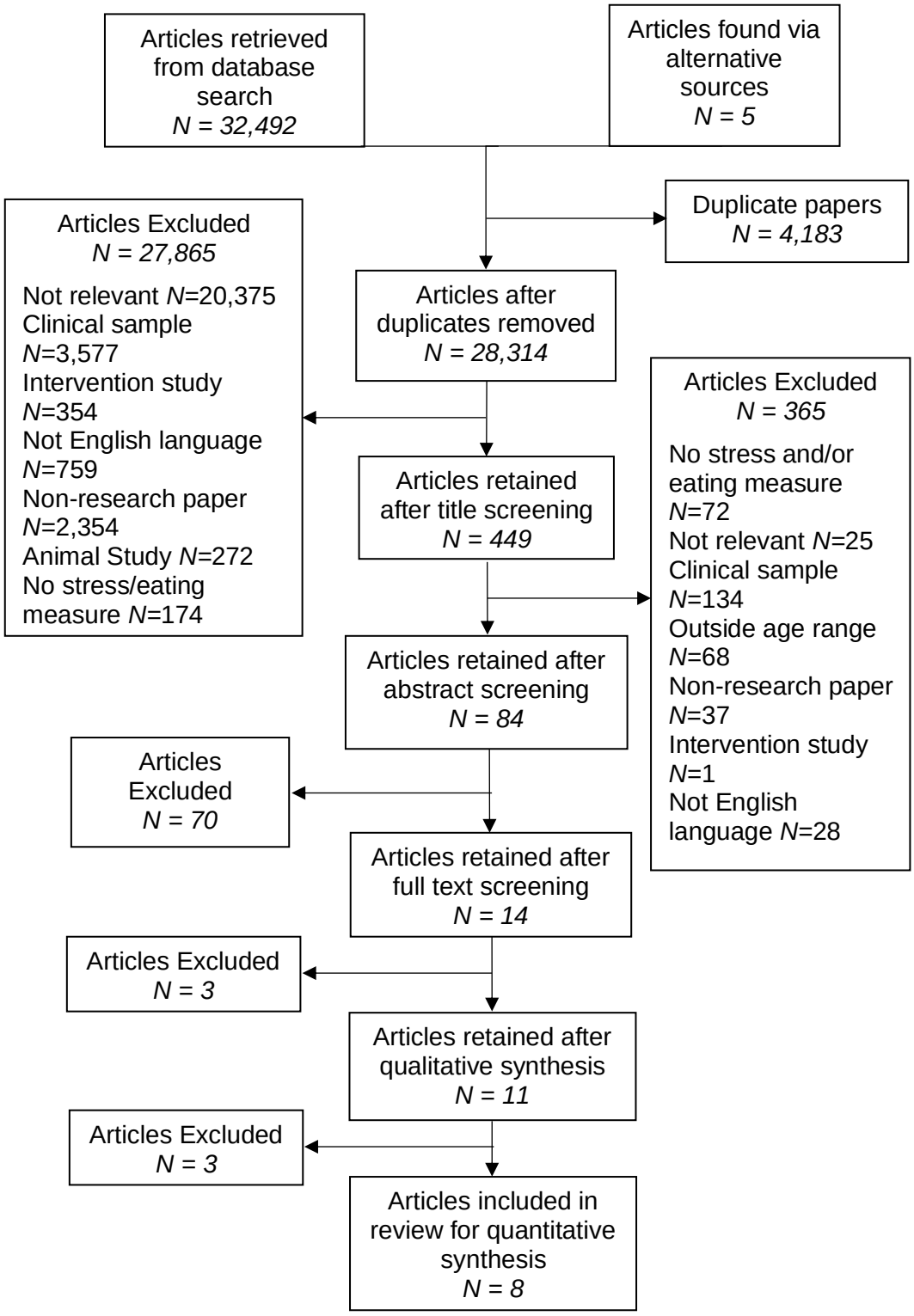


**Figure 2-7. PRISMA flow diagram of articles retained and excluded at each stage of the screening process (meta-analysis in adolescents).**

#### 2.4.4.1 Study Characteristics

A combined sample size of 67,414 was obtained in the meta-analysis, of which 33,253 were female (49.34%) and 34,161 were male (50.67%). The mean age across all participants was 15.80 years (range from 11-18 years old). One study did not report mean age. Studies were categorised based on the type of stress measurement used and the type of eating outcome measured (see Appendix Item 6 for a summary of study characteristics). Studies which included multiple eating measures were included within each relevant category. Seven studies had used a subjective measure of perceived stress, with one study using a method of induced stress based on school examinations (Michaud et al., 1990). Unhealthy eating behaviours included HELN foods, such as fast food, sweet snacks and poorer dietary habits. Healthy eating behaviours included LEHN foods including fruit, vegetables and diet quality. Five studies included a measure of unhealthy food intake (Hong & Peltzer, 2017; Jeong & Kim, 2007; Kim, Yang, Kim, & Lim, 2013; Shank et al., 2017; Son, Ro, Hyun, Lee, & Song, 2014) and four studies included a measure of healthy food intake (Austin, Smith, & Patterson, 2009; De Vriendt et al., 2012; Hong & Peltzer, 2017; Son et al., 2014). The eating behaviour for one study (Michaud et al., 1990) was categorised as other as it used total energy intake for a day and so the type of food consumed could not be determined.

Finally, studies were categorised based on overall study quality. Most studies were assessed as being low in study quality ($\kappa$ = 5), with two studies assessed as being moderate in quality and one high in overall quality ($\kappa$ = 3 for 'Moderate-to-Strong' combined category). Figure 2-8 shows a breakdown of studies across the 5 EPHPP quality assessment component ratings.

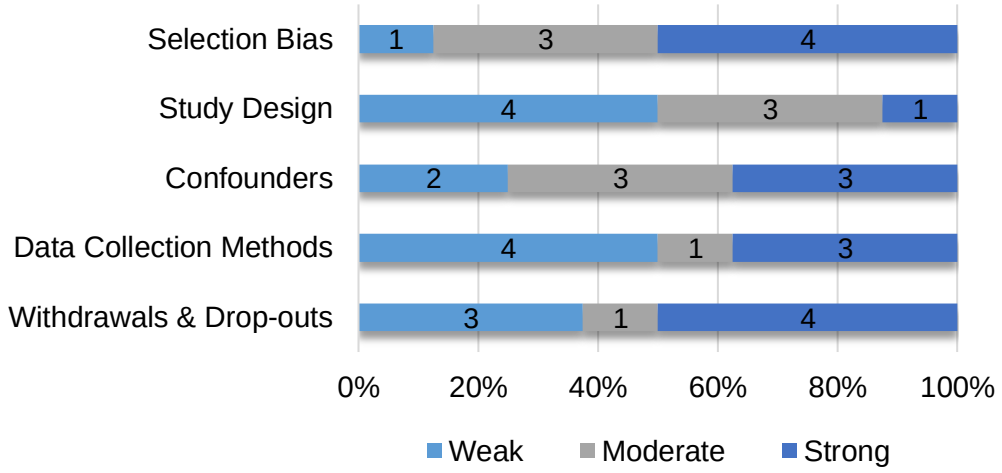


**Figure 2-8. Meta-analysis in adolescents: quality assessment scoring breakdown for included studies ($\kappa$ = 8).**

Only 1 study was identified as at risk of selection bias, and two with weak ratings regarding consideration of confounding variables. However, four studies were identified as being weak in data collection methods, where methods of measuring stress and eating behaviours were not reliable and/or valid.

### 2.4.4.2 Main Findings

The data was initially analysed to investigate the relationship between stress and food intake overall using the mean of selected outcomes (See Figure 2-9 for a proportional forest plot). Individual study findings are presented in Appendix Item 7. Overall, stress was not associated with food intake in adolescents, *Hedges' g* = 0.022, *95% CIs* [-0.096, 0.140], $Z$ = 0.367, $p$ = .713. Analyses indicated that there was significant heterogeneity across the 8 studies, $Q_{(7)}$ = 23.948, $p$ = .001, $I^2$ = 70.77 (see Table 2-3 for a summary of heterogeneity values). Similarly, no association was found between stress and food intake overall when independence between eating outcomes was assumed, *Hedges' g* = 0.024, *95% CIs* [-0.100, 0.148], $Z$ = 0.378, $p$ = .705, where significant heterogeneity was also observed, $Q_{(7)}$ = 54.135, $p$ <.001, $I^2$ = 87.069.

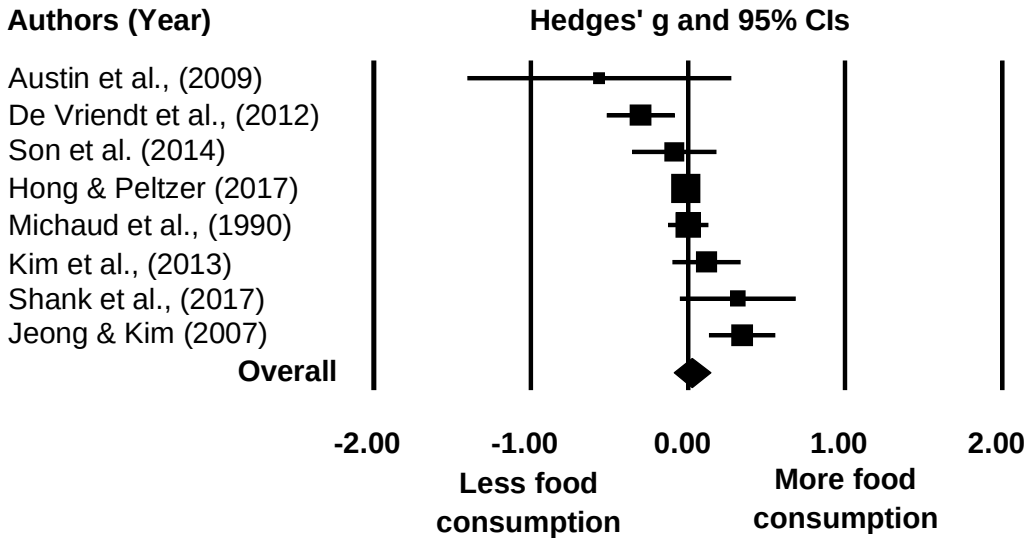


**Figure 2-9. Proportional forest plot of stress and eating behaviours overall in adolescents ($\kappa$ = 8).**

**Table 2-3. Summary table of heterogeneity across studies included in meta-analysis in adolescents.**

| Subgroup | Variables | Effect size [95% CIs] Mixed Effects Model | $I^2$% | Q and p value (Within studies) | Q & p value (Between studies) |
|---|---|---|---|---|---|
| Eating behaviour category | Unhealthy *k=5* *N=33,606* | 0.191 [0.027, 0.354] | 69.285% | 13.023 (.011) | 8.272 (.004)* |
| | Healthy *k*=4 *N=33,678* | -0.263 [-0.525, -0.001] | 76.856% | 12.962 (.005) | |
| Study quality | Strong/ Moderate *k*=3 *N=846* | -0.124 [-0.621, 0.373] | 77.519% | 8.896 (.012) | 0.483 (.487) |
| | Weak *k*=5 *N=66,884* | 0.057 [-0.056, 0.170] | 67.890% | 12.457 (.014) | |

*Note:* * Significant at p <.05.

The presence of publication bias was investigated across the 8 studies. A funnel plot of observed and imputed effect sizes (see Figure 2-10) indicated that publication bias was not present in the meta-analysis. This was confirmed using Egger's regression coefficient, *intercept* = 0.293, *df* = 6, *p* = .729 (Egger et al., 1997). However, Duval and Tweedie's trim and fill analysis (Duval & Tweedie, 2000) suggested that there may be one study missing to the right of the mean. Finally, sensitivity analysis was used to investigate the change to the overall effect size for stress and eating behaviours overall by sequentially removing one study at a time. Effect sizes ranged from -0.025 to 0.067, where removal of De Vriendt et al., 2012 resulted in an increased effect size of 0.045. The analyses indicated that systematic removal of each study from the analysis had minimal influence on the observed statistics for stress and eating behaviours overall, suggesting that no studies were skewing the data.

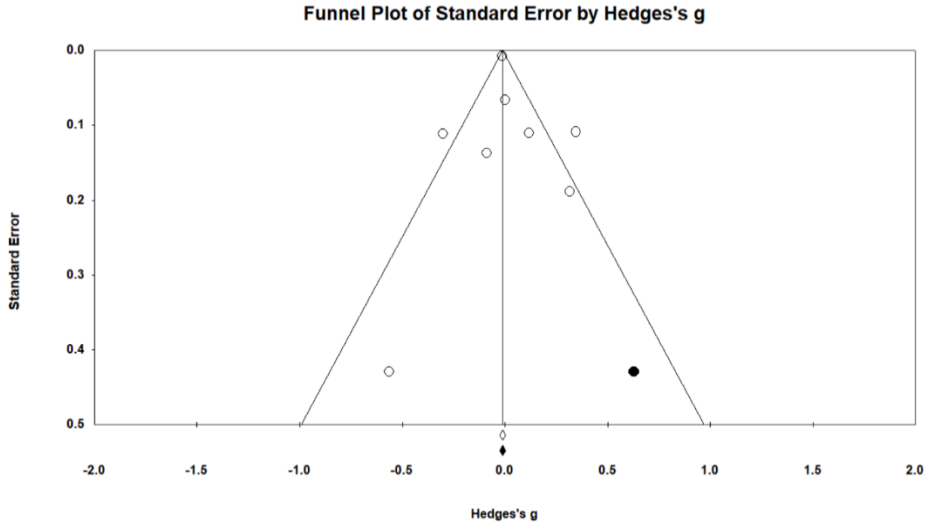


**Figure 2-10. Funnel plot of observed (white) and imputed (black) studies for the meta-analysis in adolescents.**

#### 2.4.4.3 Moderating Variables on Stress and Eating Behaviours Overall in Adolescents

The moderating effects of gender (% female), mean age, sample size and study quality were investigated on stress and eating behaviours overall using meta-regressions (maximum likelihood model) and analyses across groups. Analyses were conducted using the mean of selected outcome, followed by independence assumed between outcomes.

Seven studies indicated in the review reported the percentage of females in the sample. Using the mean of selected outcomes (r = 1), the meta-regression indicated that the percentage of females significantly moderated stress and eating behaviours overall, *coefficient* = 0.003, *standard error* = 0.001, $Z$ = 2.81, $p$ = .005, which was also found when independence between eating outcomes was assumed, *coefficient* = 0.005, *standard error* < .001, $Z$ = 5.76, $p$ < .001.

Six studies reported the mean age of the sample, and a meta-regression indicated that mean age did not moderate stress and eating behaviours overall, *coefficient* = 0.063, *standard error* = 0.044, $Z$ = 1.44, $p$ = .150, nor when independence was assumed between eating outcomes, *coefficient* = 0.053, *standard error* = 0.047, $Z$ = 1.13, $p$ = .257.

The moderating effect of sample size was investigated across the eight studies using a meta-regression. The analysis indicated no moderating effect of sample size on stress and eating behaviours overall, *coefficient* < -0.001, *standard error* < 0.001, $Z$ = -0.26, $p$ = .792. Similar results were found when assuming independence between outcomes for sample size on stress and eating behaviours overall, *coefficient* < 0.001, *standard error* < 0.001, $Z$ = -0.23, $p$ = .820.

Finally, the moderating effect of study quality as assessed on all 8 studies included in the review between strong/ moderate and weak quality. Analyses across the two study quality groupings found no moderating effect of study quality on stress and eating behaviours overall, $Q_{(1)}$ = 0.483, $p$ = .487. Similarly, no moderating effect of study quality was found when independence was assumed between outcomes, $Q_{(1)}$ = 0.572, $p$ = .449.

#### 2.4.4.4 Stress and Type of Eating Behaviour in Adolescents

Further analyses were carried out to investigate potential associations between stress and type of eating behaviour when using the mean of outcomes. A significant difference was found between stress and the type of food consumed, $Q_{(3)}$ = 19.155, $p$ <.001, where unhealthy and healthy outcomes significantly differed, $Q_{(1)}$ = 8.272, $p$ = .004. There was no difference between unhealthy and other eating outcomes, $Q_{(1)}$ = 3.109, $p$ = .078, nor healthy and other eating outcomes in adolescents, $Q_{(1)}$ = 3.172, $p$ = .075. Further analyses were conducted to investigate this association between stress and type of food intake in adolescents.

#### 2.4.4.5 Stress and Unhealthy Eating in Adolescents

Analyses indicated that stress was significantly positively associated with unhealthy food consumption, *Hedges' g* = 0.201, *95% CIs* [0.028, 0.374], $Z$ = 2.282, $p$ = .022 (see Figure 2-11 for a proportional forest plot). Furthermore, there was significant heterogeneity between studies which included stress and unhealthy food intake, $Q_{(4)}$ = 16.903, $p$ = .002, $I^2$ = 76.335. The main effect of stress and unhealthy food consumption was also found when independence was assumed between eating outcomes, *Hedges' g* = 0.212, *95% CIs* [0.038, 0.389], $Z$ = 2.356, $p$ = .018.

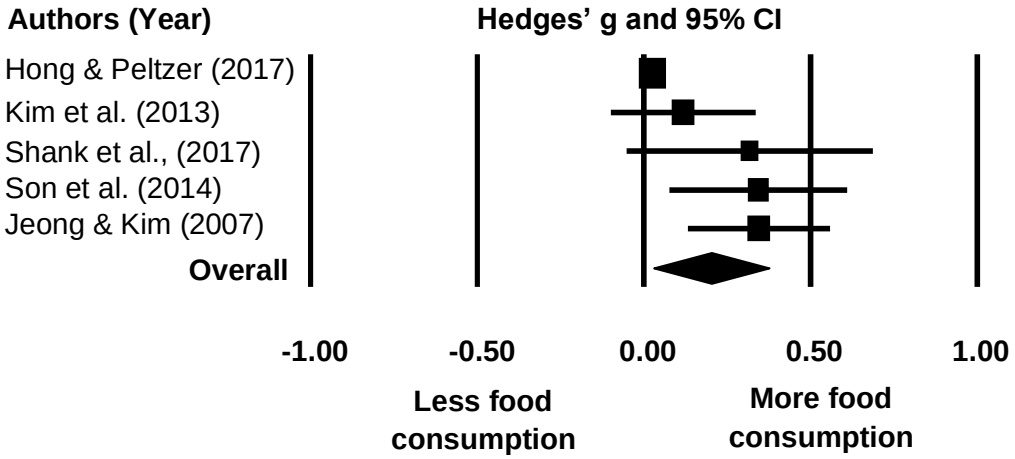


**Figure 2-11. Proportional forest plot of stress and unhealthy food consumption in adolescents ($\kappa$ = 5).**

#### 2.4.4.6 Moderating Variables on Stress and Unhealthy Eating in Adolescents

Analyses were conducted to investigate the moderating effect of gender (% female), mean age, sample size and study quality on stress and unhealthy eating in adolescents. The findings were the same when using assuming independence between the eating measures and when eating measures were not independent to one another.

The percentage of females significantly, positively moderated stress and unhealthy eating behaviours, *coefficient* = 0.005, *standard error* = 0.001, $Z = 3.77$, $p < .001$. Mean age was not found to moderate the association between stress and unhealthy eating behaviours, *coefficient* = 0.629, *standard error* = 0.044, $Z = 1.44$, $p = .150$.

Further analyses indicated a moderating effect of sample size on stress and unhealthy eating behaviours, *coefficient* < 0.001, *standard error* < 0.001, $Z = -3.77$, $p = .002$, where smaller sample sizes were associated with a stronger effect between stress and unhealthy eating behaviours. Finally, no moderating effect of study quality was found on stress and unhealthy eating outcomes in adolescents, $Q_{(1)} = 0.477$, $p = .490$.

#### 2.4.4.7 Stress and Healthy Eating in Adolescents

When using the mean of outcomes, a negative association was found between stress and healthy food consumption, however this was not statistically significant, *Hedges' g* = -0.286, *95% CIs* [-0.576, 0.004], $Z = -1.934$, $p = .053$ (see Figure 2-12 for a proportional forest plot). In contrast, stress was significantly, negatively associated with healthy food consumption when independence between outcomes was assumed, *Hedges' g* = -0.292, *95% CIs* [-0.576, -0.008], $Z = -2.017$, $p = .044$. There was significant heterogeneity between studies using stress and healthy eating behaviours, $Q_{(3)} = 20.144$, $p < .001$, $I^2 = 85.107$.


**Figure 2-12. Proportional forest plot of stress and healthy food consumption in adolescents ($\kappa$ = 4).**

#### 2.4.4.8 Moderating Variables on Stress and Healthy Eating in Adolescents

Analyses were conducted to investigate the moderating effect of mean age, sample size and study quality on stress and unhealthy eating in adolescents. A meta-regression was not conducted on the percentage of females on stress and healthy eating outcomes in adolescents due to there being insufficient studies for the number of covariates. The findings were the same when using assuming independence between the eating measures and when eating measures were not independent to one another.

Mean age did not moderate stress and healthy eating behaviours, *coefficient* = 0.249, *standard error* = 0.149, $Z$ = -1.67, $p$ = .095.

Analyses indicated a moderating effect of sample size on stress and healthy eating behaviours, *coefficient* < 0.001, *standard error* < 0.001, $Z$ = 4.31, $p$ < .001, where smaller sample sizes were associated with a smaller effect between stress and healthy eating behaviours.

Finally, no moderating effect of study quality was found on stress and healthy eating outcomes in adolescents, $Q_{(1)}$ = 0.4710, $p$ = .522.

## 2.5 Discussion

Taken together, the two meta-analyses found a small, positive effect between stress and food intake overall in adults, and no effect of stress and food intake overall in adolescents. Further analyses revealed that, in adult populations, stress was associated with a decrease in the consumption of healthy foods, and an increase in consumption of unhealthy foods. Similarly, stress was associated with increased consumption of unhealthy foods in adolescents, however the effect of stress on healthy food consumption was less clear.

These findings are in line with previous literature reviews which have indicated that food consumption increases as a function of stress in both adults (Araiza & Lobel, 2018; Greeno & Wing, 1994; Lyzwinski et al., 2018) and adolescents (Hill et al., 2018; O'Connor, 2018). However, these two meta-analyses revealed, for the first time, that across the existing body of research the strength of the relationship between stress and food consumption (both overall and for different types of food consumption) was small in magnitude. Nevertheless, this finding is noteworthy as it confirms that stress is an important factor that negatively impacts on eating behaviour and, overtime, may contribute to health risk by disrupting habitual healthy eating behaviours and promoting unhealthy eating behaviours. Furthermore, the meta-analyses identified that stress-related eating behaviours are present in adolescents. Taken together with previous findings (Hill et al., 2018), it is apparent that stress-related eating behaviours are similar across adolescents and adults. Adolescence is a key period for the formation of dietary habits (Albani et al., 2018; Todd et al., 2015) therefore it is likely that changes to normal eating habits when experiencing stress during adolescence can result in poorer health behaviours being established and continuing throughout adulthood (Mikkilä et al., 2005), consequently increasing the risk of ill health and obesity in later life (Ebbeling et al., 2002).

However, the small effect sizes found between stress and food consumption may not present an accurate picture of stress-related eating behaviours, as there was still considerable heterogeneity of unexplained variance throughout analyses. Individual differences play a crucial role in explaining the association between stress and eating behaviours (Greeno & Wing, 1994;

O'Connor & Conner, 2011). For example, changes to normal eating behaviours when experiencing stress can depend on the activation of different biological systems when we experience stress (Rabasa & Dickson, 2016), where the experience of stress may result in increased (a hyperphagic response), decreased (a hypophagic response) or no changes to eating behaviours. Although stress is thought to increase food consumption, only ~30-40% of people consistently increase their food intake under conditions of stress (Oliver & Wardle, 1999; Sproesser et al., 2014). Without consideration of these differing responses to stress, samples may include individuals across these three groupings which would result in smaller effect sizes overall compared to studies were hyperphagic individuals are identified. Future research should identify patterns of stress-related eating within each sample to understand how individual differences influence stress-eating behaviours.

Furthermore, few studies using samples of adolescents were identified for their inclusion in this meta-analysis, highlighting a gap in current research. In contrast, a large number of studies ($N$ = 29) in the adult meta-analysis used samples originating from higher education environments. The transition from late adolescence to adulthood has been noted in previous research for its impact on health outcomes (Ames, Leadbeater, & MacDonald, 2018; Boyce & Kuijer, 2015; Hu et al., 2016; Watts, Loth, Peterson, Boutelle, & Neumark-Sztainer, 2016). For example, studies have linked the transition from secondary school to universities with increased weight gain (for a meta-analysis see Vadeboncoeur, Townsend, & Foster, 2015). However, few studies include samples ranging from adolescents to young adults which would enable a comparison of stress-related eating habits between these two age groups to identify whether poorer dietary behaviours are being established prior to this transitional period.

The considerable heterogeneity found in the meta-analysis in adults may also be explained through individual differences in the evaluation and type of stressor experienced, which has previously been found to influence stress-induced eating behaviours (Miller et al., 2007). For example, research has found that the severity of a stressor is more predictive of eating behaviours than merely whether one is experienced (Adam & Epel, 2007), although this is not consistently

reported in previous research (Conner et al., 1999). The type of stressor can also have a differential influence on stress-induced eating behaviours. Ego-threatening stressors (O'Connor et al., 2008) and those with social evaluation (such as stress induction paradigms) elicit much stronger stress responses and may be more likely to result in changes to normal eating behaviours (Dickerson & Kemeny, 2004). Few studies in these meta-analyses considered situational factors around the experience of stress, which may provide greater insights into stress-induced eating than merely the occurrence of stress.

Moderation analyses in adolescents identified only one moderating variable (gender) on stress-eating associations. The lack of moderating variables may be due to the small number of studies identified in the review, and resulting small numbers included in subgroup analyses. Similarly, moderation analyses in the meta-analysis on adults indicated few factors which may influence the strength of this effect and highlighted gaps in the literature.

Study quality was found to moderate the relationship between stress and eating overall, where studies weaker in quality resulted in a greater effect between stress and food consumption. More specifically, no moderating effect was found for studies strong in quality on type of eating outcome. In contrast, studies weak in quality were most strongly associated with stress and healthy food intake, whilst studies moderate in quality were most strongly associated with stress and unhealthy food consumption. This suggests that weaker quality studies may be inflating the association between stress and eating behaviours.

The type of stress measurement used did not moderate stress and food intake (for overall, unhealthy or healthy foods), however effects were stronger in studies using perceived stress compared to those using stress-induction methodologies. Furthermore, subgroup analyses highlighted a stronger association between stress and food consumption in studies using daily diaries. Compared to measures of perceived stress (such as the Perceived Stress Scale; Cohen, Kamarck, & Mermelstein, 1983) daily diaries can provide greater insights into the association between stress and health behaviours due to their ability to document both between and within-person variability (O'Connor et al., 2009). Similarly, objective measures of stress (such as cortisol sampling or blood

pressure) introduce fewer biases than self-reported perceived measures of stress, although the two measures may be capturing different aspects of the stress experience (Hellhammer, Wüst, & Kudielka, 2009). Additionally, this highlights the importance of employing robust methodologies to create a more accurate picture of stress-related health behaviours.

A differential effect of gender was found between the two meta-analyses. In adolescents, the proportion of females was found to moderate stress and food intake overall, where stress-eating associations were greater in studies with more females. In contrast, the meta-analysis in adults did not find any differences on stress and food intake overall, nor on the type of foods consumed (unhealthy and healthy) between females and males. However, subgroup analyses found a stronger association between stress and unhealthy food consumption in females compared to males, whilst the effect of stress and healthy eating was stronger in males compared to females. This is partly in line with previous studies, and the findings of the meta-analysis in adolescents, which have suggested that females are more likely to change their eating behaviours when experiencing stress compared to males (Sims et al., 2008; Stone & Brownell, 1994; Weinstein et al., 1997). However, caution should be taken when interpreting these results as, across the two meta-analyses, 38 studies included data on females only (35 in adults and 3 in adolescents), whilst only 9 studies included data on males only. This difference between females and males may therefore be due to a greater volume of data available for females compared to males, and the influence of stress on eating behaviours in males may be largely unrepresented. Studies should aim to recruit samples with balanced gender splits to better represent males within this field of research and report key findings on stress and eating in both genders separately.

No moderating effect of age was found in either of the meta-analyses, suggesting that habits formed around maladaptive coping strategies when experiencing stress can continue throughout the lifespan (Mikkilä et al., 2005). Taken together with a previous meta-analysis in the area, stress-related eating habits which are formed in earlier years appear to remain throughout the adult life (Hill et al., 2018).

Similarly, in the meta-analysis in adults, the source of the samples did not moderate the association between stress and eating overall. Further analyses indicated that the effect of stress on unhealthy and healthy food consumption was similar regardless of the sample source. Use of undergraduate samples within research has been highlighted previously (Ball & Lee, 2000; Henrich et al., 2010), however reliance on convenience samples may not provide an accurate picture of the complex relationship between stress and eating habits in adults. Furthermore, reliance on WEIRD studies (i.e., samples which are Western, Educated, Industrialised, Rich and Democratic) is an ongoing issue in psychology research which can limit generalisability of findings (Henrich et al., 2010).

In the meta-analysis in adults, dietary restraint was not found to moderate stress and food intake overall, which is contrary to previous research (O'Connor et al., 2008; Wallis & Hetherington, 2004). It is likely that, as few studies reported data on dietary restraint in this review, there may have been insufficient studies to detect an association. The interaction between stress-related eating and dietary restraint may be more complex than initially thought, as research has suggested that stress may not increase intake in restrained eaters through their diet behaviour or negative affect alone, with other factors (such as non-stressful cognitive load) contributing instead to this interaction (Lowe & Kral, 2006).

## 2.6 Conclusions

The relationship between stress and health is complex and multifaceted, involving behavioural, neural and endocrine systems (Finch et al., 2019). The findings of these meta-analyses have highlighted that stress can differentially influence the amount and type of food consumed, and the relationship is influenced by few moderating variables. These findings support previous literature reviews (Adam & Epel, 2007; Araiza & Lobel, 2018; Lyzwinski et al., 2018; Torres & Nowson, 2007) and, for the first time, identify the strength of this association. More importantly, the meta-analyses highlighted a clear gap in the literature for stress-related eating behaviours in adolescents.

Theories have posited that eating is used as a coping mechanism when experiencing stress, where food is used to alleviate symptoms of stress such as

negative affect and anxiety (Dallman et al., 2003; Torres & Nowson, 2007; Wethington et al., 2015). Reward theories posit that, under conditions of stress, changes in glucocorticoids (including cortisol) and CRF sensitize areas of the brain associated with reward (e.g., nucleus accumbens), increasing the drive to eat HELN and highly palatable foods (Cottone et al., 2009, Sinha & Jastreboff 2013). This change in food intake towards highly palatable foods served an evolutionary purpose to maintain energy availability to response to physical stressors (i.e., predators) throughout periods where food was scarce. However, most stressors are now physiological by nature, and so changes to normal eating behaviours under stress can result in a positive energy balance.

Although the findings from the two meta-analyses demonstrate that stress is associated with increased intake of HELN foods, differentiating between seeking foods for their nutritional content (i.e., high in fat, sugar or salt) and seeking foods for their palatability is challenging. For example, Sinha and Jastreboff (2013) theorize that stress, reward and palatability of foods forms a positive feedback loop, where increased consumption of highly palatable foods under conditions of stress can subsequently enhance incentive salience for these foods.

It is possible that foods which are eaten under conditions of high stress may be sought because they are highly palatable and are eaten to attenuate the experience of stress, opposed being consumed due to a specific nutrient profile (Morris, Beilharz, Maniam, Reichelt & Westbrook, 2015). In line with these theories, the two meta-analyses identified that both adults and adolescents choose more HELN foods when experiencing stress, whilst simultaneously decreasing their intake of healthy foods such as fruit and vegetables.

Nevertheless, eating habits established during childhood are thought to continue throughout adult life (Mikkilä et al., 2005). Concurrent with this theory and taken together with previous findings (Hill et al., 2018), this meta-analysis has identified that stress-related eating habits are consistently present from childhood and throughout adulthood.

Several moderating variables were investigated across the two meta-analyses; however, few effects were found to influence the association between

stress and food consumption. Due to the limited research available, very few moderating variables could be investigated on stress-eating associations in adolescents. The meta-analysis in adults investigated more moderating variables on stress-eating associations, however the review identified a lack of studies in existing literature which have considered potential moderating variables from which findings could be synthesized. Moderating variables are particularly useful as they can provide insights into individual differences in the experience of stress. These variables can be used to address stress-eating behaviours and reduce this maladaptive coping mechanism in emerging adulthood.

Similarly, differences in physiological reactivity, particularly cortisol reactivity, have been associated with differential effects on the experience of stress and subsequent eating behaviours (for reviews see Klatzkin, Baldassaro, & Rashid, 2019; O'Connor, 2018). Although cortisol reactivity has been found to influence this association in both adults (Appelhans et al., 2010; Epel et al., 2001; Newman et al., 2007) and children (Francis et al., 2013; Michels et al., 2013), few studies have investigated this variable on stress-eating behaviours in adults, with no studies identified in samples of adolescents.

The meta-analysis in adults did not find differences between perceived and induced stress on food intake. However, a strong association on stress-related eating was found for studies using daily diaries (categorised as a type of perceived stress) compared to perceived and induced stress measurements. These findings suggest that daily diaries are better predictors of stress-eating associations, possibly due to their ability to document within and between-person data (Bolger, Shrout, Green, Rafaeli, & Reis, 2006). Similarly, combining objective measures of stress (such as cortisol sampling) with subjective measures may provide greater insights into stress-induced eating behaviours compared to either method used in isolation.

In summary, the findings from this chapter identified that stress is associated with a change in the amount and type of foods consumed in adolescents and throughout adulthood. Currently, there is limited research on stress-eating associations in adolescents. Furthermore, few studies have investigated the moderating role of variables (such as eating style, personality

and cortisol reactivity to stress) on stress and eating habits in adolescents. Finally, there is a gap in the literature for combining objective and subjective measures of stress to develop current understanding of stress-eating associations, particularly in adolescence.

# Chapter 3
# A Daily Diary Study of Stress and Eating Behaviours in Adolescents and Young Adults

## 3.1 Introduction

The findings of the two meta-analyses presented in Chapter 2 highlighted that stress is associated with changes to the amount and type of foods consumed. Previous reviews have consistently reported that stress is associated with increased food consumption (Adam & Epel, 2007; Araiza & Lobel, 2018; O'Connor & Conner, 2011), where higher stress is associated with increased consumption of unhealthy foods, and decreased consumption of healthy foods (Lyzwinski et al., 2018; Torres & Nowson, 2007). However, the meta-analyses revealed, for the first time, the strength of this effect.

Specifically, the meta-analyses identified a small, positive effect between stress and the consumption of unhealthy foods in both adolescents and adult samples. A small, negative effect was found between stress and healthy food consumption in adults and adolescents, although this association was less robust in adolescents, with differing results depending on the method of analysis used.

Currently, there is limited research on stress-related eating habits in adolescents, with only 8 studies included in the meta-analysis. Therefore the present study aimed to address this gap in the literature and build on the findings outlined in Chapter 2. The primary aim of this study was to investigate stress-related eating behaviours in adolescents (aged 13 to18 years old) and young adults (18 to 24 years old) using daily diaries.

Furthermore, the study aimed to determine whether stress-related eating habits in adolescents are comparable to those in young adults. Stress-related eating behaviours are thought to be used as a maladaptive coping mechanism (Dallman et al., 2003; Torres & Nowson, 2007; Wethington et al., 2015), resulting in the formation of unhealthy eating habits when experiencing stress (Pool et al., 2015). As eating habits are established during adolescence, unhealthy eating habits formed during this age period can continue throughout adult life (Mikkilä et

al., 2005), contributing to weight gain and subsequent ill health (Reilly & Kelly, 2011). Although there are few studies in adolescents, the meta-analyses identified at least 31 studies investigating stress-related eating behaviours in samples of young adults recruited from higher education environments, including recently published studies (such as Errisuriz, Pasch, & Perry, 2016; Klatzkin, Baldassaro, & Hayden, 2018; Kwan & Gordon, 2016; Vidal et al., 2018). However, there have been no comparisons of stress-related eating behaviours between adolescents and young adults within the same study. The present study aimed to address this gap in the literature and compare stress-related eating habits in adolescents and young adults to identify potential patterns in the emergence of this maladaptive coping mechanism when experiencing stress. Based on the collective findings from the meta-analyses, it was predicted that stress-related eating habits would be similar across adolescents and young adults.

As outlined in Chapter 2, there is existing research on stress-related eating in samples of undergraduate students which have used a range of methodologies, mainly cross-sectional (for example Boyce & Kuijer, 2015; Lai et al., 2012; Peker & Bermek, 2011; Vidal et al., 2018), or stress induction tasks (for example Barker, Blain, & Russell, 2015; Dweck, Jenkins, & Nolan, 2014; Raspopow, Abizaid, Matheson, & Anisman, 2010; Wallis & Hetherington, 2004). However, the meta-analyses highlighted a lack of daily diary-based studies for measuring stress and eating behaviours across both adolescents (which identified no studies using a daily diary design) and young adults (Boggiano et al., 2015; Conner et al., 1999; O'Connor & O'Connor, 2004).

Daily diaries are a useful method to employ when researching health behaviours as they can document fluctuations in health behaviours, including eating habits, which cannot be captured using cross-sectional studies (Bolger et al., 2006). This study aimed to investigate the effect of daily stress on eating behaviours, specifically consumption of between meal snacks. Between meal snacks are an important eating outcome in the stress-eating relationship as they can lead to increases in daily energy intake and can influence health outcomes longer term. For example, small changes in food intake by 50 to 100 kcal a day can negatively influence health through weight gain (Mozaffarian, Hao, Rimm,

Willett, & Hu, 2011), and consequently contribute to high levels of overweight and obesity (Jauch-Chara & Oltmanns, 2014; Sinha & Jastreboff, 2013). In samples of adults, research has indicated that the consumption of between meal snacks increases as a function of daily stress (Conner et al., 1999; Newman et al., 2007), with individuals choosing to eat HELN snacks over LEHN ones (O'Connor et al., 2008). Similarly, the combined findings outlined in Chapter 2 demonstrated the association between stress and eating behaviours is dependent on the type of foods being consumed. This study aimed to determine the effect of daily stress on the amount and type of snacks consumed in emerging adulthood.

Measuring stress on a daily level through online diaries enables comparisons of within and between-subjects variables, meaning that factors such as personality traits can be investigated for their potential moderating effects on daily stress and eating behaviours (O'Connor et al., 2009). The findings from the two meta-analyses presented in Chapter 2 highlighted a lack of consideration for moderating variables on stress-eating behaviours, especially in adolescents. Due to the limited number of studies available on adolescents, few moderating variables could be explored in the meta-analyses. Therefore, this study aimed to determine the influence of conscientiousness and eating styles as moderating variables on stress-eating behaviours in adolescents and young adults.

The type of stress experienced has been found to influence health differently in samples of adults (Epel et al., 2018). For example, interpersonal stressors have been strongly associated with negative health outcomes including depression (Sheets & Craighead, 2014) and poorer health in adolescent women (Miller, Rohleder, & Cole, 2009). Similarly, using daily diaries O'Connor et al. (2008) found that work related, ego threatening, and interpersonal stressors were associated with increased snack consumption in adults (mean age 40 years). Interestingly, O'Connor et al. (2008) also found that stressors which were physical in nature were associated with decreased snack consumption. Due to these differing effects of type of stressor on health outcomes, this study aimed to investigate the effects of the type of stress (in addition to total stress) on daily eating habits.

Research has also highlighted the moderating effect of the personality trait conscientiousness on stress and health outcomes (see Section 1.6.4 for a summary of findings), where individuals higher in conscientiousness have fewer stress-related eating habits compared to those lower in conscientiousness (O'Connor et al., 2009). There is some research on conscientiousness and stress in adolescents, although this is limited. In a longitudinal study of adolescent women (mean age 17 years), Murphy et al. (2013) found that conscientiousness moderated the severity of stressors, with highly conscientious individuals reporting less intense stressors compared to those lower in this trait. This has also been found in samples of adults, where conscientiousness has been found to reduce the experience of stress (Gartland et al., 2012). The current survey aimed to determine the role of conscientiousness on stress-induced eating behaviours in adolescents and young adults.

Similarly, individual differences in eating style have been found to moderate stress-related eating behaviours in adults (see section 1.6.2 for a summary of the literature). Higher levels of dietary restraint, emotional and external eating have all been associated with increased stress-induced eating behaviours in adults (Roberts et al., 2007; Wallis & Hetherington, 2004; O'Connor et al., 2008). The moderating effect of eating style on stress and food intake has also been found in younger children. For example, Michels et al. (2012) found that emotional eating was associated with stressful events and unhealthy eating behaviours in children aged 5-12 years. Similarly, dietary restraint has been found to moderate the number of snacks consumed after a stressor in children aged 9 years (Roemmich et al., 2007; Roemmich et al., 2002). Understanding the moderating role of eating style in emerging adulthood is important to identify maladaptive eating behaviours in response to stress. Previous research has suggested that emotional eating in response to stress can transition from adolescence into adulthood (Wilson et al., 2015). This trend is likely to form because adolescents are given more autonomy over their food choice and are less dependent on the family home environment (Bassett, Chapman, & Beagan, 2008). Furthermore, understanding the influence of moderating variables such as eating style will help inform future research and interventions to reduce stress-related eating behaviours in adolescents and young adults.

## 3.2 Aims and Objectives

This study aimed to understand current trends in daily eating habits of adolescents aged 13 to 18 years old and investigate whether daily stress was associated with between meal snack consumption. Based on the findings from Chapter 2, it was predicted that higher stress would be associated with greater intake of between meal snacks.

Furthermore, this study aimed to compare stress-related eating habits between adolescents and young adults, to determine whether maladaptive eating behaviours when stressed are consistent throughout emerging adulthood. Based on the collective findings from the two meta-analyses outlined in Chapter 2, it was predicted that stress-related eating habits would be similar across adolescents and young adults.

Finally, this study aimed to investigate the influence of moderating variables on stress-related eating habits. Specifically, the study aimed to investigate the effect of eating style (restrained, external and emotional eating) on stress and snack consumption overall. Additionally, the study aimed to investigate the moderating role of conscientiousness on daily stress and eating habits.

## 3.3 Method

### 3.3.1 Design and Participants

The study aimed to recruit 100 adolescents aged 13-18 years old and 100 young adults aged 18-25 years old. The sample size was determined by the availability of funding and sample sizes of previous studies in the area (see section 2.4 for a meta-analysis on stress-related eating behaviours in adolescents). Participants were eligible for the study if they were English speaking and were aged 13-18 years old for adolescents or over 18 years old for young adults. Participants were asked to record whether they had an existing or previous history of disordered eating (such as anorexia or bulimia). Participants who disclosed previous or existing eating disorders were excluded from analyses. Participants were also asked to note whether they had any medical conditions

which required a specialist diet (such as coeliac disease or diabetes) and this variable was controlled for in the analyses.

Adolescents were primarily recruited via local secondary schools and sixth form/colleges in West and South Yorkshire. Teachers were initially approached using formal letters and emails which were followed up with phone calls. Forty-four schools and colleges were approached, in addition to 5 youth clubs. Of these 49 sources, 11 expressed an interest in the study. The majority of those contacted did not respond to invitations ($N$ = 35) and two responded however declined to participate. Of the 11 sources who were interested in being involved in the study, 6 failed to follow up on their interest. The adolescent sample was recruited from 5 schools and via open days held at the University of Leeds.

As an incentive for schools to take part, teachers were given the opportunity for their class to receive a talk on research methods which linked to the Psychology A-Level curriculum. Additionally, students were encouraged to include their participation in the study in their UCAS applications. Finally, the research findings were presented to classes and a summary of the findings given to teachers. The study was also advertised to adolescents during open days at the University of Leeds via the distribution of information sheets with contact details.

Parental consent was obtained for participants aged 13, 14 or 15 years old. All participants aged under 18 years old were given a letter inviting them to take part, along with contact details of the primary researcher. This enabled parents (or anyone in loco parentis) to withdraw their child from the study. A total of 107 adolescents consented to take part in the study and completed the initial questionnaire (see Figure 3-1 for participant retention rates). For their participation in the study, adolescents who had completed the baseline questionnaire and at least one diary entry on time (i.e., not backfilled) were entered into a prize-draw with 10 chances to win a £20 Love2shop voucher.

Young adults were recruited via the University of Leeds School of Psychology participant pool. The participants were undergraduate Psychology students who received up to 14 course credits upon completion of the study. A total of 101 undergraduate students agreed to participate in the study and completed the initial questionnaire (see Figure 3-1 for a flow diagram of participant retention).

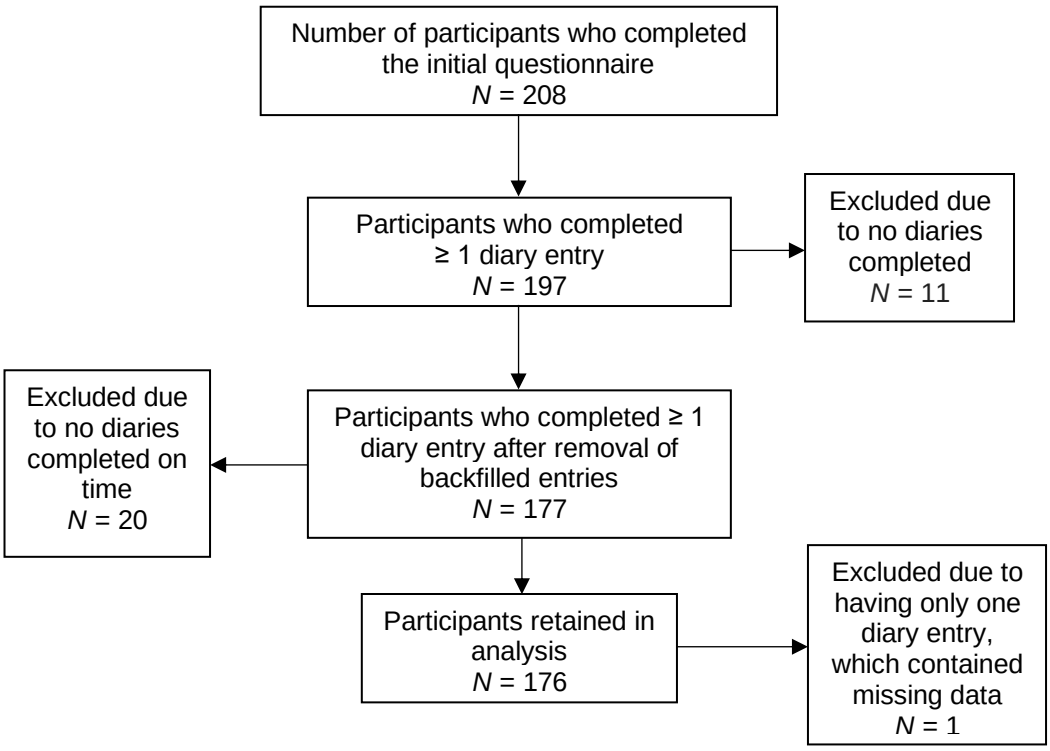


**Figure 3-1. Flow diagram of participant recruitment and retention based on completion of online daily diaries.**

### 3.3.2 Procedure

Participants aged 13-18 years old were approached in school environments and were given a study pack to take home. The pack included an information sheet about the study (including an outline of the study aims), a student consent form, parental consent form for those aged 13, 14 or 15 years old and the initial questionnaire. After the study packs were collected, participants were notified that the daily diary period should start the following day. The daily diaries were hosted online through Jisc Online Surveys (formally Bristol Online Surveys) and participants were asked to complete one diary entry each evening,

for 10 consecutive days. End of day data collection methods such as daily diaries are particularly useful in documenting day to day temporal changes and are a reliable method of data collection (Bolger et al., 2006). A 10-day period was chosen to capture sufficient data on stress-related eating habits across both weekdays and weekends, which may be missed with shorter diary periods. Furthermore, longer diary periods (i.e., those over several weeks) may have been off-putting to both participants and schools, which may have resulted in larger dropout rates and/ or difficulties in recruitment, particularly in adolescents. Previous diary-based studies have used between 4 and 28 consecutive days of diaries (Boggiano et al., 2015; Conner et al., 1999; O'Connor et al., 2009).

An email or text message reminder with a link to the online diary was sent each evening at approximately 9pm. Participants were instructed to complete the diary just before they went to bed. At the end of the diary period, participants were sent a final email/text message with a link to the online de-brief sheet. Additionally, participants were reminded that they were able to withdraw their data from the study up to 14 days after receiving the study de-brief. The same procedure was followed for the undergraduate students, except for the consent form and initial questionnaires which were completed online.

All study materials were adapted for use within the two age groups to ensure that the content of materials was suitable for the intended audience. This was achieved using the Flesch Readability Ease Scale (Flesch, 1948), where readability ranged from 54.7 to 69.2 across study items. Reading ease was lower (i.e., more challenging to read) than advised for some study materials used in the adolescent sample. For example, the study de-brief had the lowest readability score of 69.2, however omitting two sentences regarding ethical approval and withdrawal of data would have increased the readability score to 60.5 overall for the study de-brief.

To ensure anonymity, participants created a unique code which was used in the initial questionnaire and online daily diaries. The code was formulated from the day of their birth date, the first letter of their mother’s first name and the last 2 digits of their mobile number. As an additional safeguard for participants, access to local mental health and eating disorder services were presented at the

end of the initial questionnaire and the daily diaries. Ethical approval was received on 31/10/2016 (reference code 16-0284) with an amendment accepted on 30/11/2017 (reference code PSC-182).

### 3.3.3 Measures

The initial questionnaire included basic demographic information (age, gender, height and weight) as well as questions relating to pubertal development, eating style and conscientiousness.

Pubertal development was assessed using the Pubertal Development Scale (Petersen, Crockett, Richards, & Boxer, 1988) which measures five indices of growth; body hair, growth, skin changes, changes to voice and facial hair growth (males only) and breast development (females only). Participants selected one of 5 responses on each of the growth indices (‘*Not Yet Started’, ‘Barely Started’, ‘Definitely Started’, ‘Seems Complete’* or ‘*Don’t Know’*). Scores were summed across the items to create a total score for pubertal development. The questionnaire was not given to young adults as it was assumed that all young adults would be post-pubertal due to their age (i.e., 18 years or over).

Three eating styles were measured in the initial questionnaire using the Dutch Eating Behavior Questionnaire (Van Strien et al., 1986) which has been adapted for use with an English audience (Wardle, 1987). The Dutch Eating Behavior Questionnaire (DEBQ) uses 33 questions to measure three types of eating behaviour; Restrained (with 10 questions), Emotional (13 questions) and External eating (10 questions). Participants are asked to rate the frequency of experiencing each eating behaviour using a 5-point Likert scale from ‘*Never’* to ‘*Very Often*’ where higher scores reflect a greater tendency to exhibit the eating behaviour. Restrained eating refers to being able to exert self-control over ones eating habits (example question: *‘Do you deliberately eat less in order not to become heavier?’*). Emotional eating refers to eating in response to experiencing specific emotions, such as sadness or boredom (example item: *‘Do you have a desire to eat when you are disappointed?’*). Finally, external eating relates to the tendency to over-eat in response to external food cues (example item: *‘If food smells and looks good, do you eat more than you usually do?’*). Evers et al. (2011) have reported the internal consistency to be high for restrained (α = .92),

emotional (α = .96) and external eating questions (α = .78). In the present sample, internal consistency was found to be similar to that previously reported across the whole sample (restraint α = .90; emotional eating α = .92; external eating α = .80). Similarly, internal consistency was high across the three scales in adolescents and young adults separately (restraint adolescents α = .90, young adults α = .92; emotional eating adolescents α = .93, young adults α = .92; external eating adolescents α = .82, young adults α = .80).

Finally, conscientiousness was measured using a 10-item scale taken from the public domain measure of the International Personality Item Pool (Goldberg et al., 2006), which includes items on the Big Five personality dimensions (www.ipip.ori.org/ipip/). In this scale, conscientiousness was defined as the tendency to be organised and efficient, where individuals strive for achievement and prefer planning over spontaneity (example item: *'Pay attention to details'*). Participants were instructed to respond based on their current self (and not how they wish to be in the future), and in relation to other people of the same age and gender. Participants were asked to rate each item on a 5-point Likert scale from '*Very Inaccurate'* to '*Very Accurate'*, which included a neutral response ('*Neither Accurate nor Inaccurate')*. The internal consistency was high across the scale items for the overall sample (α = .81), and for adolescents (α = .82) and young adults (α = .81) separately.

#### 3.3.3.1 Daily Diary Measures

The daily diary recorded any stressors participants had experienced as well as their eating habits each day. The eating habits were between-meal snack consumption (including perceptions of healthy and unhealthy snacks eaten) and portions of fruit and vegetables.

The following description of a daily hassle was included in the daily diary;

*"[Hassles are] events, thoughts or situations which, when they occur, produce negative feelings such as annoyance, irritation, worry or frustration, and/or make you aware that your goals and plans will be more difficult or impossible to achieve"*

*(O'Connor et al., 2008, p. S20)*

Participants were able to record up to six stressors each evening using free-response text boxes. Stressors were coded into five categories as used previously by O'Connor et al., (2008) and stressors could be appear in more than one category (with the expection of 'other' stressors). A description of each stress category with an example stressor is presented in Table 3-1.

The number of stressors recorded each day were summed to create a total stress score. Similarly, the number of stressors falling into each of the 5 categories were summed to create a total for each.

**Table 3-1. Description of stress categories with an example item taken from the study dataset.**

| Category | Criteria | Example |
|---|---|---|
| Ego-threatening | Includes stressors where there is potential for failure (but only when explicitly stated e.g., did not do well on a practical report), receiving criticism or having a job interview. | *"Being unprepared for a psychology exam"* |
| Interpersonal | Relating to any communications with others, or problems with relationships (romantic or otherwise). Also includes stressors caused by others (e.g., housemates being untidy). | *"Argument between two family members"* |
| Work & Academic | Stressors relating to school, university or employment, including volunteering, mentoring and coaching. Also includes stressors around being late to work, school or university. | *"Having a lot of uni work and job work over the weekend and not much time"* |
| Physical | Stressors which are physical in their nature (e.g., being ill, running for a train) and/or produce feelings of anxiety (if stated explicitly). | *"Being on the verge of a panic attack"* |
| Other | For stressors which do not fit into any of the above categories, or where participants have not provided sufficient information about the stressor. | *"Couldn't decide what to have for dinner"* |

Inter-rater agreement was obtained on at least 10% of stressors reported in the daily diaries (total *N* = 1,933; second coded *N* = 204) by an independent researcher. The level of agreement was high overall ($\kappa$ = .85) and was good for each stress category; ego-threatening $\kappa$ = .98, interpersonal $\kappa$ = .90, work/academic $\kappa$ = .87, physical $\kappa$ = .77, other $\kappa$ = .71 (Cohen, 1960).

The perceived intensity of each stressor was measured using a 5-point Likert scale from *"Not at all Intense"* to *"Very Intense"*. Intensity was described as how severe or extreme participants' feelings were when experiencing the stressor. Intensity ratings were averaged for each diary day.

Similar to the stressors, participants were asked to record up to eight between-meal snacks per day. Participants were instructed to report the brand (where applicable) and quantity of each snack consumed. Participants were also instructed to include high energy drinks as a between-meal snack (such as fruit juice, fizzy drinks and alcohol). Between-meal snacks were summed to give a total number of snacks consumed per diary entry and were used as an outcome measure.

Snacks were coded into 4 categories based on their nutritional content; high in fat, high in sugar, high in both fat and sugar, and low-to-medium in fat and sugar content (see Table 3-2 for an example of snack categories). It is important to note that all data for this study were collected prior to introduction of the sugar tax on fizzy drinks as part of Public Health England's Sugar Reduction Programme. Therefore, coding of any drinks was based on the nutritional content prior to the implementation of national sugar reductions.

Snacks which contained 17.6g/100g of fat (or 21g/portion for snacks over 100g) or more were coded as being high in fat. Snacks with ≤ 17.5g/100g were coded as being low-to-medium in fat. Similarly, foods which contained at least 22.6g/100g of sugar (or > 27g per portion for snacks over 100g) were categorised as being high in sugar content. Snacks with ≤ 22.5g/100g of sugar were coded as being low-to-medium in sugar content. Participants were also asked to record any drinks consumed between meals (other than water) which were also coded based on fat and sugar content. High fat drinks were categorised as those containing at least 8.76g/100g (or > 10.5g per portion for drinks more than 150g).

High sugar drinks were identified as those containing at least 11.26g/100g of sugar or more (or greater than 13.5g per portion of 150g). These cut offs were based on the Food Standards Agency Front of Pack nutritional labels using the traffic light system (Department of Health, 2016). The nutritional content of the foods was determined using summary food composition tables outlined by McCance and Widdowson (Finglas et al., 2014) and via retailer's websites.

**Table 3-2. Description of between meal snack categories with an example item taken from the study dataset.**

| Category | Criteria | Examples |
|---|---|---|
| High fat | ≥17.6g/100g of fat (or 21g/portion for snacks over 100g) | *Ice cream, protein bar, Pringles (crisps), nuts.* |
| High sugar | ≥22.6g/100g of sugar (or >27g per portion for snacks over 100g) | *Mints, dried banana, Haribo (sweets), cereal bar.* |
| High fat and high sugar | ≥17.6g/100g of fat and ≥22.6g/100g of sugar | *Snicker, chocolate bar, Mars bar, brownie.* |
| Low-to-medium in fat and sugar | ≤ 17.5g/100g of fat and ≤22.5g/100g of sugar | *Strawberries, rice cake, yogurt, grapes.* |

A minimum of 10% of reported between-meal snacks were second coded by an independent reviewer (total snacks $N$ = 2,363; second coded $N$ = 249). Cohen's kappa (Cohen, 1960) was found to be good for overall coding of snacks ($\kappa$ = .80), with high agreement levels for the coding of high fat ($\kappa$ = .84), high sugar ($\kappa$ = .71), high fat and sugar snacks ($\kappa$ = .84) and low-to-medium fat and sugar snacks ($\kappa$ = .81).

Portions of fruit and vegetables were reported separately in the daily diary, with an overall measure created by summing the two variables.

### 3.3.4 Analytical Method

A total of 208 participants completed the initial questionnaire; 107 adolescents and 101 young adults. From these 1,449 diaries were completed prior to the removal of backfilled entries. Backfilled diaries were identified as those completed after 3am, which was determined via the electronic time and

date stamp of the time of submission. After the removal of backfilled diaries, participants were retained in the data set if they had complete data (i.e., no missing values) on at least one diary entry. Participants who completed no diary entries prior to the 3am cut-off or had missing data on only one diary entry (*N* = 1) were excluded from the analysis.

After the removal of backfilled diaries (*N* = 130; 8.97% of diaries initially completed), 32 participants were excluded from analyses (29 adolescents and 3 young adults). The final sample size was 176 participants (78 adolescents and 98 young adults) who completed a total of 1,318 daily diaries (see Figure 3-2 for a breakdown of diary completion rates). This equates to a participant drop-out rate of 27.10% in adolescents and 2.97% in young adults (drop-out rate overall 15.38%).

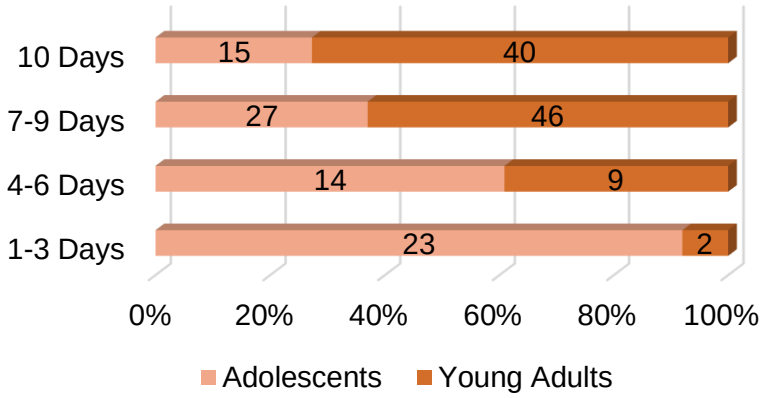


**Figure 3-2. Number of participants completing diary days, split by age group**

A multivariate analysis of variance (MANOVA) was conducted to compare participants who were excluded from the study against those retained in the data set. The analysis indicated that there was a significant difference of age, $F(1, 206) = 24.71$, $p < .001$, where those who were excluded from the analysis were younger (*mean* = 16.59 years, *SD* = 1.41 years) than those retained in the analysis (*mean* = 18.01 years, *SD* = 1.50 years).

Furthermore, the MANOVA indicated that there was a significant difference on pubertal score, $F(1, 206) = 16.67$, $p < .001$, where participants who were excluded scored lower on pubertal development scale, (*mean* = 16.94, *SD* = 2.40), than those retained in the analysis (*mean* = 18.68, *SD* = 2.19). No

differences were found between included and excluded participants on eating style (restraint, emotional and external eating) or conscientiousness.

A Chi-Square Test of Independence (McHugh, 2013) was used to compare potential differences in gender between included and excluded participants. As the assumption for the Chi-Squared was violated (where 25% had an expected count of < 5) the Likelihood Ratio was used. The analysis found a significant difference of gender (*Likelihood Ratio* = 10.68, *df* = 1, *p* = .001) where 25% of those excluded from the dataset were male (*N* = 8) and 5.11% of included participants were males (*N* = 9).

#### 3.3.4.1 Missing Data

Missing data was assessed across all participants on variables included in the initial questionnaire. Missing data ranged from 0% to 1.7% across eating style and conscientiousness questionnaire items. Little's Missing Completely at Random (MCAR; Little, 1988) test found that the data were not missing completely at random, $\chi^2$ *(543)* = 610.63, *p* = .023, (Schlomer, Bauman, & Card, 2010).

Missing data were treated at item level using series mean imputation for each participant individually. For example, where a missing point was present, data were imputed based on the mean value taken from a participant's responses on the same scale (such as conscientiousness). Although this method may introduce bias when data are not missing completely at random (Eekhout et al., 2014) descriptive statistics and correlations did not differ between data with missing values and data where values had been imputed. This method was deemed most appropriate to accurately reflect participants' responses.

Missing data was also assessed in the daily diaries for variables on eating behaviours (specifically portions of fruit and vegetables). Missing data on these measures ranged from 0.8% to 1.4% (where the total missing was 2.2%). Little's MCAR analysis was not significant, $\chi^2$ *(2)* = 0.55, *p* = .760, indicating that the data were missing in a completely random way. Similar to the baseline data, missing data in the daily diaries were treated using series mean imputation based on participant's responses across their other diary entries. This method was deemed

most appropriate to treat missing data in this study for the type of analyses required to analyse the data.

#### 3.3.4.2 Method of Analysis

The data was initially analysed using SPSS (IBM Corporation, 2017) for descriptive statistics for level 1 and level 2 data separately. Further analyses were conducted using HLM 7 (Raudenbush, Bryk, Cheong, Congdon, & Du Toit, 2011) to create HMLM. Two-level structures were used to match within-person data (i.e., daily stress and eating behaviours) to between-person data (i.e., demographics, eating style and conscientiousness).

The data was initially modelled using a single level structure based on the following model;

$$Level\ 1: \quad \gamma_{ij} = \beta 0_j + \beta_{1j}\,(stress) + r_{ij}$$

where $\gamma_{ij}$ reflects within-person variability in the eating behaviour outcome across diary days for person ($i$ and $j$ respectively). $\beta 0_j$ represents the intercept and $\beta_{1j}$ represents the model slope estimates for the stress measure. Finally, $r_{ij}$ represents the error for daily measures and $\gamma$ represents the structural coefficient associated with the level 1 model.

Cross-level models were carried out to investigate the possible moderating effect of age group, gender, eating style and conscientiousness on overall stress and between-meal snack consumption based on the following equation;

$$\begin{aligned} &Level\ 1: && \gamma_{ij} = \beta 0_j + \beta_{1j}\,(stress) + r_{ij} \\ &Level\ 2: && \beta_0 = \gamma_{00} + \gamma_{01}\,(age\ group) \\ & && \beta_1 = \gamma_{10} + \gamma_{11}\,(age\ group) \end{aligned}$$

where $\beta_0$ represents the main effect between the eating outcome ($\gamma_{00}$ - in this case between-meal snack consumption) and the moderating variable ($\gamma_{01}$) of age group. Finally, $\beta_1$ represents the potential moderating effect between all variables in the model i.e., using the above model, the potential moderating effect of age group on total stress and total snacks.

Unstandardized coefficients from HMLM analyses have been reported. Finally, where moderating effects were identified in the level 2 models, Preacher's

calculator (Preacher & Kelley, 2011) was used create plots displaying the cross-level interactions between variables. Prior to conducting Preacher's calculator, moderating variables and stress measures were mean centred to produce standardised plots.

## 3.4 Results

A total of 1,318 daily diaries were recorded across 176 participants. The sample consisted of 98 young adults (*N* = 840 daily diaries) and 78 adolescents (*N* = 478 daily diaries). Overall, participants were predominately female (*N* = 167, 94.5% female; *N* = 9 males) with a mean age of 18 years (range 15-24 years old). The majority of participants identified as being white British (59%), followed by Indian or British Indian (14.20%) and Pakistani or British Pakistani (10.80%). Finally, 21 participants (11.93%) reported being on a diet. Descriptive statistics for level 1 and level 2 variables are presented in Table 3-3.

The average number of snacks per day was similar in adolescents (*Mean* = 1.85, *SD* = 1.27) and young adults (*Mean* = 1.76, *SD* = 1.16). The young adults reported slightly more stressors per day on average (*Mean* = 1.58, *SD* = 1.20) compared to the adolescents (*Mean* = 1.26, *SD* = 1.09). Furthermore, young adults consumed more portions of fruit and vegetables on average per day (*Mean* = 3.31, *SD* = 2.25) than the adolescents (*Mean* = 1.88, *SD* = 1.67).

**Table 3-3. Descriptive statistics for level 1 (within-subjects) and level 2 (between-subjects) variables for whole sample and by age group.**

| Level and variables | Whole Sample | | Adolescents | | Young Adults | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| ***Level 1 Variables*** | | | | | | |
| Snacks / day | 1.79 | 1.21 | 1.85 | 1.27 | 1.76 | 1.16 |
| Stressors / day | 1.47 | 1.17 | 1.26 | 1.09 | 1.58 | 1.20 |
| Average stress intensity / day | 4.56 | 4.04 | 2.49 | 1.79 | 2.53 | 1.45 |
| Ego Threat Stressors / day | 0.06 | 0.25 | 0.08 | 0.27 | 0.05 | 0.23 |
| Interpersonal stressors / day | 0.28 | 0.53 | 0.26 | 0.51 | 0.30 | 0.55 |
| Work / Academic stressors / day | 0.52 | 0.71 | 0.64 | 0.82 | 0.45 | 0.64 |
| Physical Stressors / day | 0.59 | 0.80 | 0.37 | 0.64 | 0.71 | 0.85 |
| Other stressors / day | 0.16 | 0.44 | 0.06 | 0.25 | 0.22 | 0.51 |
| High Fat snacks | 0.29 | 0.50 | 0.31 | 0.51 | 0.28 | 0.49 |
| High sugar Snacks | 0.25 | 0.52 | 0.30 | 0.59 | 0.22 | 0.47 |
| High Both snacks | 0.54 | 0.69 | 0.67 | 0.72 | 0.46 | 0.66 |
| Low-to-medium Snacks | 0.72 | 0.85 | 0.57 | 0.80 | 0.81 | 0.86 |
| Portions of Fruit & Vegetables | 2.79 | 2.17 | 1.88 | 1.67 | 3.31 | 2.25 |
| ***Level 2 Variables*** | | | | | | |
| Age | 18.01 | 1.50 | 16.65 | 0.58 | 19.09 | 1.06 |
| BMI[2] | 22.29 | 3.27 | 21.85 | 3.98 | 22.48 | 2.92 |
| Puberty | 18.68 | 2.19 | 17.03 | 2.43 | 20.00 | 0.00 |
| Restrained Eating | 25.23 | 8.60 | 24.08 | 8.73 | 26.15 | 8.43 |
| Emotional Eating | 37.28 | 10.79 | 36.32 | 11.74 | 38.04 | 9.96 |
| External Eating | 34.29 | 5.72 | 34.17 | 6.23 | 34.39 | 5.31 |
| Conscientiousness | 31.25 | 6.16 | 31.31 | 6.48 | 31.20 | 5.93 |

[2] BMI was calculated for 127 participants (total) based on self-reported height and weight.

### 3.4.1 Level 1 Models for Total Sample: Total stress and eating outcomes

Models were used to investigate associations between total daily stress and number of snacks. Table 3-4 shows the results for total stress on snack consumption. Total stress was positively associated with total snacks ($\beta = 0.13$, $p < .001$). Total stress was also positively associated with high sugar snacks ($\beta = 0.04$, $p = .042$) and low-to-medium fat/sugar snacks ($\beta = 0.06$, $p = .046$). No effects were found between total stress and snacks high in fat only, or snacks high in both fat and sugar. Similarly, no effect was found between stress and portions of fruit and vegetable intake.

**Table 3-4. Level 1 analyses investigating stress and between meal snacks (including snack categories) and portions of fruit and vegetables.**

| Model and Variable | | β | Coefficient | SE | p |
|---|---|---|---|---|---|
| **Intercept:** | Total snacks | $\beta_{00}$ | 1.81 | 0.07 | <.001 |
| *L1 slope:* Total stress - total snacks | | $\beta_{10}$ | 0.13 | 0.03 | <.001 |
| **Intercept:** | High fat snacks | $\beta_{00}$ | 0.28 | 0.02 | <.001 |
| *L1 slope:* Total stress - high fat snacks | | $\beta_{10}$ | 0.02 | 0.01 | .207 |
| **Intercept:** | High sugar snacks | $\beta_{00}$ | 0.26 | 0.02 | <.001 |
| *L1 slope:* Total stress - high sugar snacks | | $\beta_{10}$ | 0.04 | 0.02 | .042 |
| **Intercept:** | High fat & sugar snacks | $\beta_{00}$ | 0.54 | 0.03 | <.001 |
| *L1 slope:* Total stress - high fat & sugar snacks | | $\beta_{10}$ | 0.01 | 0.02 | .652 |
| **Intercept:** | Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.73 | 0.04 | <.001 |
| *L1 slope:* Total stress - low-to-medium snacks | | $\beta_{10}$ | 0.06 | 0.03 | .046 |
| **Intercept:** | Fruit & vegetable intake | $\beta_{00}$ | 2.71 | 0.13 | <.001 |
| *L1 slope:* Total stress - fruit & vegetable intake | | $\beta_{10}$ | -0.07 | 0.06 | .202 |

Type of stress was also modelled against total snack intake (see Table 3-5 for results). Ego-threat stressors were positively associated with snack intake ($\beta$ = 0.31, $p$ = .017), as was work/academic stress ($\beta$ = 0.13, $p$ = .011). No associations were found between interpersonal, physical and other stress on snack intake.

**Table 3-5. Level 1 results of stress types on total snack intake.**

| Model and Variable | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| **Intercept:** Total snacks | $\beta_{00}$ | 1.81 | 0.07 | <.001 |
| *L1 slope:* Ego-threat stress - total snacks | $\beta_{10}$ | 0.31 | 0.13 | .017 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.81 | 0.07 | <.001 |
| *L1 slope:* Interpersonal stress - total snacks | $\beta_{10}$ | 0.09 | 0.06 | .125 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.81 | 0.07 | <.001 |
| *L1 slope:* Work/academic stress - total snacks | $\beta_{10}$ | 0.13 | 0.05 | .011 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.81 | 0.07 | <.001 |
| *L1 slope:* Physical stress - total snacks | $\beta_{10}$ | 0.07 | 0.05 | .147 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.81 | 0.07 | <.001 |
| *L1 slope:* Other stress - total snacks | $\beta_{10}$ | 0.03 | 0.06 | .566 |

### 3.4.2 Cross-level Models for Total Sample: Moderators of total stress and total snack intake

Cross-level models were used to identify potential moderating variables of total stress and total snack intake (see Table 3-6 for a summary of results). Analyses indicated no main effects for moderating variables (age, gender, eating style or conscientiousness) on total snack consumption. Furthermore, no moderating effects of age group or gender were found between total stress and total snacks. Similarly, the association between total stress and total snack intake was not moderated by any of the three eating styles (restraint, emotional or external eating). Finally, the analysis revealed that total stress and snack intake was significantly moderated by conscientiousness ($\beta$ = 0.02, $p$ = .015).

**Table 3-6. Moderating variables on total stress and total snack consumption.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 1.82 | 0.06 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.18 | 0.07 | <.001 |
| Age group – snacks | $\beta_{01}$ | -0.14 | 0.13 | .279 |
| Age group x stress -snacks | $\beta_{11}$ | -0.05 | 0.07 | .408 |
| Snacks | $\beta_{00}$ | 1.82 | 0.06 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.18 | 0.03 | <.001 |
| Gender – snacks | $\beta_{01}$ | -0.04 | 0.29 | .889 |
| Gender x stress -snacks | $\beta_{11}$ | -0.05 | 0.14 | .714 |
| Snacks | $\beta_{00}$ | 1.82 | 0.06 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.18 | 0.03 | <.001 |
| Restraint – snacks | $\beta_{01}$ | < -.001 | 0.008 | .964 |
| Restraint x stress -snacks | $\beta_{11}$ | < -.001 | 0.004 | .858 |
| Snacks | $\beta_{00}$ | 1.81 | 0.06 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.18 | 0.03 | <.001 |
| Emotional – snacks | $\beta_{01}$ | 0.004 | 0.006 | .528 |
| Emotional x stress -snacks | $\beta_{11}$ | 0.001 | 0.003 | .674 |
| Snacks | $\beta_{00}$ | 1.82 | 0.06 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.18 | 0.03 | <.001 |
| External – snacks | $\beta_{01}$ | 0.01 | 0.01 | .212 |
| External x stress -snacks | $\beta_{11}$ | -0.001 | 0.006 | .914 |
| Snacks | $\beta_{00}$ | 1.82 | 0.06 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.18 | 0.03 | <.001 |
| Conscientiousness – snacks | $\beta_{01}$ | 0.004 | 0.001 | .711 |
| Conscientiousness x stress - snacks | $\beta_{11}$ | 0.02 | 0.01 | .015 |

The simple slopes of the relationship between stress and eating at low (-31.25), mean (0) and high (31.25) levels of conscientiousness are illustrated in Figure 3-3. The slopes demonstrated that as total conscientiousness increased from low (*coefficient* = -0.20, *t(174)* = -1.83, *p* = .069), to the mean (*coefficient* = 0.14, *t(174)* = 4.02, *p* < .001), to high (*coefficient* = 0.65, *t(174)* = 2.92, *p* = .004) levels, the impact of stress on eating increased. Stress was significantly positively related to eating at mean and high levels of conscientiousness. Conversely, stress was negatively associated with eating at low levels of conscientiousness, however this effect was not significant.

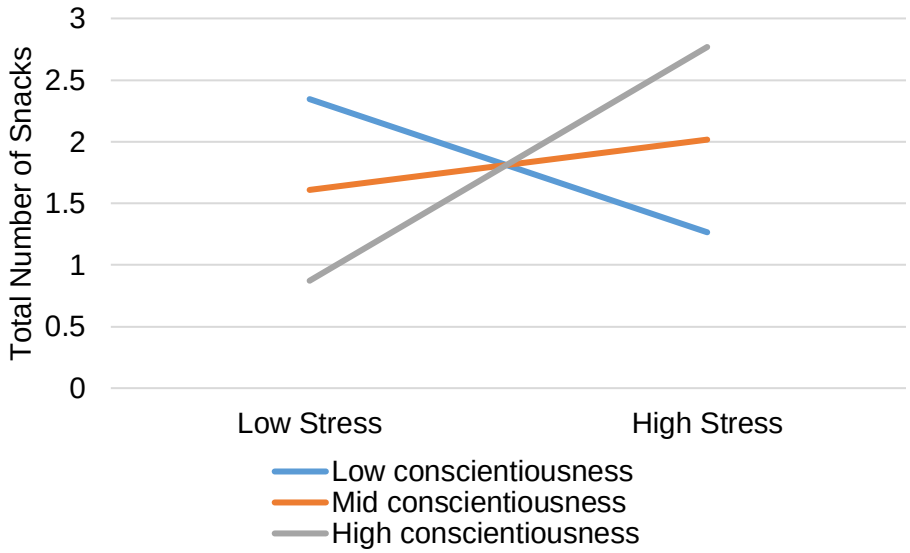


**Figure 3-3. Simple slope for the moderating effect of conscientiousness on total stress and total snack intake (whole sample).**

### 3.4.3 Level 1 Models for Adolescents: Total stress and eating outcomes

Analyses were conducted in adolescents and young adults separately to investigate the effect of daily stress on eating behaviours (see Table 3-7 for level 1 models in adolescents only). A significant, positive relationship was found between total stress and total snacks ($\beta = 0.15$, $p = .016$). Further level 1 models revealed that total stress was not associated with any of the snack sub-categories, although the interaction between total stress and low-to-medium fat and sugar snacks was trending towards significant ($\beta = 0.08$, $p = .052$).

**Table 3-7. Level 1 analyses in adolescents only investigating stress and between meal snacks (including snack categories) and portions of fruit and vegetables.**

| Model and Variables | | β | Coefficient | SE | p |
|---|---|---|---|---|---|
| **Intercept:** | Total snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 slope:* Total stress - total snacks | | $\beta_{10}$ | 0.15 | 0.06 | .016 |
| **Intercept:** | High fat snacks | $\beta_{00}$ | 0.29 | 0.04 | <.001 |
| *L1 slope:* Total stress - high fat snacks | | $\beta_{10}$ | 0.02 | 0.03 | .358 |
| **Intercept:** | High sugar snacks | $\beta_{00}$ | 0.31 | 0.04 | <.001 |
| *L1 slope:* Total stress - high sugar snacks | | $\beta_{10}$ | 0.03 | 0.03 | .278 |
| **Intercept:** | High fat & sugar snacks | $\beta_{00}$ | 0.65 | 0.05 | <.001 |
| *L1 slope:* Total stress - high fat & sugar snacks | | $\beta_{10}$ | 0.02 | 0.04 | .566 |
| **Intercept:** | Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.61 | 0.07 | <.001 |
| *L1 slope:* Total stress - low-to-medium snacks | | $\beta_{10}$ | 0.08 | 0.04 | .052 |
| **Intercept:** | Fruit & vegetable intake | $\beta_{00}$ | 1.89 | 0.15 | <.001 |
| *L1 slope:* Total stress - fruit & vegetable intake | | $\beta_{10}$ | -0.03 | 0.08 | .735 |

The type of stressor was modelled against total snack intake in adolescents (see Table 3-8 for level 1 models). The analyses indicated that the type of stress was not associated with total snack intake in adolescents. The strongest association was found between ego threatening stressors and total snacks ($\beta = 0.32$, $p = .093$) however this was not significant.

**Table 3-8. Level 1 results of stress types on total snack intake in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| **Intercept:** Total snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 slope:* Ego-threat stress - total snacks | $\beta_{10}$ | 0.32 | 0.19 | .093 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 slope:* Interpersonal stress - total snacks | $\beta_{10}$ | 0.19 | 0.13 | .146 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 slope:* Work/academic stress - total snacks | $\beta_{10}$ | 0.12 | 0.08 | .156 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 slope:* Physical stress - total snacks | $\beta_{10}$ | 0.03 | 0.10 | .777 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 slope:* Other stress - total snacks | $\beta_{10}$ | -0.01 | 0.20 | .962 |

### 3.4.4 Cross-level Models in Adolescents: Moderators of Total Stress and Total Snack Intake

The moderating effect of age, gender, restrained eating, emotional eating, external eating, and conscientiousness was investigated on total stress and total snack intake in adolescents (see Table 3-9 for cross-level models). The analyses did not find any moderating effects on total stress and total snack intake in adolescents.

**Table 3-9. Moderating variables on total stress and total snack consumption in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.16 | 0.06 | .014 |
| Age – snacks | $\beta_{01}$ | -0.10 | 0.21 | .626 |
| Age x stress -snacks | $\beta_{11}$ | -0.12 | 0.15 | .455 |
| Snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.16 | 0.06 | .014 |
| Gender – snacks | $\beta_{01}$ | 0.55 | 0.69 | .431 |
| Gender x stress -snacks | $\beta_{11}$ | 0.122 | 0.20 | .543 |
| Snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.16 | 0.06 | .014 |
| Restraint – snacks | $\beta_{01}$ | 0.01 | 0.01 | .486 |
| Restraint x stress -snacks | $\beta_{11}$ | -0.01 | 0.01 | .362 |
| Snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.16 | 0.06 | .014 |
| Emotional – snacks | $\beta_{01}$ | 0.01 | 0.01 | .401 |
| Emotional x stress -snacks | $\beta_{11}$ | -0.001 | 0.003 | .817 |
| Snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.16 | 0.06 | .014 |
| External – snacks | $\beta_{01}$ | 0.01 | 0.02 | .438 |
| External x stress -snacks | $\beta_{11}$ | -0.01 | 0.01 | .316 |
| Snacks | $\beta_{00}$ | 1.86 | 0.11 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.16 | 0.06 | .014 |
| Conscientiousness – snacks | $\beta_{01}$ | -0.002 | 0.02 | .895 |
| Conscientiousness x stress - snacks | $\beta_{11}$ | 0.01 | 0.01 | .326 |

### 3.4.5 Level 1 Models for Young Adults: Total Stress and Eating Outcomes

Analyses were conducted in young adults to investigate the effect of total stress and daily eating habits (see Table 3-10 for a summary of level 1 models). Similar to the adolescents, total stress was significantly associated with snack intake in young adults ($\beta = 0.13$, $p = .002$). Further analyses indicated that stress was not associated with the type of snacks consumed, nor daily intake of fruit and vegetables.

**Table 3-10. Level 1 analyses in young adults only investigating stress and between meal snacks (including snack categories) and portions of fruit and vegetables.**

| Model and Variable | | β | Coefficient | SE | p |
|---|---|---|---|---|---|
| **Intercept:** | Total snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 slope:* Total stress - total snacks | | $\beta_{10}$ | 0.13 | 0.04 | .002 |
| **Intercept:** | High fat snacks | $\beta_{00}$ | 0.28 | 0.03 | <.001 |
| *L1 slope:* Total stress - high fat snacks | | $\beta_{10}$ | 0.02 | 0.02 | .305 |
| **Intercept:** | High sugar snacks | $\beta_{00}$ | 0.22 | 0.02 | <.001 |
| *L1 slope:* Total stress - high sugar snacks | | $\beta_{10}$ | 0.04 | 0.02 | .086 |
| **Intercept:** | High fat & sugar snacks | $\beta_{00}$ | 0.46 | 0.04 | <.001 |
| *L1 slope:* Total stress - high fat & sugar snacks | | $\beta_{10}$ | 0.01 | 0.03 | .779 |
| **Intercept:** | Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.82 | 0.05 | <.001 |
| *L1 slope:* Total stress - low-to-medium snacks | | $\beta_{10}$ | 0.05 | 0.04 | .200 |
| **Intercept:** | Fruit & vegetable intake | $\beta_{00}$ | 3.31 | 0.17 | <.001 |
| *L1 slope:* Total stress - fruit & vegetable intake | | $\beta_{10}$ | -0.10 | 0.07 | .196 |

Associations between the type of stressors and total snack intake were investigated in young adults (see Table 3-11 for level 1 models). The analyses indicated that only work/academic stressors were significantly associated with total snack intake in young adults ($\beta = 0.05$, $p = .018$), although ego threatening stressors were trending towards significant ($\beta = 0.31$, $p = .063$).

**Table 3-11. Level 1 results of stress types on total snack intake in young adults.**

| Model and Variable | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| **Intercept:** Total snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 slope:* Ego-threat stress - total snacks | $\beta_{10}$ | 0.31 | 0.17 | .063 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 slope:* Interpersonal stress - total snacks | $\beta_{10}$ | 0.05 | 0.06 | .449 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 slope:* Work/academic stress - total snacks | $\beta_{10}$ | 0.14 | 0.06 | .018 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 slope:* Physical stress - total snacks | $\beta_{10}$ | 0.08 | 0.05 | .142 |
| **Intercept:** Total snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 slope:* Other stress - total snacks | $\beta_{10}$ | 0.04 | 0.06 | .517 |

### 3.4.6 Cross-level Models in Young Adults: Moderators of Total Stress and Total Snack Intake

Cross-level models were used to investigate moderating variables on stress and total snack intake in young adults (see Table 3-12 for all models). The analyses indicated that total stress and total snack intake was moderated by conscientiousness ($\beta = 0.02$, $p = .006$). Age, gender and eating style (restrained, emotional and external) were not found to moderate stress and snack intake, however a main effect of age and snack intake was found ($\beta = 0.17$, $p = .005$), where more snacks were reported in older participants compared to younger participants.

**Table 3-12. Moderating variables on total stress and total snack consumption in young adults.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.13 | 0.04 | .002 |
| Age – snacks | $\beta_{01}$ | 0.17 | 0.06 | .005 |
| Age x stress -snacks | $\beta_{11}$ | 0.05 | 0.04 | .241 |
| Snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.13 | 0.04 | .002 |
| Gender – snacks | $\beta_{01}$ | -0.34 | 0.19 | .081 |
| Gender x stress -snacks | $\beta_{11}$ | -0.32 | 0.28 | .262 |
| Snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.13 | 0.04 | .002 |
| Restraint – snacks | $\beta_{01}$ | -0.01 | 0.01 | .507 |
| Restraint x stress -snacks | $\beta_{11}$ | 0.01 | 0.01 | .230 |
| Snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.13 | 0.04 | .002 |
| Emotional – snacks | $\beta_{01}$ | 0.003 | 0.01 | .649 |
| Emotional x stress -snacks | $\beta_{11}$ | <-0.001 | 0.01 | .950 |
| Snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.13 | 0.04 | .002 |
| External – snacks | $\beta_{01}$ | 0.02 | 0.02 | .254 |
| External x stress -snacks | $\beta_{11}$ | 0.003 | 0.01 | .680 |
| Snacks | $\beta_{00}$ | 1.78 | 0.08 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.13 | 0.04 | .002 |
| Conscientiousness – snacks | $\beta_{01}$ | 0.002 | 0.01 | .849 |
| Conscientiousness x stress - snacks | $\beta_{11}$ | 0.02 | 0.01 | .006 |

The simple slopes of the relationship between stress and eating at low (-31.20), mean (0) and high (31.20) levels of conscientiousness in young adults are illustrated in Figure 3-4. The slopes indicate that as total conscientiousness increased from low (*coefficient* = -0.47, *t(96)* = -2.19, *p* = .031), to the mean (*coefficient* = 0.15, *t(96)* = 3.54, *p* < .001), to high (*coefficient* = 0.77, *t(96)* = 3.30, *p* = .001) levels, the impact of stress on eating increased.

More specifically, stress was significantly negatively related to eating at low levels of conscientiousness (where young adults who were lower in conscientiousness decreased their snack intake under conditions of high stress), and significantly positively related to eating at mean and high levels of conscientiousness (where young adults who were higher in conscientiousness increased their snack intake under conditions of high stress compared to low stress).

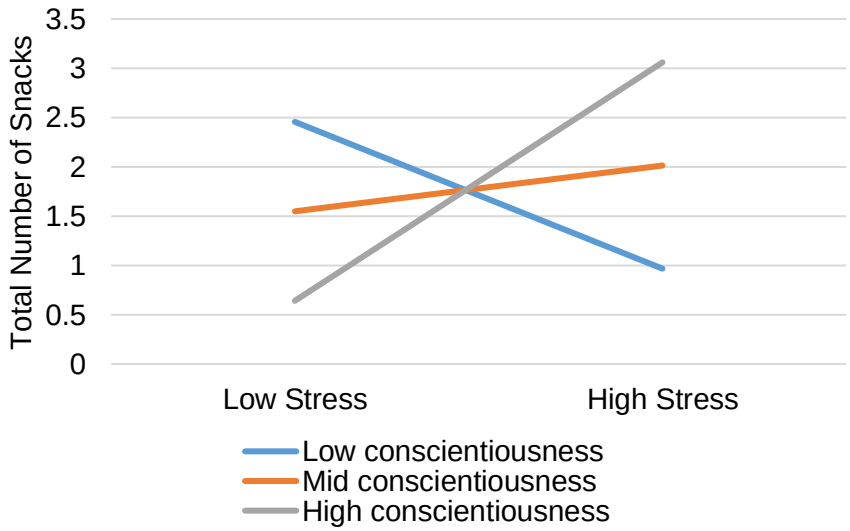


**Figure 3-4. Simple slopes for conscientiousness on stress and total snack intake in young adults.**

## 3.5 Discussion

The aim of this daily diary study was to identify current patterns in stress-related eating behaviours in adolescents and young adults. The study aimed to determine whether stress and eating habits were similar across adolescents and young adults, as well as identify potential moderating variables on this relationship.

This study found that daily stress was positively associated with daily snack consumption. Specifically, total stress was associated with increased intake of high sugar snacks, and snacks low-to-medium in fat and sugar content across the whole sample. In contrast, total stress was not associated with snacks only high in fat, or snacks which were high in both fat and sugar. These findings are in line with those of the two meta-analyses presented in Chapter 2 which found that stress was associated with greater intake of unhealthy, HELN foods. However, an association was not found between stress and high fat snacks, or snacks high in both fat and sugar. This is contrary to previous studies which have found that stress is positively associated with fat and sugar intake (Newman et al., 2007; Ng & Jeffery, 2003; Roberts et al., 2014) however, in this study, the effect was only found in unhealthy foods which were high in sugar. These findings are in keeping with previous theories that HELN foods are used as a maladaptive form of coping when experiencing stress (Tryon et al., 2013).

This study also found that stress was positively associated with the consumption of healthier snacks (i.e., those low-to-medium in fat and sugar content) across all participants, whilst no effect was found between stress and fruit and vegetable consumption. When analysed in adolescents and young adults separately, these significant effects were not observed, possibly as a result of low power. The findings from the two meta-analyses identified that stress was negatively associated with the consumption of healthy foods, although this effect was less clear in adolescents. Similarly, research has found that stress is associated with reduced consumption of fruit and vegetables in both adults (O'Connor et al., 2008; Wallis & Hetherington, 2009) and adolescents (Hong & Peltzer, 2017), where stress has been suggested to be a barrier to healthy eating (Unusan, 2006). However, a meta-analysis in children aged 8 to 18 years old did

not find an association between stress and healthy food intake (Hill et al., 2018). In the present study, it is likely that an effect was not found because self-reported intake of fruit and vegetables was already very low, particularly in adolescents who reported consuming on average less than two portions per day. Fruit and vegetable consumption are often reported to be lower than recommended guidelines in adolescents, with as many as 70% of adolescents eating less than 5 portions per day (Huang et al., 2019). Taken together, these findings highlight the need to encourage better dietary behaviours in adolescents and young adults, as these poorer health behaviours, such as increased consumption of high sugar snacks and low intake of fruit and vegetables, may be enhanced under conditions of stress.

In line with previous research, this study found that the type of stressor experienced was differentially associated with snack intake. Specifically, ego threatening, and work/academic stressors were associated with increased consumption of snacks across the whole sample. Further analyses showed a significant effect of work/academic stressors and snack intake in young adults, but not in adolescents. Similarly, ego threatening stressors were strongly associated with snack intake in young adults, although this interaction was not significant. These findings are corroborated by previous research in samples of adults, which have found that ego-threatening stressors (O'Connor et al., 2008) and those with an element of social evaluation (such as stress induction paradigms) elicit much stronger stress responses, and may be more likely to result in changes to normal eating behaviours (Dickerson & Kemeny, 2004). Similarly, work related stressors have been associated with changes to eating habits in adults (O'Connor et al., 2008). Based on the findings from the current study, it appears that the number of stressors experienced (and not the type) is a key predictor of snack intake in adolescents, whilst the type of stressor is an important factor for stress-eating associations in young adults.

In contrast, the current study found no effect of physical, interpersonal or other stressors on snack intake. This is contrary to some studies which have found that physical stressors were associated with decreased consumption of

snacks, and interpersonal stressors were associated with increased snack intake (O'Connor et al., 2008).

Moderation analyses revealed that there was no effect of age on stress and snack intake across the whole sample, with analyses indicating strong associations between stress and snack intake in adolescents and young adults separately. Taken together, these findings suggest that stress-related eating habits are similar throughout emerging adulthood from the ages of 15 to 24 years. This supports the findings of the two meta-analyses presented in Chapter 2, which found associations between stress and the type of food consumed were similar across studies using both adolescents and adults. Furthermore, these findings support previous reviews which suggest that stress-related eating habits may form in children as young as 8 years old (Hill et al., 2018).

Previous research has highlighted the importance of understanding health behaviours in emerging adulthood (Ames et al., 2018; Boyce & Kuijer, 2015; Hu et al., 2016; Watts et al., 2016), where increased autonomy over food choice and maintaining norms within peer groups around eating habits (Koehn, Gillison, Standage, & Bailey, 2016) may facilitate choices towards unhealthy foods when stressed, rather than healthier choices. Understanding patterns and moderators of stress-related eating behaviours in emerging adulthood can inform future research to reduce this maladaptive eating behaviour.

This study also investigated the moderating role of eating style on stress and snack intake. Analyses indicated that eating style (dietary restraint, external and emotional eating) did not moderate stress and snack intake in neither adolescents nor young adults. Mean values for these eating styles were similar to those reported in previous research (for example Conner et al., 1999). This finding is contrary to previous literature which has found that individual differences in levels of dietary restraint (Roberts et al., 2007), external (Conner et al., 1999) and emotional eating (Wallis & Hetherington, 2004) can moderate stress and eating behaviours, including objectively measured stress (Newman et al., 2007).

Similarly, fewer snacks per day were reported in the current study compared to previous, daily diary studies investigating stress-eating associations

(O'Connor et al., 2009; O'Connor et al., 2008; O'Connor, Armitage, & Ferguson, 2015) which may, in turn, influence the likelihood of detecting an effect of potential moderating variables. Aside from these differences with daily diary studies, the moderating effect of eating style on stress and eating behaviours has not been consistently reported in previous literature (Lai et al., 2012; Newman et al., 2007; O'Connor & O'Connor, 2004; Van Strien et al., 2009).

This study did, however, find a moderating effect of conscientiousness on stress and snack intake across the whole sample. Further analyses indicated that the moderating effect of conscientiousness on the daily stress to daily snack intake relationship was specific to young adults and was not found in adolescents. Simple slopes analyses indicated that stress-eating associations were greater in young adults who were higher in conscientiousness compared to individuals who were lower in this personality trait. Interestingly, the direction of this interaction is contrary to some previous research, which have reported that higher levels of conscientiousness are associated with reduced stress-related eating behaviours in adults (O'Connor et al., 2009; O'Connor & O'Connor, 2004; Steptoe et al., 2017) and fewer stress-related health problems (Ferguson, 2013). Similarly, in a sample of adolescents, Macchi et al. (2017) found that higher impulsivity (a factor within conscientiousness, where higher impulsivity represents lower conscientiousness) when making decisions was associated with unhealthy eating behaviours.

However, there are findings to suggest that highly conscientious individuals may experience more stressors than those lower in this trait, and consequently engage in more stress-eating behaviours. For example, in a longitudinal study of 236 medical students in Norway, Tyssen et al. (2007) found that high conscientiousness was associated with greater stress, independent of other personality factors. They suggested that individuals higher in conscientiousness were at greater risk of experiencing stress compared to individuals lower in this trait, who were protected against stress. Similarly, O'Connor et al. (2009) found that higher levels of conscientiousness was associated with greater stress and more smoking and caffeine consumption. Theories have posited that individuals higher in conscientiousness are better at

coping with stressors (Penley & Tomaka, 2002) as they may adopt problem focused responses (Bartley & Roesch, 2011; Watson & Hubbard, 1996). However, the findings of the current study suggest that highly conscientious young adults may use maladaptive health behaviours, such as eating more between meal snacks, as a method of coping with stress compared to those lower in this trait. In contrast, this study also highlighted that the moderating effect of conscientiousness on stress-eating associations was not present in adolescents.

These inconsistencies in findings regarding the moderating role of conscientiousness on stress-related eating habits may be due to individual differences on the lower order facets of this personality trait (Roberts, Chernyshenko, Stark, & Goldberg, 2005). For example, Gartland et al. (2012) found that the facets of order and industriousness moderated the experience of stress. Furthermore, these lower order facets have also been found to moderate stress-related eating behaviours. Low levels of self-efficacy have been associated with reduce fruit and vegetable intake when experiencing stress (O'Connor et al., 2009). Therefore, based on the findings of the current study, further research should focus on the facets of conscientiousness to understand individual differences in stress-related eating behaviours in adolescents and young adults.

## 3.6 Conclusions

This study aimed to address some of the gaps in the literature identified in Chapter 2. At present, there is limited research on stress-related eating behaviours in adolescents. The current study addressed this gap in the literature and built on previous research to investigate whether stress-eating associations in adolescents were comparable to those of young adults. The findings of the current study suggest that stress and eating habits are similar across emerging adulthood, however differences exist in the moderating variables on this relationship.

Specifically, conscientiousness was found to moderate stress-eating associations, however only in young adults. Although conscientiousness can provide insights into differences in health behaviours, research has suggested

that its lower order facets may provide greater insights into individual differences in health behaviours, including stress-related eating, compared to measures of total conscientiousness. This may explain the differences between adolescents and young adults in the current sample. Based on these findings, the study outlined in Chapter 4 aimed to investigate this moderating effect further using total conscientiousness, as well as its six lower order facets.

Similarly, although no moderating effects of eating styles were found on stress and eating habits, they should not be dismissed from future research. Currently, there is limited research on stress-related eating in adolescents, with fewer studies investigating moderating variables on this association. Previous research on the moderating effect of eating styles in samples of adults has been mixed (see section 1.6.2 for a summary of findings), and may be partly due to methodological differences between studies. Therefore, although an association was not found in this study, eating styles should still be considered in stress-eating relationships.

Finally, a gap in the literature still exists regarding the use of objective measures of stress. The findings from Chapter 2 identified few studies which have utilised objective measures of stress to investigate the role of cortisol reactivity on stress-eating associations. Therefore, Chapter 4 aimed to address this gap in the literature by combining subjective, daily stress with objective measures (through saliva and hair samples) to investigate the role of cortisol reactivity on stress-related eating habits in emerging adulthood.

# Chapter 4
# Investigating the role of cortisol in stress and eating habits across emerging adulthood

## 4.1 Introduction

The findings from Chapter 3 indicate that stress is associated with changes to the eating behaviours of adolescents and young adults. Specifically, the daily diary study found that increased stress was associated with increased intake of high sugar snacks. This is in line with previous research, which has found a small, but significant effect of stress on unhealthy food consumption in adults and adolescents (see Chapter 2 for a meta-analysis). Interestingly, the study presented in Chapter 3 found no association between stress and healthy food consumption. Although previous research has found negative associations between stress and healthy food consumption in adults (Lyzwinski et al., 2018; Torres & Nowson, 2007), it is evident that stress does not influence healthy eating habits in the same way across children (Hill et al., 2018) and throughout emerging adulthood. The findings from Chapter 3 highlighted that daily intake of healthy foods, particularly fruit and vegetables, were very low in both adolescents and young adults. Therefore, it is likely that an effect was not found between stress and healthy food consumption because this age group are eating few portions of fruit and vegetables daily (and less than recommended levels).

Finally, the study investigated several moderating variables thought to influence the strength of associations between stress and food intake. Of the six moderators investigated (age, gender, conscientiousness, restrained, emotional and external eating), an effect was only found on conscientiousness, where individuals higher in this trait reported more daily stressors and a greater intake of between-meal snacks compared to individuals lower in this trait. Specifically, the moderating effect of conscientiousness was only found in young adults, and not in adolescents.

Whilst the daily diary study addressed some of the gaps in the literature which were identified in the two meta-analyses (see Chapter 2 for more details),

there still exists a gap for studies using objective measures of stress, particularly cortisol sampling, in stress-eating behaviours across emerging adulthood. Although daily diaries are useful in documenting the subjective experience of daily stress, cortisol sampling can provide greater insights into an individual's physiological response to stress (see section 1.6.1 for a summary of research) and its associations with health (Feder et al., 2009).

Experiencing a stressor results in activation of the HPA axis, increasing circulating glucocorticoids in the body, including cortisol (Ulrich-Lai & Herman, 2009), which can be used as a biomarker of stress (DeRijk & de Kloet, 2008). Saliva sampling is often used to determine individual differences in physiological functioning as it is a relatively non-invasive approach. Furthermore, saliva sampling enables biologically active cortisol to be collected, which is unbound to carrier proteins (Törnhage, 2009).

Previous research investigating cortisol reactivity (i.e., physiological response to an acute stressor) have demonstrated that individual differences in the physiological response of the HPA axis can moderate stress-eating associations. Broadly, two patterns of cortisol reactivity have been identified in previous research; a heightened (where circulating cortisol increases following a stressor) and a blunted profile (where cortisol remains low or unchanged following a stressor). These patterns of cortisol reactivity have not only been associated with differences in health behaviours but have also been found to moderate stress-eating associations.

In a sample of adults, Newman et al. (2007) reported that individuals who were considered to be high reactors (i.e., had increasing cortisol in response to a stressor) consumed a greater number of snacks compared to those with a low or unaltered cortisol response. Similarly, Epel et al. (2001) found that women with heightened cortisol reactivity consumed more food following a stress-induction task compared to women with a blunted response. Appelhans et al. (2010) reported a similar effect, however this was specific to women with obesity (and was in women with healthy weight).

Interestingly, similar effects have been reported in samples of children. Michels et al. (2013) found that children (median age 8.4 years) with a steeper

cortisol reactivity profile (i.e., a heightened response) ate more snacks and fatty foods compared to children with blunted cortisol responses. This same pattern has also been found in children, even in the absence of hunger (Francis et al., 2013).

However, this finding has not been consistently reported in previous research. For instance, Tryon et al. (2013) found high chronic stress, but low cortisol reactivity, was associated with a greater food intake following a stress-induction task. Furthermore, variability in findings may be due to methodological issues regarding measured food intake following stress-induction tasks. For example, in a meta-analysis, Robinson, Hardman, Halford, and Jones (2015) found that laboratory-based food intake studies can increase participants' awareness of their behaviours and can subsequently lead to reduced food intake. Therefore, the current study aimed to investigate the role of cortisol reactivity on daily stress-eating associations using self-reported dairies.

The current study aimed to assess cortisol reactivity in response to a group stress-induction task. There are a number of stress-induction tasks which have been used to elicit a stress response, including the Maastricht Acute Stress Task (MAST; Smeets et al., 2012) which combines a physical stimuli with mental arithmetic to produce a stress response via stimulation of the sympathetic nervous system, increased blood pressure (al'Absi, Petersen, & Wittmers, 2002) and skin conductance (Buchanan, Tranel, & Adolphs, 2006). However, cortisol responses to physical stressors have been found to be modest (al'Absi et al., 2002; Gluck, Geliebter, Hung, & Yahav, 2004) or unchanging (McRae et al., 2006).

In contrast, stress tasks which include an element of social evaluation, such as the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), have been found to elicit strong reactivity of the HPA axis and circulating cortisol. In a meta-analysis of stress-induction tasks, Dickerson and Kemeny (2004) reported that combining a stressor with a social evaluation element produced the largest cortisol response with the longest recovery following the stress test, compared to tasks that did not include an element of social evaluation. Aside from eliciting a stronger physiological response, social evaluation tasks such as the TSST are

easier to conduct outside of laboratory environments as they require less equipment compared to tasks which incorporate a physical stressor. Furthermore, a variation of the TSST (referred to as the Group Trier Social Stress Task; TSST-G) has been developed by Von Dawans, Kirschbaum, and Heinrichs (2011) which enables groups of up to 6 participants to be tested together, opposed to participants being tested singularly. Based on the effectiveness of the TSST to elicit a physiological response, as well as the advantage of group testing, the TSST-G was used in the current study to elicit stress-responses in adolescents (aged 16-18 years old, recruited from local sixth forms and colleges) and young adults.

The study aimed to include a second, objective measure of stress using hair cortisol. In contrast to saliva samples (which indicate momentary circulating cortisol levels), hair samples can provide a measure of tonic cortisol levels over the past few weeks or months (Steptoe et al., 2017). Aside from providing a reliable measure of chronically occurring stress (Russell, Koren, Rieder, & Van Uum, 2012; Sauvé, Koren, Walsh, Tokmakejian, & Van Uum, 2007), hair cortisol concentrations are free from acute, momentary variations which can occur in saliva samples, such as changes in mood (Stalder et al., 2017).

Previous research has found associations between hair cortisol concentrations (HCC) and health. For example, HCC has been associated with differences in health behaviours such as physical activity and smoking (Wosu, Valdimarsdóttir, Shields, Williams, & Williams, 2013). Similarly, elevated HCC has been linked to poorer health outcomes, including depression (Abell et al., 2016) and increased body adiposity (Jackson, Kirschbaum, & Steptoe, 2017). Research on HCC and eating habits is currently limited however, like cortisol reactivity to stress, differences in HCC may be associated with deviations to eating habits. For example, Steptoe et al. (2017) found a negative association between hair cortisol concentrations and fruit and vegetable intake. However, it should be noted that, whilst both measures use cortisol, saliva and hair cortisol provide insights into two distinct physiological responses (i.e., saliva indicates acute stress reactivity whilst hair provides a marker for chronic activation of the

HPA axis). As such, potential effects on both eating behaviours and the stress-eating relationship would be anticipated due to these methodological differences.

Interestingly, Miller et al. (2007) suggest that objective and subjective measures of stress should be combined in research due to the complex nature of the HPA axis and individual variability in the experience of stress. Furthermore, combining objective measures of stress with daily diaries can provide greater insights into day-to-day variations in stress and eating habits (O'Connor et al., 2008) as opposed to either method used in isolation (Stalder et al., 2017). Therefore, this study aimed to combine objective measures of stress (saliva and hair samples) with daily stress and eating habits.

Finally, the present study aimed to investigate the role of moderating variables on cortisol and stress-eating associations in adolescents and young adults. Previous research has highlighted several moderating variables which are thought to influence stress-related eating habits in adults (see section 1.6 for a summary of moderating variables). However, the findings from Chapter 3 found that, of six moderating variables, only conscientiousness moderated daily stress and snack intake, and this was specific to young adults. Furthermore, this effect was contrary to some previous literature (see section 1.6.4 for a summary of research findings), as young adults who were higher in conscientiousness reported more stressors and greater intake of between-meal snacks compared to young adults who were low in this personality trait.

Although conscientiousness has been associated with differences in health behaviours (Bogg & Roberts, 2004; Hagger-Johnson et al., 2012; O'Connor et al., 2009), research has suggested that the lower order facets of conscientiousness may be more predictive of health outcomes, compared to measures of overall conscientiousness. For example, in a meta-analysis, Kern and Friedman (2008) found that the lower order facets of achievement and order had the strongest associations with longevity, compared to other facets such as responsibility.

Similarly, Sutin, Stephan, and Terracciano (2018) investigated facets of conscientiousness on objective markers of health. They found that self-control, responsibility and organisation were associated with lower adiposity, better

physical assessments and healthier outcomes on cardiovascular, metabolic and inflammatory indices, compared to traditionalism and virtue, both of which had fewer associations with these biological markers.

Overall conscientiousness has been associated with differences in physiological markers of stress. In a sample of adults, Steptoe et al. (2017) reported that individuals higher in conscientiousness had on average lower HCC compared to those lower in this trait. However, the effect of lower order facets on objective and subjective stress-eating associations is yet to be determined. Therefore, the current study aimed to determine the moderating effect of conscientiousness, and its lower order facets, on stress-eating associations in emerging adulthood.

Furthermore, the current study aimed to investigate the moderating role of eating styles (dietary restraint, emotional and external eating) on stress-eating associations across emerging adulthood. Similarly, the current study aimed to investigate factors around eating behaviours, including hunger, disinhibition and cognitive restraint of eating. Eating styles have previously been associated with differences in stress-related eating behaviours in adults (see section 1.6.2 for a summary of research), however these factors are under-researched in samples of adolescents. Although no effects of eating styles were found in Chapter 3, the current study aimed to investigate the moderating effect of eating styles on objective and subjective stress-eating associations.

Consequently, the current study aimed to investigate the role of emotion regulation, specifically cognitive reappraisal and expressive suppression, on stress-related eating habits in emerging adulthood. Previous research has found moderating effects of emotional eating on stress and food intake (see section 1.6.2 for a summary of research), however the study presented in Chapter 3 did not find a moderating effect of emotional eating on daily stress and snack intake in either adolescents or young adults. Evers et al. (2010) suggest that strategies employed to regulate emotions can provide greater insights into individual differences in eating behaviours compared to general measures of emotions, such as emotional eating styles. Using an emotion-induction task, Evers et al. (2010) found that individuals high in emotion suppression consumed more food

compared to individuals who rated lower in emotion suppression. Therefore, the current study aimed to investigate eating styles, along with emotion regulation, to understand individual differences in stress-eating associations across emerging adulthood.

## 4.2 Aims and Objectives

The current study aimed to address the gap in the literature highlighted in Chapter 2 by combining objective and subjective measures of stress. Specifically, this study aimed to investigate stress reactivity (using saliva cortisol), chronically occurring stress (using HCC) along with self-reported daily stressors and eating habits across emerging adulthood.

Similarly, this study aimed to build on the findings presented in Chapter 3 to understand stress-eating associations in adolescents and young adults, in addition to moderating variables of this relationship.

More specifically, the study aimed to determine the role of cortisol reactivity (using a stress-induction task) on daily stress and eating behaviours in adolescents and young adults. Previous research has found differences in cortisol reactivity profiles and eating habits; however, these findings are specific to adult samples, and are yet to be researched in adolescents. Additionally, the current study aimed to determine the effect of chronically occurring stress (through HCC) on daily stress and eating habits across emerging adulthood.

Finally, this study aimed to investigate the moderating role of eating styles, emotion regulation and conscientiousness on stress-eating associations across emerging adulthood.

## 4.3 Method

### 4.3.1 Design and Participants

The study aimed to recruit 75 adolescents aged 16-18 years and 75 young adults aged 18-25 years. The appropriate sample size was determined by the availability of funding for cortisol sampling and sample sizes of previous research (see Chapter 2 for a summary of research). Participants were eligible for the study if they were ≥ 16 years and were English speaking. As outlined in section 3.3.1, participants were asked to note any previous or existing disordered eating behaviours and were excluded from analyses. Similarly, participants were asked to note any specialist diets and/or medical conditions which involved dietary restrictions. This variable was controlled for in analyses. Finally, due to the nature of the stress-induction task, participants who disclosed experiencing anxiety, or anxiety-related mental health problems (including post-traumatic stress disorder), were not eligible to participate and were screened out of the study.

Adolescents were recruited from local sixth forms/colleges in Leeds. Teachers were initially approached using formal letters and were followed up with a phone call and/or email invitation. Twenty-one sixth forms/colleges were approached, in addition to four youth clubs. Of these 25 sources, six expressed an interest in taking part in the study; 3 declined the invitation and 16 did not reply. Half of the sixth forms/colleges interested in taking part were involved with the study. Two of the schools were too far away to recruit from, whilst one school could not take part due to time constraints. Therefore, adolescents were recruited from three local sixth forms/colleges. Finally, one participant was recruited via an open day at the University of Leeds and completed the study at the School of Psychology. To encourage involvement, the same incentives for schools were used as those outlined in section 3.3.1.

All participants provided written consent prior to taking part in the study. Participants aged 16 and 17 years were given an information pack for parents / adults in loco parentis which outlined the study aims, tasks and provided details on how to withdraw their child's consent. A total of 66 adolescents consented to take part in the study and completed the initial questionnaire and stress task (see

Figure 4-1 for a flow diagram of participant retention). Three participants were excluded due to violations to the stress-task protocol, with a further 3 excluded due to completing no diaries on time. Finally, one participant was excluded for existing or previous disordered eating, leaving 59 adolescents included in the study. For their participation, adolescents who had completed the initial questionnaire, stress task and at least one daily diary received a £5 Love2shop voucher.

The same method of recruitment outlined in section 3.3.1 was used for young adults. A total of 83 young adults initially signed up to take part in the study, of which 70 completed the initial questionnaire and stress-induction task. From this, three participants disclosed existing or previous disordered eating and were excluded from analyses. A further three participants were excluded; one for violations during the stress task, one for completing insufficient daily diaries and one due to insufficient data across all four saliva samples. The resulting sample size for young adults was 64.

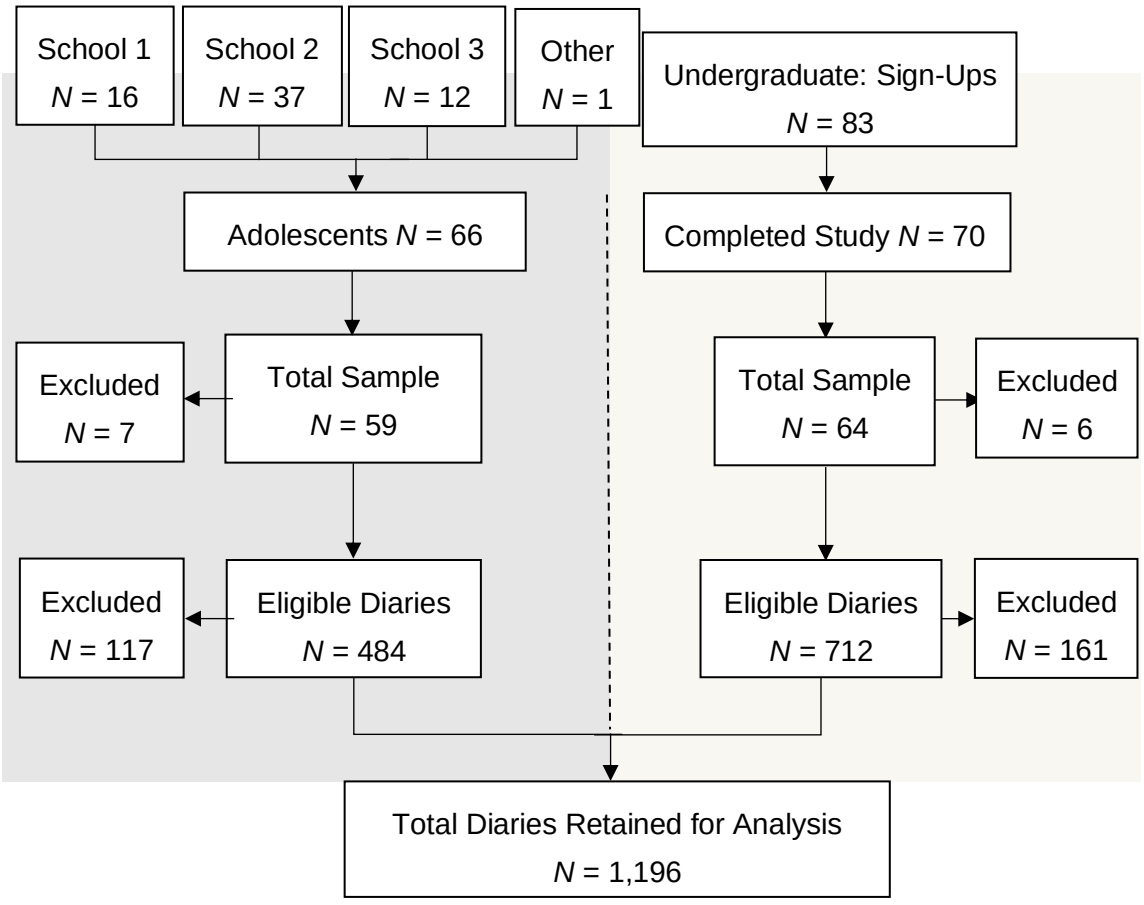


**Figure 4-1. Flow diagram of participant retention and number of diary days completed following exclusions.**

### 4.3.2 Procedure

Adolescents were approached in sixth forms/colleges and were given an information sheet outlining the study aims. Testing sessions were arranged with teachers, and participants who expressed an interest in taking part were scheduled to attend a testing session in school. Young adults were recruited through the School of Psychology participant pool scheme, where participants signed up to attend a scheduled testing session which took place at the University of Leeds. For their participation, young adults received up to 14 course credits depending on their level of engagement with the study.

All testing sessions (for both adolescents and young adults) were scheduled to take place between 1pm and 3pm, and participants were asked not to consume any food at least one hour prior to the session. This was to ensure that the saliva samples were not invalidated by time differences in normal diurnal cortisol patterns, or by fluctuations in circulating cortisol caused by food consumption near to the sampling period (Kudielka, Broderick, & Kirschbaum, 2003). Prior to taking part in the study, participants were asked to read through the study information sheet and complete a screening questionnaire to assess their eligibility.

After providing written consent, participants provided the first of four saliva samples, 10 minutes prior to starting the stress task. After providing the first saliva sample, participants were required to complete the group Trier Social Stress Task (TSST-G) as outlined by Von Dawans et al. (2011) with groups of up to six participants (see section 4.3.2.2 for further details on the stress task and sampling procedure). Saliva samples were taken at three time points subsequent to the task, at 0 minutes, 10 and 40-minutes following completion of the TSST-G. During this sampling period following the TSST-G, participants were asked to complete the baseline questionnaire on paper. The baseline questionnaire included questions regarding demographics, personality traits and eating behaviours (see section 4.3.2.1 below for further details).

Following this first part of the study, participants were asked to complete an online daily diary from home for 14 consecutive days. Depending on their

preference, participants received either an email or a text message reminder each evening at 9pm with a link to the diary. The daily diaries were the same as those outlined in Chapter 3 (details are included in section 3.3.3.1). The diary recorded any hassles experienced throughout the day and recorded their eating behaviours. Participants were instructed to complete the diary just before going to bed each evening to allow participants to record any stressors or eating behaviours which may have occurred after reminders had been sent. At the end of the diary period, participants were invited to meet with the researcher for information regarding the hair sampling procedure (full details of the hair sampling procedure are included in section 4.3.2.4). Adolescents at school were met as a group, whilst young adults met individually with the researcher at the university. In this follow up, participants were given an information sheet outlining the hair sampling procedure, including the method of taking samples, quantity of hair taken, and example images of hair samples. All participants were asked to complete a brief feedback form outlining their views on providing hair samples for research. Finally, participants who were willing to provide hair samples completed a questionnaire regarding their hair care before two samples were taken.

Participants were de-briefed after all participants had completed the study. This was to ensure that potential participants were unaware of the nature of the stress task. Participants were sent an online de-brief sheet which outlined the study aims, nature of the stress task and details on how to withdraw their data if required. Ethical approval was received via the School of Psychology Research Ethics Committee on 23/02/2017 (reference number 17-0077) with an amendment accepted on 19/10/2017 (reference number 17-503).

#### 4.3.2.1 Initial Questionnaire

The initial questionnaire gained information on participant demographics (age, gender, BMI), conscientiousness (and its lower order facets), eating styles (restrained, external, emotional) and emotion regulation (suppression and reappraisal). Additionally, a dichotomous question regarding smoking (*'Do you smoke?'* followed by *'If yes, when did you last smoke?'*) was also included to ensure that the effects of nicotine could be controlled for in analysis for the saliva cortisol samples, as research has found that smoking can alter normal cortisol

levels (Badrick, Kirschbaum, & Kumari, 2007; Direk, Newson, Hofman, Kirschbaum, & Tiemeier, 2011; Steptoe & Ussher, 2006). The following measures for conscientiousness, eating styles and emotion regulation were included in the initial questionnaire.

#### 4.3.2.1.1 Conscientiousness

The Chernyshenko Conscientiousness Scale (Chernyshenko, 2003) is a 60-item questionnaire used to measure conscientiousness and its six lower order facets of Industriousness, Traditionalism, Order, Virtue, Self-Control and Responsibility (Hill & Roberts, 2011). The questionnaire includes 10 items per subscale. Using a 5-point Likert scale from *'Very Inaccurate'* to *'Very Accurate',* participants indicated the extent to which the item presented an accurate description of themselves. Higher scores in the Chernyshenko Conscientiousness Scale (CSS) reflect an increased degree of trait conscientiousness and the corresponding facets.

Roberts et al. (2005) described the six facets as the following. Industriousness reflects being hardworking and ambitious (example item: *'I have high standards and work towards them'*). Traditionalism refers to the maintenance of societal rules and customs as well as having respect for authority (example item: *'In my opinion, all laws should be strictly enforced'*). Order reflects planning ahead, organisation and tidiness (example item: *'Organization is a key component of most things I do'*). Virtue is the propensity to be honest and moral (example item: *'I firmly believe that under no circumstances it is okay to lie'*). Self-control is the extent to which one is restrained and patient, being able to delay gratification and not act impulsively (example item: *'I rarely jump into something without first thinking about it'*). Finally, Responsibility reflects the propensity to be cooperative, dependable and to help others (example item: *'I go out of my way to keep promises'*). The CSS has previously been reported to have high internal consistency overall (α = .80) as well as for each of the six lower order facets with an *α* value ranging from .76 to .88 (Gartland et al., 2012). Similarly, in the current sample, internal validity was high overall (α = .91) and for the six lower order facets (α = .65 to .86). In young adults, internal consistency was high for total conscientiousness (α = .91) and across the lower order facets (range α = .67 to

.90). Similarly, internal consistency remained high for total conscientiousness in adolescents (α = .92), although values were slightly lower across the six facets (range α = .63 to .82). The scale has also been found to have good construct validity, predicting (amongst others) health and work behaviours (Chernyshenko, 2003; Chernyshenko, Stark, Drasgow, & Roberts, 2007).

#### 4.3.2.1.2 Emotion Regulation

Developed by Gross and John (2003) the Emotion Regulation Questionnaire (ERQ) aims to assess how individuals differ in regulating their emotions. The 10-item questionnaire uses a 7-point Likert scale (from strongly disagree to strongly agree) to measure two strategies of emotion regulation; cognitive reappraisal and expressive suppression. Cognitive reappraisal is a strategy whereby changes in thought are used to change current emotional state. To measure this, the ERQ contains six items, which include *'I control my emotions by changing the way I think about the situation I'm in'.* In contrast, expressive suppression involves inhibiting expressive behaviours which are associated with a given emotion (Gross, 1998). This emotion modulation strategy is measured using four items, for example *'I control my emotions by not expressing them'*. Scores across the items are summed and the average calculated for the two emotion regulation strategies.

The scale has been found to have on average a high level of test-retest reliability (Gross & John, 2003), determined over a three month period (*α* = .69 for both scales) and a high degree of internal consistency for both expressive suppression (*α* = .73) and cognitive reappraisal (*α* = .79). Internal reliability was fair in the current study across the whole sample for expressive suppression (*α* = .75) and cognitive reappraisal (*α* = .76). Reliability for these two scales was high across both adolescents (expressive suppression *α* = .76; cognitive reappraisal *α* = .77) and young adults (expressive suppression *α* = .74; cognitive reappraisal *α* = .74).

#### 4.3.2.1.3 Dutch Eating Behavior Questionnaire (DEBQ)

The Dutch Eating Behavior Questionnaire (DEBQ) was included in the initial questionnaire for the current study (Van Strien et al., 1986). Details of this

scale are described in section 3.3.3. Internal consistency was found to be high across restrained (whole sample $\alpha$ = .91; adolescents $\alpha$ = .88; young adults $\alpha$ = .92), emotional (whole sample $\alpha$ = .93; adolescents $\alpha$ = .94; young adults $\alpha$ = .92), and external eating styles (whole sample $\alpha$ = .88; adolescents $\alpha$ = .89; young adults $\alpha$ = .86) for the whole sample, and by age groups separately.

#### 4.3.2.2 The Group Trier Social Stress Task (TSST-G)

The procedure for the TSST-G followed that outlined by (Von Dawans et al., 2011), and the study protocol is included in Appendix Item 8. Two separate rooms were used to complete the study. One room was used to complete all aspects of the study expect the TSST-G whilst the TSST-G was set up and completed in a separate room to minimise anticipatory stress prior to the first saliva sample (Wetherell, Lovell, & Smith, 2015).

Participants were asked to refrain from eating an hour prior to the study starting as eating and drinking before saliva samples can degrade cortisol levels through dilution (Kudielka et al., 2003). The materials used for collecting saliva samples were obtained from Salimetrics. Participants were given individual packs with four SalivaBio oral swabs and four pre-labelled swab storage tubes. Prior to the sampling period, participants were given a demonstration on how to safely use the swabs, which were placed under the tongue for a minimum of 2 minutes per sample, after which they were placed into the corresponding tube number for each sample. At the end of each testing session, the samples were frozen at -20°C in a secure room at the University of Leeds. Finally, the saliva samples were transported on dry ice via a private courier to Anglia Ruskin University for assay. Cortisol levels were determined using a competitive Enzyme-Linked Immunosorbent Assay kit (ELISA).

After providing a baseline saliva sample (taken 10 minutes prior to the TSST-G) participants were verbally presented with a scenario whereby they were asked to convince a panel of two body language experts why they are the best candidate for a hypothetical job. Additionally, they were informed of a second task, however, were told that instructions for this task would be given after the speech task had been completed. They were also informed that the talk would be video recorded so that their non-verbal behaviours could be analysed. The two

panel members were not experts and were formed of either undergraduate or postgraduate research students from the University of Leeds.

After receiving the instructions, participants were given five minutes to prepare their talk, however they were informed that they were not permitted to use any notes during their talk. At the end of the preparation period, participants were allocated a random number from 1 to 6 (or less depending on the size of the group) before being led to a separate room which was arranged in a standardised format for each testing session as previously outlined by Kirschbaum et al. (1993) and Von Dawans et al. (2011). A schematic illustration by Von Dawans et al. (2011) is presented below (Figure 4-2). In the current study, only one video recorder was used.

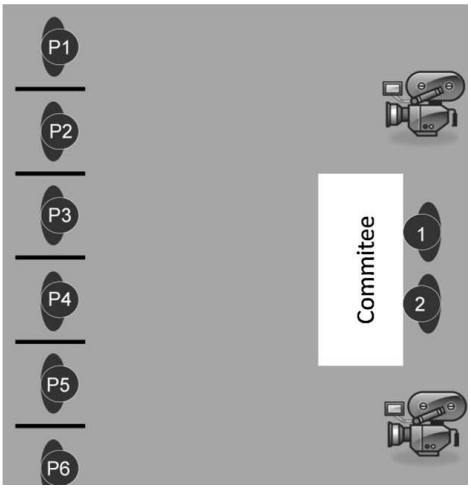


**Figure 4-2. Schematic illustration of the set up for the TSST-G, taken from Von Dawans et al., (2011).**

Participants were asked to sit in their allocated seat number and were informed by the researcher that the panel would randomly select each participant to give their talk. Participants were instructed to stand in front of the panel when their number was called, and to begin their talk. After receiving these instructions, the researcher turned on the video camera and seated themselves to the side of the participants before the panel proceeded to select participants for their talks. Unbeknown to the participants at the time, the video camera was not actively

recording, and served to elicit a strong response from the HPA axis through social evaluation.

When selected, participants were required to talk for a duration of two minutes. If they stopped before this time, a panel member would inform them that they have time left to continue. If participants stopped a second time before the end of the two-minute period, the panel would wait for 20 seconds before asking a pre-determined question from a list outlined in the study protocol.

After all participants had given their talk, they were presented with instructions for a mental arithmetic (serial subtraction) task. Using a different, random order, participants were asked to stand in front of the panel and count aloud, backwards in stages of 16 from a given starting number. Participants were interrupted and asked to start again when an error was made. The serial subtraction task lasted 80 seconds per participant.

Once all participants had completed the mental arithmetic task, they were taken back to the initial study room. The second saliva sample was taken immediately after the TSST-G (+0 minutes), with a further two taken 10 and 40 minutes following the completion of the stress-induction task.

All participants were fully debriefed about the nature of the project once the study had obtained the required sample size. This was to reduce the chance that new participants would have prior knowledge about the stress task which may not have elicited as strong a cortisol response. Following the completion of the study, participants were informed video recording was not used to analyse their body language or facial expressions and served only to elicit stress through social evaluation. Additionally, the study debrief informed the participants that the panel members were not experts in body language.

#### 4.3.2.3 Daily Diary Measures

After completing the TSST-G and the baseline questionnaire, participants were asked to complete an online daily diary for 14 consecutive days. The daily diaries were the same as those used in Chapter 3. The diaries recorded daily stressors, between-meal snacks and portions of fruit and vegetables, which were coded into type of stressors (coded as either ego-threatening, interpersonal,

work/academic, physical or other), type of snacks (coded as either high in fat, high in sugar, high in fat and sugar, or low-to-medium in fat and sugar content) and total fruit and vegetable intake (for full details on the measures and coding, see section 3.3.3.1).

Cohen's kappa (Cohen, 1960) was calculated to determine level of agreement on coding for stressors and between-meal snacks. A minimum of 10% of stressors were second coded by an independent researcher (total stressors *N* = 1,950; second coded *N* = 208). Agreement was high for the coding of stressors overall ($\kappa$ = .73), with good to moderate agreement on the stress categories; ego threatening ($\kappa$ = .81), interpersonal ($\kappa$ = .86), work/academic ($\kappa$ = .89), physical ($\kappa$ = .59), and other ($\kappa$ = .53). One possible reason for the lower agreement levels for physical and other stressors may be due to the description of the stressors provided by participants being ambiguous and lacking in detail to determine a clear category. Disagreements in the coding of stressors were discussed between the reviewers and an agreement reached.

Similarly, between-meal snacks were second coded by the same independent researcher (total snacks *N* = 2,415; second coded *N* = 250). Agreement levels were high for the overall coding of snacks ($\kappa$ = .84), and for snack categories separately; high fat ($\kappa$ = .85), high sugar ($\kappa$ = .80), high fat and sugar ($\kappa$ = .88) and low-to-medium fat and sugar ($\kappa$ = .81).

#### 4.3.2.4 Hair Sampling Procedure

All participants were invited to meet the researcher at the end of the daily diary period. During this follow up session, participants were asked to read through the information sheet which outlined why hair samples were used in the current study, how the samples were taken and how much hair was required for analysis (see Appendix Item 9 for the hair sampling information sheet). The information sheet was designed to answer anticipated questions and potential barriers participants may have around providing hair samples in research. After reading through this information sheet, participants were encouraged to ask questions regarding hair sampling.

Following this, participants completed a brief feedback form on their opinions of giving hair as part of research, including any barriers they may have,

how likely they would be to provide hair (using a 5 point scale from *Very Unlikely* to *Very Likely*) and any information which they would like to know which was not addressed in the information sheet. The feedback form provided qualitative information on facilitators and barriers to providing hair samples as part of a research study.

Following this, participants were given the opportunity to provide two small hair samples (~25mg) for the current study provided their hair was at least 2cm long from the scalp. Those who did not wish to provide hair samples were given their reimbursement for taking part (a £5 Love2shop vouchers or course credits) and informed that the study de-brief would be sent via email and/or text message once the study had recruited all participants.

Participants who consented to providing hair samples were asked to complete a short questionnaire regarding their hair care habits to obtain information about any colouring or bleaching, washing and product use in the last 24 hours, month and 3 months, although a recent study did not find associations between frequency of hair washing or dying on HCCs in women (Kristensen, Larsen, Olsen, Fahrenkrug, & Heitmann, 2017). Similarly, participants were asked to note any medications they were taking as some medications can influence circulating hormones such as cortisol.

Following this, the researcher sectioned the hair and tied two samples (using linen thread) at the medial posterior vertex area of the head. Taking the samples from the medial posterior vertex served two purposes; the first to reduce variability in HCCs which may result in samples taken from different areas of the head (Sauvé et al., 2007) and secondly to reduce noticeability after sample were taken (for participants with long hair). The participant was asked again if they were happy to provide the samples before cutting the hair close to the scalp. Samples were marked to indicate which end of the sample was closest to the scalp prior to sealing in foil envelopes.

Hair samples were stored securely in a locked cabinet, in the same room as the saliva samples. Hair samples are more robust than saliva samples, and so can be kept at room temperature for extended periods of time (Russell et al., 2012). Samples were trimmed to 1cm, which typically reflects a one-month period

retrospectively (Sauvé et al., 2007). At the end of the data collection period, the samples were sent to Anglia Ruskin University for assay. Hair cortisol was measured using an ELISA kit.

A total of 41 participants were willing to provide hair samples for the present study, however four participants were excluded; 2 due to violations in the TSST-G protocol, one for an existing/previous eating disorder, and one for having HCCs being below the limit of detection for both hair samples. Therefore, HCC data were analysed on the remaining 37 participants.

### 4.3.3 Analytical Method

A total of 136 participants completed the initial questionnaire, of which 132 also completed the TSST-G (4 participants were excluded due to violations to the stress-task protocol). Participants were included in the study if they had completed at least one daily diary on time (i.e., before 3am, and not backfilled). A total of 1,474 diaries were initially recorded, of which 230 were removed due to backfilling (15.6%) resulting in the exclusion of four participants.

A further 48 diaries were removed due further exclusions; four participants were excluded from the study due to disclosing existing or previous disordered eating, one participant was excluded due to insufficient saliva cortisol across all four samples. A total of 278 daily diaries were excluded from the study (18.8%), leaving 1,196 for analysis, with a sample size of 123 participants (59 adolescents and 64 young adults). The breakdown of diary completion rates is presented in Figure 4-3 below.

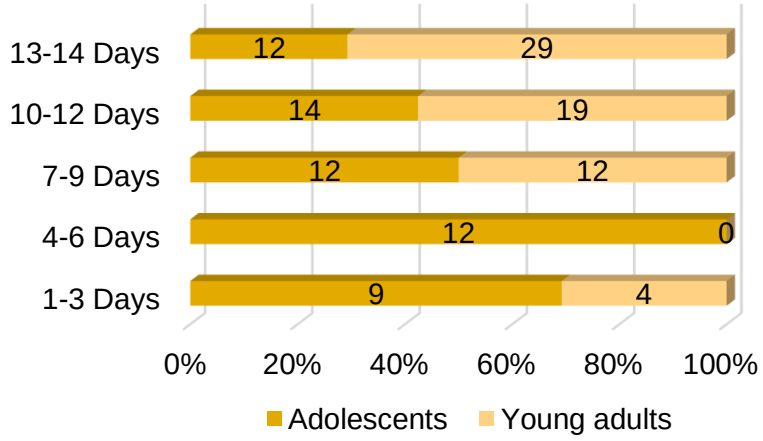


**Figure 4-3. Breakdown of diary completion rates for adolescents and young adults.**

MANOVAs were conducted to compare the differences between participants included and excluded in the study. Analyses indicated no differences between included and excluded participants on age, total conscientiousness, eating styles (restraint, emotional, external) or emotion regulation (suppression and reappraisal). Furthermore, analyses indicated no differences on saliva (AUCg and AUCi) and hair cortisol concentrations between included and excluded participants.

A Chi-Square Test of Independence (McHugh, 2013) was used to compare gender differences between included and excluded participants. As the assumption for the Chi-Squared was violated (where 25% had an expected count of < 5) the Likelihood Ratio was used. The analysis indicated no significant difference of gender between participants included and excluded in the study (*Likelihood Ratio* = 0.024, *df* = 1, *p* = .878).

#### 4.3.3.1 Missing Data

Similar to Chapter 3, missing data were analysed on the initial questionnaire (level 2 data), and daily diaries (level 1 data).

In the initial questionnaire, there was a high percentage of missing data for the smoking variable (at 14.6%), however this was due to the question being added to the initial questionnaire after the start of recruitment. Participants with missing data on this variable were coded as being non-smokers, due to their age (i.e., under the legal age of smoking) and based on the valid data on this variable (i.e., very few smokers in the sample).

Missing data ranged from 0% to 17.9% across conscientiousness subscales, eating style and emotion regulation items (total missing 1.10%). The highest level of missing values was due to an item being omitted from the questionnaire which was subsequently added during the recruitment phase of the study. Little's MCAR test was not significant, indicating that the data were missing completely at random in the initial questionnaire, $\chi^2$ *(4,066)* = 1263.62, *p* = 1.00 (Schlomer et al., 2010). The same method of treating missing data was employed as that outlined in section 3.3.4.1, where missing data were imputed using series mean of participants responses on subsequent items of each scale.

Missing data was also assessed in the daily diaries on two eating outcomes; portions of fruit and vegetables. Missing data ranged from 0.9% to 1.3% (total missing 1.14%). Little's MCAR test indicated that the data were missing completely at random, $\chi^2$ *(2)* = 0.24, *p* = .887 (Schlomer et al., 2010). Missing data were imputed using the series mean for each participant on these two variables separately.

#### 4.3.3.2 Treatment of Cortisol Data

***Saliva Cortisol***

The mean inter-assay coefficient variation between duplicate repeats was 3.92% (range from 0% to 28.55%). The coefficient variation was high for 8 samples, however the difference between duplicates was within an accepted range (0.03 µg/dL). Prior to analysis, salivary cortisol data was converted from µg/dL to nmol/L and assessed for missing data and outlying values. Missing data were calculated at each of the four measurement points, where missing data ranged from 1.16% (for baseline and +0 minutes following TSST-G) to 4.1% (at +10 minutes after the TSST-G). The mean of missing data across all sampling points was 3.25%. Little's Missing Completely at Random (MCAR) test was not significant, indicating that the data was missing completely at random, $\chi^2$ *(16)* = 24.58, *p* = .078 (Schlomer et al., 2010). Therefore, missing values were imputed with the sample mean value for each time point.

The data was then assessed for outliers and anomalies. Outliers were identified where values exceeded 2.5 standard deviations above the sample mean for each time point, as these values were likely a result of participant illness, violation to protocol during collection or technical problems during assay (Smith et al., 2018). A total of 12 samples were identified as being outliers (2.44%), where 2 high values were found at the baseline sampling time point (-10 minutes), 3 at +00 minutes, 3 at +10 minutes and 4 at +40 minutes following completion of the TSST-G. These outlying values were truncated (i.e., winsorized) to 2.5 standard deviations above the mean for each time point (Schlotz, 2011).

Similarly, outliers were identified where values were <1nmol/l, as these values were likely the result of violations to the sampling procedure, or were

anomalies in the data set (Starr, Dienes, Li, & Shaw, 2019). Three samples were identified as having extreme, low cortisol concentrations, one at +00 minutes and two samples at +40 minutes following the TSST-G. Due to the limited number of low outlying values in the data set, these extreme values were replaced with the mean value for that sampling point.

Following this, two measures of the Area Under the Curve (AUC) were calculated following procedures outlined in previous research (Gartland, O'Connor, Lawton, & Bristow, 2014; O'Connor, Walker, Hendrickx, Talbot, & Schaefer, 2013) using the formula by Pruessner, Kirschbaum, Meinlschmid, and Hellhammer (2003). The time between sample 1 and 2 (i.e., the sample before and immediately following the TSST-G) was calculated for each group of participants. This was because the duration of the TSST-G was variable depending on the number of participants in each group, where times ranged from 10 minutes to 35 minutes (see Table 4-1 below for a summary elapsed time between sample 1 and 2).

**Table 4-1. Differences in time elapsed between cortisol sample 1 and 2, as a function of group size.**

| Group size | Average time between sample 1 and sample 2 | Range |
|---|---|---|
| 1 | 10 minutes | 10 minutes |
| 2 | 15.33 minutes | 14-18 minutes |
| 3 | 17.33 minutes | 13-20 minutes |
| 4 | 22.55 minutes | 20-24 minutes |
| 5 | 26.70 minutes | 25-29 minutes |
| 6 | 30.55 minutes | 29-35 minutes |

Firstly, AUC with respect to ground (AUCg) was calculated to indicate total cortisol response throughout the TSST-G using the following equation:

$$AUCg = \sum_{i=1}^{n-1} \frac{(m(i+1) + m_i) \cdot t_i}{2}$$

where differences in time between sampling points $\cdot\, t_i$ were accounted for in the change in cortisol between measurement points$(m(i+1) + m_i)$.

In contrast, AUC with respect to increase (AUCi) was used as an indicator of the HPA axis reactivity with values reflecting change in cortisol levels as a result of the stress task. The following equation (based on that for AUCg) was used to calculate AUCi:

$$AUCi = \left(\sum_{i=1}^{n-1} \frac{(m(i+1) + m_i) \cdot t_i}{2}\right) - \left(m_i \cdot \sum_{i=1}^{n-1} t_i\right)$$

where the total time elapsed across the sampling period was accounted for along with the baseline cortisol response $\left(m_i \cdot \sum_{i=1}^{n-1} t_i\right)$ to provide total cortisol reactivity against baseline cortisol levels in response to the TSST-G only. A Pearson's correlation was used to determine the association between AUC measures. The analysis indicated a positive correlation between AUCg and AUCi ($r$ = .684, $p$ < .001), where higher AUCg was associated with higher AUCi.

***Hair cortisol***

Hair cortisol concentration (pg/mg) was analysed for 37 participants included in the study using Enzyme-Linked Immunosorbent Assay (ELISA). Samples were trimmed to 1cm from the scalp end to reflect HCCs from the previous month. Overall, there was missing data for 7 samples (10.15% of all samples) due to cortisol levels being below the limit of detection at assay. Little's MCAR was not significant, indicating that the data was missing in a completely random way, $\chi^2$ *(2)* = 5.41, $p$ = .067, (Schlomer et al., 2010).

Unlike the saliva samples, hair samples were assayed in singulate (i.e., cortisol concentrations were obtained from each sample only once), therefore Pearson's correlation was used to ensure values were similar across the two

samples. Analyses indicated a strong correlation between HCC (pg/mg) across the two hair samples for each participant, $r$ = 0.84, $p$ <.001, indicating that HCC readings were reliable.

Where data was available on both samples, the mean of the two samples was calculated and used in analysis. Single data points were used where participants had one HCC reading. Variations in HCC resulting from sample weight were treated statistically prior to analyses (i.e., sample weight was controlled for in HCC calculations). Higher values reflected greater levels of HCC over the previous month.

#### 4.3.3.3 Method of Analysis

This study followed the same method of analysis as outlined in Chapter 3 (see section 3.3.4 for details on method of analysis), where descriptive statistics for level 1 and level 2 variables were obtained using SPSS (IBM Corporation, 2017). Following this, hierarchical multi-linear models were created in HML 7 (Raudenbush et al., 2011) to match within-person data (i.e., daily stress and eating behaviours) with between-person data (i.e., demographics, eating styles, conscientiousness, cortisol reactivity and HCC).

The data was initially modelled using a single level structure based on the following model;

$$Level\ 1: \quad \gamma_{ij} = \beta 0_j + \beta_{1j}\,(stress) + r_{ij}$$

where $\gamma_{ij}$ reflects within-person variability in the eating behaviour outcome across diary days for person ($i$ and $j$ respectively). $\beta 0_j$ represents the intercept and $\beta_{1j}$ represents the model slope estimates for the stress measure. Finally, $r_{ij}$ represents the error for daily measures and $\gamma$ represents the structural coefficient associated with the level 1 model.

Cross-level models were carried out to investigate the possible moderating effect of age group, gender, eating style and conscientiousness on overall stress and between-meal snack consumption based on the following equation;

$$\textit{Level 1:} \qquad \gamma_{ij} = \beta 0_j + \beta_{1j}\,(stress) + r_{ij}$$

$$\textit{Level 2:} \qquad \beta_0 = \gamma_{00} + \gamma_{01}\,(age\ group)$$
$$\beta_1 = \gamma_{10} + \gamma_{11}\,(age\ group)$$

where $\beta_0$ represents the main effect between the eating outcome ($\gamma_{00}$ - in this case between-meal snack consumption) and the moderating variable ($\gamma_{01}$) of age group. Finally, $\beta_1$ represents the potential moderating effect between all variables in the model. Unstandardized coefficients from HML analyses have been reported. Finally, Preacher's calculator (Preacher & Kelley, 2011) was used to create simple slope plots displaying the cross-level interactions to investigate moderating effects. Prior to conducting Preacher's calculator, moderating variables and stress measures were mean centred to produce standardised plots.

Finally, smoking and group size of the TSST-G were compared against saliva cortisol measures (AUCg and AUCi) to determine whether these factors should be controlled for in analyses. Similarly, presence of medications and frequency of hair washing were initially modelled against HCCs to determine whether these variables influenced HCC and should be controlled for in subsequent analyses.

## 4.4 Results

A total of 123 participants completed the study (59 adolescents and 64 young adults), with 1,196 individual diary entries. The sample was predominately female (*N* = 102; 83% and 21 males) with a mean age of 17.93 years (range 16-22 years). Most participants identified as being White British (*N* = 85; 69%) followed by Black African (*N* = 4; 3.3%). BMI was calculated based on self-reported height and weight in 81 participants who had complete data on both height and weight measures. The mean BMI for the sample was 22.57kg/m$^2$ (range 14.76 to 37.25 kg/m$^2$). Finally, 3 participants reported being on a specialist

diet (2.4%) and 16 participants reported being smokers (13%). Descriptive statistics for level 1 and level 2 variables are presented in Table 4-2.

Overall, participants reported experiencing <2 stressors per day (mean = 1.63) and eating on average two between-meal snacks per day (mean = 2.02). Young adults reported slightly more stressors per day (mean = 1.88) than adolescents (mean = 1.26), along with greater perceived intensity of daily stressors (young adults = 5.79; adolescents = 4.03). The types of between-meal snacks consumed, and types of stressors experienced were similar across the two age groups, although young adults reported more physical stressors (mean = 0.65) compared to adolescents (mean = 0.32). Finally, young adults reported eating more portions of fruit and vegetables per day (mean = 3.34) than adolescents (mean = 2.10).

Adolescents and young adults were similar on average on total conscientiousness and emotional and external eating styles. Young adults scored higher on average on restrained eating style (mean = 27.50) than adolescents (mean = 22.78). For cortisol measures, young adults had on average greater AUCg (mean = 453.38 nmol/L) and HCC (mean = 8.05 pg/mg) compared to adolescents (AUCg = 426.15 nmol/L; HCC = 6.52 pg/mg). In contrast, young adults exhibited reduced cortisol response to the TSST-G (AUCi = 55.81 nmol/L) compared to adolescents (AUCi = 138.41 nmol/L).

**Table 4-2. Descriptive statistics of whole sample and age groups for level 1 (within-subjects) and level 2 (between-subjects) variables.**

| Level and variables | Whole Sample | | Adolescents | | Young Adults | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| *Level 1 Variables* | | | | | | |
| Snacks / day | 2.02 | 1.43 | 1.97 | 1.56 | 2.05 | 1.34 |
| Stressors / day | 1.63 | 1.26 | 1.26 | 1.17 | 1.88 | 1.26 |
| Average stress intensity / day | 5.08 | 4.36 | 4.03 | 4.29 | 5.79 | 4.26 |
| Ego Threat Stressors / day | 0.15 | 0.40 | 0.15 | 0.41 | 0.15 | 0.39 |
| Interpersonal stressors / day | 0.30 | 0.55 | 0.23 | 0.49 | 0.35 | 0.58 |
| Work / Academic stressors / day | 0.71 | 0.80 | 0.68 | 0.82 | 0.72 | 0.78 |
| Physical Stressors / day | 0.52 | 0.83 | 0.32 | 0.67 | 0.65 | 0.89 |
| Other stressors / day | 0.28 | 0.54 | 0.20 | 0.45 | 0.34 | 0.58 |
| High Fat snacks | 0.36 | 0.63 | 0.39 | 0.66 | 0.35 | 0.60 |
| High Sugar Snacks | 0.28 | 0.53 | 0.30 | 0.58 | 0.27 | 0.50 |
| High Both snacks | 0.57 | 0.69 | 0.59 | 0.73 | 0.55 | 0.66 |
| Low-to-medium Fat and Sugar Snacks | 0.81 | 1.00 | 0.69 | 1.03 | 0.88 | 0.97 |
| Portions of Fruit & Vegetables | 2.84 | 2.22 | 2.10 | 2.00 | 3.34 | 2.23 |
| *Level 2 Variables* | | | | | | |
| Age | 17.93 | 1.38 | 16.80 | 0.69 | 18.98 | 0.97 |
| BMI[3] | 22.57 | 4.03 | 22.84 | 4.43 | 22.40 | 3.78 |
| AUCg | 440.37 | 237.39 | 426.15 | 255.75 | 453.38 | 220.35 |
| AUCi | 95.43 | 230.49 | 138.41 | 238.37 | 55.81 | 217.37 |
| Hair Cortisol Concentration[4] | 7.47 | 2.79 | 6.52 | 3.07 | 8.05 | 2.50 |
| Total Conscientiousness | 206.08 | 25.74 | 208.06 | 26.73 | 204.25 | 24.86 |
| Restrained Eating | 25.24 | 8.68 | 22.78 | 7.99 | 27.50 | 8.73 |
| Emotional Eating | 35.28 | 11.68 | 34.30 | 12.67 | 36.19 | 10.71 |
| External Eating | 33.76 | 7.33 | 32.41 | 7.96 | 35.01 | 6.51 |
| Reappraisal | 29.00 | 5.69 | 28.12 | 5.87 | 29.81 | 5.43 |
| Suppression | 15.43 | 5.22 | 16.59 | 5.15 | 14.36 | 5.08 |

[3] BMI was calculated for 81 participants (total; 32 adolescents and 49 young adults) based on self-reported height and weight.

[4] Hair samples were obtained for 37 participants (14 adolescents and 23 young adults).

### 4.4.1 Level 1 Models for Total Sample: Total Stress on Eating Behaviours

Level 1 models were initially used to investigate associations between daily stress and between-meal snack consumption (see Table 4-3 for a summary of results). Analyses indicated that stress was positively associated with total snacks ($\beta = 0.18$, $p < .001$). Furthermore, total stress was also positively associated with low-to-medium fat/sugar snacks ($\beta = 0.10$, $p < .001$). No effects were found between total stress and snacks high in fat only, high in sugar only, high in fat and sugar, or portions of fruit and vegetables across the whole sample.

**Table 4-3. Summary of level 1 results for stress and between-meal snack intake (including snack categories), and portions of fruit and vegetables.**

| Model and Variables | | β | Coefficient | SE | p |
|---|---|---|---|---|---|
| **Intercept:** | Total snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 slope:* Total stress - total snacks | | $\beta_{10}$ | 0.176 | 0.041 | <.001 |
| **Intercept:** | High fat snacks | $\beta_{00}$ | 0.376 | 0.031 | <.001 |
| *L1 slope:* Total stress - high fat snacks | | $\beta_{10}$ | 0.011 | 0.023 | .628 |
| **Intercept:** | High sugar snacks | $\beta_{00}$ | 0.274 | 0.025 | <.001 |
| *L1 slope:* Total stress - high sugar snacks | | $\beta_{10}$ | 0.026 | 0.015 | .084 |
| **Intercept:** | High fat & sugar snacks | $\beta_{00}$ | 0.567 | 0.033 | <.001 |
| *L1 slope:* Total stress - high fat & sugar snacks | | $\beta_{10}$ | 0.038 | 0.021 | .077 |
| **Intercept:** | Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.812 | 0.065 | <.001 |
| *L1 slope:* Total stress - low-to-medium snacks | | $\beta_{10}$ | 0.099 | 0.029 | <.001 |
| **Intercept:** | Fruit & vegetable intake | $\beta_{00}$ | 2.703 | 0.155 | <.001 |
| *L1 slope:* Total stress - fruit & vegetable intake | | $\beta_{10}$ | 0.030 | 0.046 | .509 |

The type of stressor was modelled against total snack intake (see Table 4-4 for a summary of results). Analyses indicated that ego-threatening stressors were positively associated with total snack intake ($\beta = 0.23$, $p = .020$), as was work/academic stress ($\beta = 0.19$, $p < .001$). No associations were found between interpersonal, physical or other stressors on total snack intake across the whole sample.

**Table 4-4. Summary of level 1 results for type of stress on total snack intake (whole sample).**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| **Intercept:** Total snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 slope:* Ego-threat stress - total snacks | $\beta_{10}$ | 0.226 | 0.096 | .020 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 slope:* Interpersonal stress - total snacks | $\beta_{10}$ | 0.101 | 0.071 | .157 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 slope:* Work/academic stress - total snacks | $\beta_{10}$ | 0.186 | 0.053 | <.001 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 slope:* Physical stress - total snacks | $\beta_{10}$ | 0.097 | 0.055 | .080 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 slope:* Other stress - total snacks | $\beta_{10}$ | 0.073 | 0.069 | .292 |

### 4.4.2 Cross-level Models for Moderators of Total Stress and Total Snack Intake (Whole Sample)

The moderating effect of level two variables on total stress and total snack intake were investigated using cross-level models (see Table 4-5 and Table 4-6 for results). Analyses indicated no main effects of age group, gender, emotion regulation (reappraisal and suppression) or total conscientiousness on total snack consumption. Similarly, these variables did not moderate total stress and total snack intake overall across the whole sample.

**Table 4-5. Summary of results for moderating variables (age, gender, emotion regulation and total conscientiousness) on total stress and total snack consumption.**

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.180 | 0.042 | <.001 |
| Age group – snacks | $\beta_{01}$ | 0.021 | 0.191 | .911 |
| Age group x stress -snacks | $\beta_{11}$ | -0.048 | 0.085 | .573 |
| Snacks | $\beta_{00}$ | 1.712 | 0.347 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.284 | 0.152 | .064 |
| Gender – snacks | $\beta_{01}$ | 0.274 | 0.304 | .369 |
| Gender x stress -snacks | $\beta_{11}$ | -0.097 | 0.132 | .464 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.174 | 0.042 | <.001 |
| Reappraisal – snacks | $\beta_{01}$ | 0.006 | 0.019 | .735 |
| Reappraisal x stress -snacks | $\beta_{11}$ | -0.005 | 0.006 | .434 |
| Snacks | $\beta_{00}$ | 2.032 | 0.093 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.174 | 0.041 | <.001 |
| Suppression – snacks | $\beta_{01}$ | -0.026 | 0.018 | .148 |
| Suppression x stress -snacks | $\beta_{11}$ | -0.006 | 0.007 | .379 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.177 | 0.042 | <.001 |
| Conscientiousness – snacks | $\beta_{01}$ | 0.002 | 0.004 | .602 |
| Conscientiousness x stress - snacks | $\beta_{11}$ | <-.001 | 0.002 | .789 |

The moderating effect of facets of conscientiousness was investigated (see Table 4-6 for results). Analyses indicated no main effects of the six facets of conscientiousness on total snack intake. Similarly, no moderating effects were found on any of the facets for total stress and total snack intake across the whole sample.

**Table 4-6. Summary of results for the moderating effect of facets of conscientiousness on total stress and total snack consumption.**

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.175 | 0.042 | <.001 |
| Order – snacks | $\beta_{01}$ | -0.002 | 0.011 | .839 |
| Order x stress -snacks | $\beta_{11}$ | -0.008 | 0.005 | .105 |
| Snacks | $\beta_{00}$ | 2.031 | 0.093 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.177 | 0.042 | <.001 |
| Virtue – snacks | $\beta_{01}$ | 0.020 | 0.016 | .196 |
| Virtue x stress -snacks | $\beta_{11}$ | <-0.001 | 0.006 | .919 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.176 | 0.041 | <.001 |
| Traditionalism – snacks | $\beta_{01}$ | 0.006 | 0.018 | .754 |
| Traditionalism x stress - snacks | $\beta_{11}$ | 0.004 | 0.008 | .586 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.178 | 0.042 | <.001 |
| Self-control – snacks | $\beta_{01}$ | 0.004 | 0.015 | .793 |
| Self-control x stress -snacks | $\beta_{11}$ | -0.006 | 0.006 | .323 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.174 | 0.042 | <.001 |
| Industriousness – snacks | $\beta_{01}$ | 0.001 | 0.015 | .938 |
| Industriousness x stress -snacks | $\beta_{11}$ | 0.005 | 0.007 | .455 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.174 | 0.042 | <.001 |
| Responsibility – snacks | $\beta_{01}$ | 0.008 | 0.017 | .646 |
| Responsibility x stress -snacks | $\beta_{11}$ | 0.007 | 0.008 | .397 |

Finally, the moderating effect of eating styles was investigated on total stress and total snack intake for the whole sample (see Table 4-7 for results). No main effects were observed for the three eating styles, although restrained ($\beta$ = -0.02, $p$ = .057) and external eating styles ($\beta$ = 0.02, $p$ = .064) were trending towards significant. A moderating effect was found for emotional ($\beta$ = 0.01, $p$ = .017) and external eating styles ($\beta$ = 0.01, $p$ = .033) on the total stress and total snack relationship. Restrained eating style did not moderate the stress-eating association across the whole sample.

**Table 4-7. Summary of results for the moderating effect of eating styles on total stress and total snack consumption.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.032 | 0.093 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.181 | 0.040 | <.001 |
| Emotional – snacks | $\beta_{01}$ | 0.011 | 0.007 | .146 |
| Emotional x stress -snacks | $\beta_{11}$ | 0.007 | 0.003 | .017 |
| Snacks | $\beta_{00}$ | 2.033 | 0.093 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.177 | 0.041 | <.001 |
| Restrained – snacks | $\beta_{01}$ | -0.018 | 0.009 | .057 |
| Restrained x stress -snacks | $\beta_{11}$ | -0.002 | 0.005 | .610 |
| Snacks | $\beta_{00}$ | 2.030 | 0.093 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.175 | 0.040 | <.001 |
| External – snacks | $\beta_{01}$ | 0.023 | 0.012 | .064 |
| External x stress -snacks | $\beta_{11}$ | 0.010 | 0.005 | .033 |

The interaction between emotional and external eating on the stress and total snacks relations were decomposed using simple slopes analysis. The simple slopes for the relationship between stress and eating at low (-11.68), mean (0) and high (11.68) levels of emotional eating are illustrated in Figure 4-4.

The slopes indicated that as levels of emotional eating increased from low (*coefficient* = 0.10, *t(121)* = 1.97, *p* = .052), to the mean (*coefficient* = 0.18, *t(121)* = 4.50, *p* < .001), to high (*coefficient* = 0.26, *t(121)* = 4.57, *p* < .001) levels of emotional eating, the impact of stress on eating also increased. Nevertheless, it is worth noting that stress was significantly positively related to eating at all levels of emotional eating.

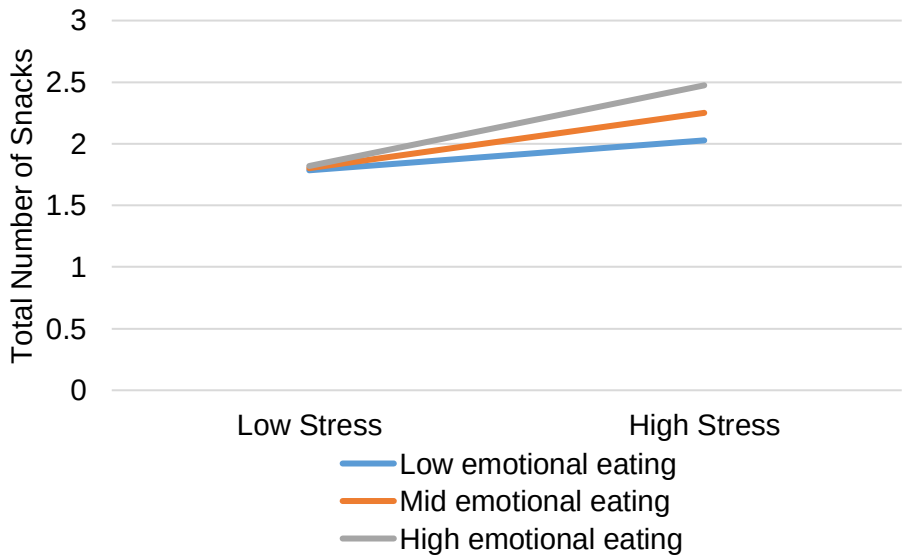


**Figure 4-4. Simple slopes for the moderating effect of emotional eating style on total stress and total snack intake (whole sample).**

The simple slopes for the relationship between stress and eating at low (-7.33), mean (0) and high (7.33) levels of external eating are illustrated in Figure 4-5. The slopes indicated that external eating increased from low (*coefficient* = 0.10, *t(121)* = 1.89, *p* = .062), to the mean (*coefficient* = 0.17, *t(121)* = 4.30, *p* < .001), to high (*coefficient* = 0.24, *t(121)* = 4.53, *p* < .001) levels of external eating, the impact of stress on eating also increased. Stress was significantly positively related to eating at mean and high levels of external eating, but not at low levels of external eating.

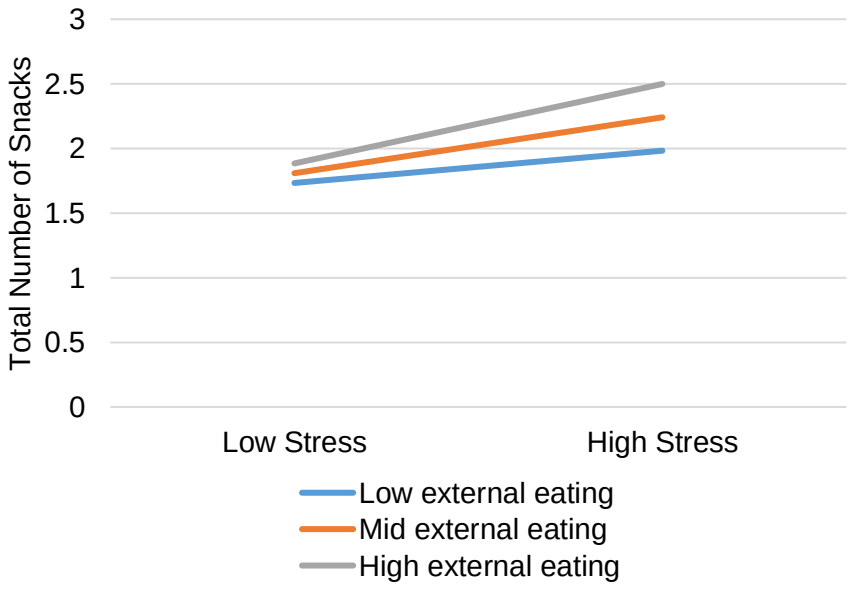


**Figure 4-5. Simple slopes for the moderating effect of external eating style on total stress and total snack intake (whole sample).**

### 4.4.3 Level 1 Models for Adolescents: Total Stress on Eating Behaviours

Level 1 models were initially used to investigate associations between daily stress and between-meal snack consumption in adolescents (see Table 4-8 for a summary of results). Analyses indicated that stress was positively associated with total snacks ($\beta$ = 0.22, *p* = .001) and low-to-medium fat/sugar snacks ($\beta$ = 0.10, *p* = .024). No effects were found between total stress and snacks high in fat only, high in sugar only, high in fat and sugar, or portions of fruit and vegetables.

**Table 4-8. Summary of level 1 results in adolescents for stress and between-meal snack intake (including snack categories), and portions of fruit and vegetables.**

| Model and Variables | | β | Coefficient | SE | p |
|---|---|---|---|---|---|
| **Intercept:** | Total snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 slope:* Total stress - total snacks | | $\beta_{10}$ | 0.217 | 0.065 | .001 |
| **Intercept:** | High fat snacks | $\beta_{00}$ | 0.413 | 0.048 | <.001 |
| *L1 slope:* Total stress - high fat snacks | | $\beta_{10}$ | 0.030 | 0.043 | .481 |
| **Intercept:** | High sugar snacks | $\beta_{00}$ | 0.291 | 0.041 | <.001 |
| *L1 slope:* Total stress - high sugar snacks | | $\beta_{10}$ | 0.021 | 0.029 | .468 |
| **Intercept:** | High fat & sugar snacks | $\beta_{00}$ | 0.577 | 0.051 | <.001 |
| *L1 slope:* Total stress - high fat & sugar snacks | | $\beta_{10}$ | 0.045 | 0.034 | .186 |
| **Intercept:** | Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.738 | 0.109 | <.001 |
| *L1 slope:* Total stress - low-to-medium snacks | | $\beta_{10}$ | 0.101 | 0.044 | .024 |
| **Intercept:** | Fruit & vegetable intake | $\beta_{00}$ | 2.031 | 0.204 | <.001 |
| *L1 slope:* Total stress - fruit & vegetable intake | | $\beta_{10}$ | -0.052 | 0.054 | .345 |

The type of stressor was modelled against total snack intake in adolescents (see Table 4-9 for a summary of results). Analyses indicated that physical stressors were positively associated with total snack intake ($\beta$ = 0.26, $p$ = .033). No associations were found between ego-threatening, interpersonal, work/academic or other stressors on total snack intake in adolescents.

**Table 4-9. Summary of level 1 results for type of stress on total snack intake in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| **Intercept:** Total snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 slope:* Ego-threat stress - total snacks | $\beta_{10}$ | 0.212 | 0.177 | .236 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 slope:* Interpersonal stress - total snacks | $\beta_{10}$ | 0.211 | 0.115 | .072 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 slope:* Work/academic stress - total snacks | $\beta_{10}$ | 0.163 | 0.112 | .150 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 slope:* Physical stress - total snacks | $\beta_{10}$ | 0.261 | 0.119 | .033 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 slope:* Other stress - total snacks | $\beta_{10}$ | 0.168 | 0.148 | .260 |

### 4.4.4 Cross-level Models for Total Stress and Total Snack Intake in Adolescents

The effect of moderating variables on total stress and total snack intake in adolescents were investigated using cross-level models (see Table 4-10 and Table 4-11 for results). Analyses indicated no main effects of age, gender, emotion regulation (reappraisal and suppression) or total conscientiousness on total snack consumption in adolescents.

Suppression was found to negatively moderate total stress and total snack intake in adolescents, ($\beta$ = -0.03, $p$ = .004). In contrast, age, gender, reappraisal and total conscientiousness did not moderate total stress and total snack intake in adolescents.

**Table 4-10. Summary of results for moderating variables (age, gender, emotion regulation and total conscientiousness) on total stress and total snack consumption in adolescents.**

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.027 | 0.151 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.190 | 0.068 | .007 |
| Age– snacks | $\beta_{01}$ | 0.168 | 0.215 | .438 |
| Age x stress -snacks | $\beta_{11}$ | -0.204 | 0.122 | .100 |
| Snacks | $\beta_{00}$ | 1.90 | 0.467 | .002 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.550 | 0.177 | .003 |
| Gender – snacks | $\beta_{01}$ | 0.413 | 0.382 | .284 |
| Gender x stress -snacks | $\beta_{11}$ | -0.266 | 0.142 | .066 |
| Snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.210 | 0.067 | .003 |
| Reappraisal – snacks | $\beta_{01}$ | -0.001 | 0.027 | .958 |
| Reappraisal x stress -snacks | $\beta_{11}$ | -0.004 | 0.009 | .629 |
| Snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.210 | 0.061 | .001 |
| Suppression – snacks | $\beta_{01}$ | -0.005 | 0.027 | .846 |
| Suppression x stress -snacks | $\beta_{11}$ | -0.025 | 0.008 | .004 |
| Snacks | $\beta_{00}$ | 2.012 | 0.149 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.219 | 0.067 | .002 |
| Conscientiousness – snacks | $\beta_{01}$ | -0.007 | 0.005 | .212 |
| Conscientiousness x stress - snacks | $\beta_{11}$ | -0.001 | 0.002 | .556 |

The moderating effect of facets of conscientiousness on total stress and total snack intake in adolescents was investigated (see Table 4-11 for results). Analyses indicated no main effects for any of the six facets on total snack intake. Similarly, no moderating effects were found on any of the facets of conscientiousness on total stress and total snack intake in adolescents.

**Table 4-11. Summary of results for the moderating effect conscientiousness facets on total stress and total snack consumption in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.019 | 0.149 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.213 | 0.068 | .003 |
| Order – snacks | $\beta_{01}$ | -0.019 | 0.022 | .387 |
| Order x stress -snacks | $\beta_{11}$ | -0.015 | 0.010 | .153 |
| Snacks | $\beta_{00}$ | 2.022 | 0.150 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.214 | 0.067 | .002 |
| Virtue – snacks | $\beta_{01}$ | -0.015 | 0.022 | .490 |
| Virtue x stress -snacks | $\beta_{11}$ | <-.001 | 0.008 | .952 |
| Snacks | $\beta_{00}$ | 2.020 | 0.151 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.212 | 0.066 | .002 |
| Traditionalism – snacks | $\beta_{01}$ | -0.014 | 0.033 | .676 |
| Traditionalism x stress - snacks | $\beta_{11}$ | 0.002 | 0.012 | .832 |
| Snacks | $\beta_{00}$ | 2.021 | 0.150 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.233 | 0.065 | <.001 |
| Self-control – snacks | $\beta_{01}$ | -0.015 | 0.020 | .466 |
| Self-control x stress -snacks | $\beta_{11}$ | -0.010 | 0.008 | .220 |
| Snacks | $\beta_{00}$ | 2.023 | 0.128 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.213 | 0.067 | .002 |
| Industriousness – snacks | $\beta_{01}$ | -0.032 | 0.022 | .141 |
| Industriousness x stress -snacks | $\beta_{11}$ | <-.001 | 0.009 | .992 |
| Snacks | $\beta_{00}$ | 2.023 | 0.150 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.211 | 0.068 | .003 |
| Responsibility – snacks | $\beta_{01}$ | -0.034 | 0.027 | .220 |
| Responsibility x stress -snacks | $\beta_{11}$ | 0.003 | 0.011 | .811 |

Finally, the moderating effect of eating style was investigated on total stress and total snack intake in adolescents (see Table 4-12 for results).

Significant main effects were found for emotional ($\beta$ = 0.02, $p$ = .038) and external eating styles on total snack intake ($\beta$ = 0.05, $p$ = .003). No main effect was found for restrained eating on total snack intake in adolescents. The three eating styles (emotional, restrained and external) did not moderate total stress and total snack intake in adolescents.

**Table 4-12. Summary of results for the moderating effect of eating styles on total stress and total snack consumption in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.020 | 0.146 | <.001 |
| *L1 Slope*: Stress and Snacks | $\beta_{10}$ | 0.225 | 0.005 | <.001 |
| Emotional – snacks | $\beta_{01}$ | 0.024 | 0.011 | .038 |
| Emotional x stress -snacks | $\beta_{11}$ | 0.007 | 0.005 | .211 |
| Snacks | $\beta_{00}$ | 2.021 | 0.120 | <.001 |
| *L1 Slope*: Stress and Snacks | $\beta_{10}$ | 0.214 | 0.065 | .002 |
| Restraint – snacks | $\beta_{01}$ | -0.016 | 0.014 | .261 |
| Restraint x stress -snacks | $\beta_{11}$ | <-.001 | 0.008 | .962 |
| Snacks | $\beta_{00}$ | 2.016 | 0.142 | <.001 |
| *L1 Slope*: Stress and Snacks | $\beta_{10}$ | 0.227 | 0.057 | <.001 |
| External – snacks | $\beta_{01}$ | 0.053 | 0.017 | .003 |
| External x stress -snacks | $\beta_{11}$ | 0.011 | 0.007 | .114 |

The simple slopes for the relationship between total stress and total snack intake at low (-5.15), mean (0) and high (5.15) levels of suppression in adolescents are illustrated in Figure 4-6.

The slopes indicated that as levels of suppression increased from low (*coefficient* = 0.34, *t(57)* = 6.19, $p$ < .001), to the mean (*coefficient* = 0.21, *t(57)* = 3.45, $p$ = .001) to high (*coefficient* = 0.08, *t(57)* = 0.89, $p$ = .376) levels of

suppression, the impact of stress on eating decreased. Specifically, stress was significantly positively related to total snack intake at low and mean levels of suppression, but not at high levels of suppression.

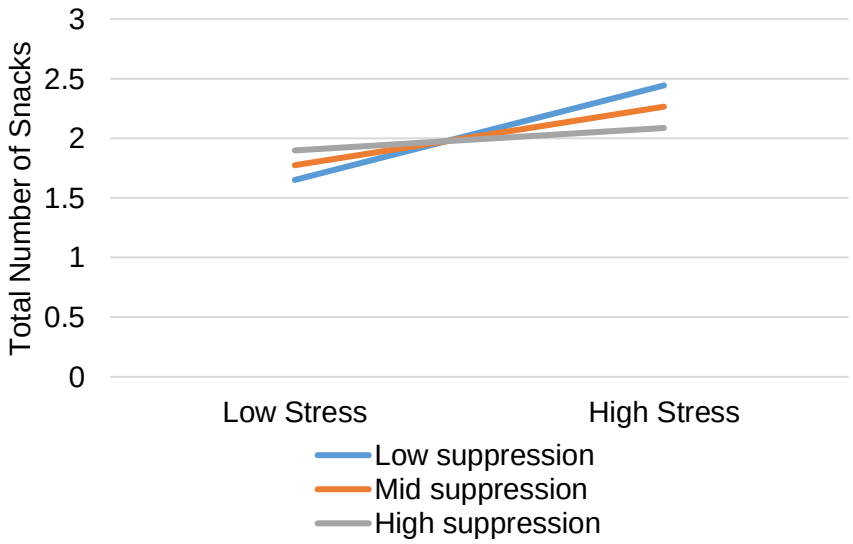


**Figure 4-6. Simple slopes for the moderating effect of suppression (emotion regulation) on total stress and total snack intake in adolescents.**

### 4.4.5 Level 1 Models for Young Adults: Total Stress on Eating Behaviours

Level 1 models were initially used to investigate associations between daily stress and between-meal snack consumption in young adults (see Table 4-13 for a summary of results). Analyses indicated that stress was positively associated with total snacks ($\beta$ = 0.16, $p$ = .004) and with low-to-medium fat/sugar snacks ($\beta$ = 0.10, $p$ = .014) in young adults. No effects were found between total stress and snacks high in fat only, high in sugar only, high in both fat and sugar, or portions of fruit and vegetables.

**Table 4-13. Summary of level 1 results in young adults for stress and between-meal snack intake (including snack categories) and portions of fruit and vegetables.**

| Model and Variables | | β | Coefficient | SE | p |
|---|---|---|---|---|---|
| **Intercept:** | Total snacks | $\beta_{00}$ | 2.042 | 0.116 | <.001 |
| *L1 slope:* Total stress - | total snacks | $\beta_{10}$ | 0.156 | 0.053 | .004 |
| **Intercept:** | High fat snacks | $\beta_{00}$ | 0.347 | 0.041 | <.001 |
| *L1 slope:* Total stress - | high fat snacks | $\beta_{10}$ | -0.003 | 0.023 | .903 |
| **Intercept:** | High sugar snacks | $\beta_{00}$ | 0.260 | 0.032 | <.001 |
| *L1 slope:* Total stress - | high sugar snacks | $\beta_{10}$ | 0.023 | 0.016 | .137 |
| **Intercept:** | High fat & sugar snacks | $\beta_{00}$ | 0.560 | 0.043 | <.001 |
| *L1 slope:* Total stress - | high fat & sugar snacks | $\beta_{10}$ | 0.033 | 0.027 | .234 |
| **Intercept:** | Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.876 | 0.077 | <.001 |
| *L1 slope:* Total stress - | low-to-medium snacks | $\beta_{10}$ | 0.097 | 0.038 | .014 |
| **Intercept:** | Fruit & vegetable intake | $\beta_{00}$ | 3.292 | 0.203 | <.001 |
| *L1 slope:* Total stress - | fruit & vegetable intake | $\beta_{10}$ | 0.094 | 0.065 | .154 |

The type of stressor was modelled against total snack intake in young adults (see Table 4-14 for a summary of results). Ego-threatening ($\beta$ = 0.25, $p$ = .013) and work/academic stressors ($\beta$ = 0.20, $p$ <.001) were positively associated with total snack intake. No associations were found between interpersonal, physical or other stressors on total snack intake in young adults.

**Table 4-14. Summary of Level 1 results for type of stress on total snack intake in young adults.**

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| **Intercept:** Total snacks | $\beta_{00}$ | 2.042 | 0.116 | <.001 |
| *L1 slope:* Ego-threat stress - total snacks | $\beta_{10}$ | 0.245 | 0.096 | .013 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.042 | 0.117 | <.001 |
| *L1 slope:* Interpersonal stress - total snacks | $\beta_{10}$ | 0.053 | 0.087 | .549 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.042 | 0.116 | <.001 |
| *L1 slope:* Work/academic stress - total snacks | $\beta_{10}$ | 0.197 | 0.049 | <.001 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.041 | 0.116 | <.001 |
| *L1 slope:* Physical stress - total snacks | $\beta_{10}$ | 0.010 | 0.052 | .844 |
| **Intercept:** Total snacks | $\beta_{00}$ | 2.042 | 0.116 | <.001 |
| *L1 slope:* Other stress - total snacks | $\beta_{10}$ | 0.037 | 0.077 | .635 |

### 4.4.6 Cross-level Models for Total Stress and Total Snack Intake in Young Adults

The effect of moderating variables on total stress and total snack intake in young adults were investigated using cross-level models (see Table 4-15, Table 4-16 and Table 4-17 for results). Analyses indicated a main effect of age ($\beta$ = -0.21, $p$ = .040), suppression ($\beta$ = -0.05, $p$ = .039) and total conscientiousness ($\beta$ = 0.01, $p$ = .002) on total snack intake in young adults.

No moderating effects were found for age, gender, emotion regulation (reappraisal and suppression) and total conscientiousness on total stress and total snack intake in young adults.

**Table 4-15. Summary of results for moderating variables (age, gender, emotion regulation and total conscientiousness) on total stress and total snack consumption in young adults.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.042 | 0.114 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.155 | 0.054 | .006 |
| Age group – snacks | $\beta_{01}$ | -0.208 | 0.099 | .040 |
| Age group x stress -snacks | $\beta_{11}$ | 0.016 | 0.053 | .762 |
| Snacks | $\beta_{00}$ | 2.032 | 0.449 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | -0.007 | 0.150 | .963 |
| Gender – snacks | $\beta_{01}$ | 0.009 | 0.396 | .981 |
| Gender x stress -snacks | $\beta_{11}$ | 0.156 | 0.116 | .183 |
| Snacks | $\beta_{00}$ | 2.042 | 0.116 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.154 | 0.054 | .006 |
| Reappraisal – snacks | $\beta_{01}$ | 0.014 | 0.026 | .593 |
| Reappraisal x stress -snacks | $\beta_{11}$ | -0.004 | 0.008 | .607 |
| Snacks | $\beta_{00}$ | 2.044 | 0.112 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.158 | 0.052 | .004 |
| Suppression – snacks | $\beta_{01}$ | -0.045 | 0.022 | .039 |
| Suppression x stress -snacks | $\beta_{11}$ | 0.014 | 0.009 | .139 |
| Snacks | $\beta_{00}$ | 2.040 | 0.110 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.156 | 0.053 | .005 |
| Conscientiousness – snacks | $\beta_{01}$ | 0.011 | 0.004 | .002 |
| Conscientiousness x stress - snacks | $\beta_{11}$ | <.001 | 0.002 | .865 |

The moderating effect of facets of conscientiousness was investigated on total stress and total snack intake in young adults (see Table 4-16 for results). Analyses revealed a main effect of virtue ($\beta$ = 0.06, $p$ = .003), industriousness ($\beta$ = 0.03, $p$ = .046) and responsibility ($\beta$ = 0.05, $p$ = .011) on total snack intake. No moderating effects were found for any of the facets on total stress and total snack intake in young adults.

**Table 4-16. Summary of results for moderating effect conscientiousness facets on total stress and total snack consumption in young adults.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.042 | 0.116 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.153 | 0.053 | .005 |
| Order – snacks | $\beta_{01}$ | 0.006 | 0.013 | .655 |
| Order x stress -snacks | $\beta_{11}$ | -0.005 | 0.006 | .369 |
| Snacks | $\beta_{00}$ | 2.040 | 0.107 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.157 | 0.054 | .005 |
| Virtue – snacks | $\beta_{01}$ | 0.056 | 0.018 | .003 |
| Virtue x stress -snacks | $\beta_{11}$ | <.001 | 0.008 | .979 |
| Snacks | $\beta_{00}$ | 2.041 | 0.115 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.155 | 0.053 | .005 |
| Traditionalism – snacks | $\beta_{01}$ | 0.024 | 0.020 | .238 |
| Traditionalism x stress - snacks | $\beta_{11}$ | 0.006 | 0.011 | .606 |
| Snacks | $\beta_{00}$ | 2.042 | 0.115 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.155 | 0.053 | .005 |
| Self-control – snacks | $\beta_{01}$ | 0.024 | 0.020 | .232 |
| Self-control x stress -snacks | $\beta_{11}$ | -0.003 | 0.008 | .684 |
| Snacks | $\beta_{00}$ | 2.039 | 0.114 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.154 | 0.053 | .005 |
| Industriousness – snacks | $\beta_{01}$ | 0.034 | 0.016 | .046 |
| Industriousness x stress -snacks | $\beta_{11}$ | 0.010 | 0.010 | .288 |
| Snacks | $\beta_{00}$ | 2.042 | 0.112 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.153 | 0.053 | .005 |
| Responsibility – snacks | $\beta_{01}$ | 0.045 | 0.017 | .011 |
| Responsibility x stress -snacks | $\beta_{11}$ | 0.010 | 0.012 | .413 |

Finally, the moderating effect of eating styles was investigated on total stress and total snack intake in young adults (see Table 4-17 for results). No significant main effects were found for any of the eating styles on total snack intake.

A moderating effect of emotional eating was found on total stress and total snack intake in young adults ($\beta$ = 0.01, $p$ = .021). No moderating effects were found for restrained and external eating styles on total stress and total snack intake in young adults.

**Table 4-17. Summary of results for the moderating effect of eating styles on total stress and total snack consumption in young adults.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.042 | 0.116 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.162 | 0.050 | .002 |
| Emotional – snacks | $\beta_{01}$ | -0.005 | 0.008 | .568 |
| Emotional x stress -snacks | $\beta_{11}$ | 0.007 | 0.003 | .021 |
| Snacks | $\beta_{00}$ | 2.039 | 0.114 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.156 | 0.053 | .004 |
| Restrained – snacks | $\beta_{01}$ | -0.023 | 0.013 | .091 |
| Restrained x stress -snacks | $\beta_{11}$ | -0.002 | 0.006 | .690 |
| Snacks | $\beta_{00}$ | 2.042 | 0.116 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.157 | 0.051 | .003 |
| External – snacks | $\beta_{01}$ | -0.013 | 0.021 | .529 |
| External x stress -snacks | $\beta_{11}$ | 0.011 | 0.006 | .089 |

The simple slopes for the relationship between stress and eating at low (25.49), mean (36.19) and high (46.89) levels of emotional eating in young adults are illustrated in Figure 4-7.

The slopes indicated that as levels of emotional eating increased from low (*coefficient* = 0.35, *t(62)* = 3.77, *p* < .001), to the mean (*coefficient* = 0.43, *t(62)* = 3.51, *p* < .001), to high (*coefficient* = 0.51, *t(62)* = 3.31, *p* = .002) levels of emotional eating, the impact of stress on eating also increased. Stress was significantly positively related to eating at all levels of emotional eating in young adults.

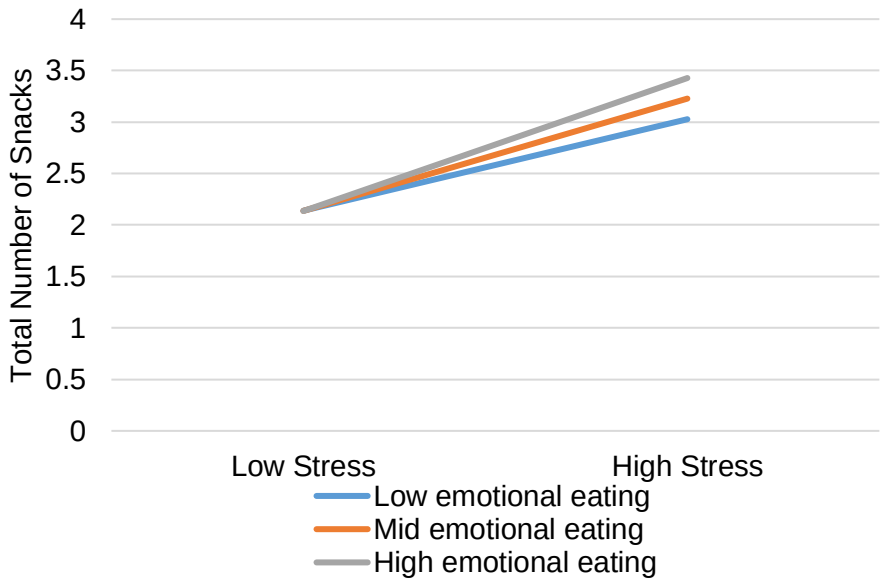


**Figure 4-7. Simple slopes for the moderating effect of emotional eating style on total stress and total snack intake in young adults.**

### 4.4.7 Effect of Stress Reactivity on Total Stress and Total Snacks

Prior to analyses, MANOVAs were conducted to determine whether group size of the TSST-G and smoking status (i.e., smokers vs non-smokers) were associated with stress reactivity (AUCg and AUCi). The analyses indicated that group size of the TSST-G was positively associated with cortisol levels for both AUCg, $F(5, 117) = 4.83$, $p < .001$, and AUCi, $F(5, 117) = 2.79$, $p = .020$, where larger groups elicited a greater stress-response compared to smaller groups. In contrast, smoking status was not associated with either AUCg, $F(1, 121) = 0.293$, $p = .590$, or AUCi, $F(1, 121) = 1.50$, $p = .224$. Therefore, group size of the stress task was controlled for in subsequent analyses.

Finally, a manipulation check was conducted to determine that the TSST-G was effective in inducing stress via increased circulating cortisol levels. Paired samples t-tests indicated a significant increase from the baseline saliva sample to sample 2 (immediately following the TSST-G), $t(122) = -5.33$, $p < .001$, and from the baseline saliva sample to peak cortisol level (i.e., +10 minutes following the TSST-G, $t(122) = -5.40$, $p < .001$. Finally, baseline cortisol was similar to the recovery sample (i.e., +40 minutes following the stress-task), $t(122) = 0.20$, $p = .840$, indicating that participants cortisol levels returned to similar levels those of the baseline sample by the fourth sampling point. Figure 4-8 shows the mean cortisol (nmol/L) by each sampling point for the whole sample.

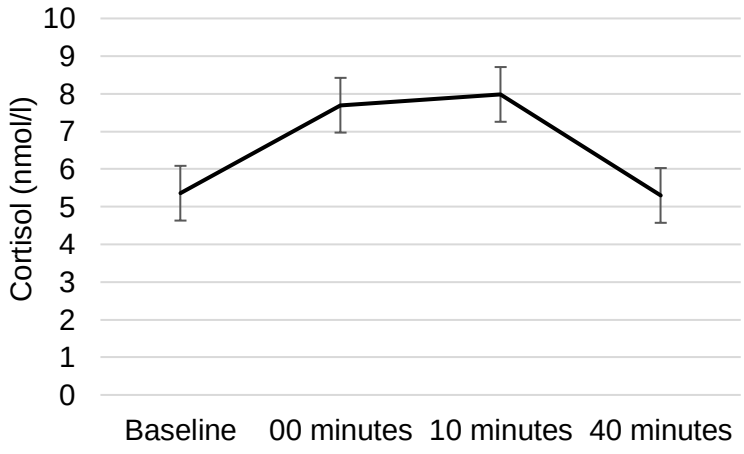


**Figure 4-8. Mean cortisol (nmol/L) response across whole sample by sampling point with standard error.**

The mean cortisol reactivity (nmol/L) was similar across the four sampling points for adolescents and young adults (see Figure 4-9 for cortisol profiles for whole sample, and by age group). In comparison to adolescents, the young adults had on average a flatter cortisol reactivity profile across the four sample points.

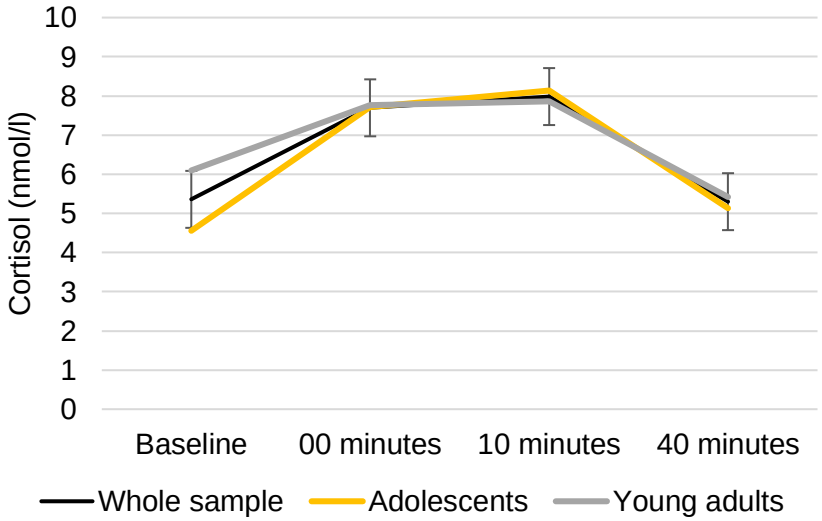


**Figure 4-9. Cortisol reactivity (nmol/L) by sampling point for the whole sample and age groups separately, with standard error.**

The moderating effect of total cortisol (AUCg) and cortisol reactivity in relation to the stress task (AUCi) when controlling for TSST-G group size were investigated using cross-level models (see Table 4-18 for results). The analyses indicated no main effects of stress reactivity on total snack intake. A moderating effect was found for AUCg on total stress and total snack intake ($\beta$ <-.001, $p$ = .012). Similarly, a moderating effect was found for AUCi on total stress and total snack intake across the whole sample ($\beta$ < -0.001, $p$ = .001).

**Table 4-18. Summary of results for the moderating effect of stress reactivity (AUCg and AUCi) on total stress and total snack intake across the whole sample.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.031 | 0.093 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.177 | 0.039 | <.001 |
| Group size - snacks | $\beta_{01}$ | -0.024 | 0.069 | .731 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .138 |
| Group size x stress –snacks | $\beta_{11}$ | -0.013 | 0.039 | .744 |
| AUCg x stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .012 |
| Snacks | $\beta_{00}$ | 0.032 | 0.094 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.170 | 0.038 | <.001 |
| Group size - snacks | $\beta_{01}$ | 0.024 | 0.074 | .744 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .802 |
| Group size x stress –snacks | $\beta_{11}$ | -0.028 | 0.037 | .450 |
| AUCi x stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .001 |

The simple slopes for the relationship between stress and eating at low (-237.39), mean (0) and high (237.39) levels of AUCg are illustrated in Figure 4-10.

The slopes indicated that as AUCg increased from low (*coefficient* = 0.28, *t(121)* = 5.08, *p* < .001), to the mean (*coefficient* = 0.17, *t(121)* = 4.41, *p* < .001), to high (*coefficient* = 0.07, *t(121)* = 1.26, *p* = .210) levels of cortisol reactivity, the impact of stress on eating decreased. Stress was significantly positively related to eating at low and mean levels of AUCg, but not to high levels of AUCg across the whole sample.

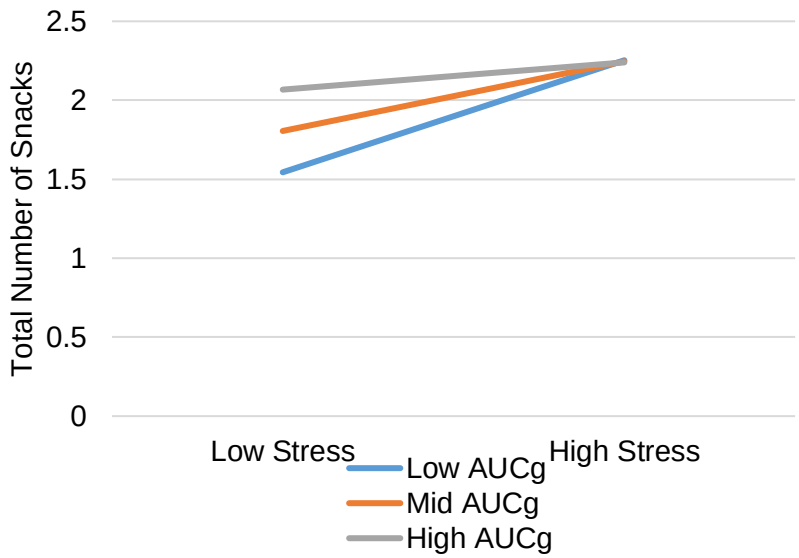


**Figure 4-10. Simple slopes for the moderating effect of AUCg on total stress and total snack intake (whole sample).**

The simple slopes for the relationship between stress and eating at low (-230.49), mean (0) and high (230.49) levels of AUCi are illustrated in Figure 4-11. This showed that as AUCi increased from low (*coefficient* = 0.29, *t(121)* = 5.56, $p < .001$), to the mean (*coefficient* = 0.17, *t(121)* = 4.32, $p < .001$), to high (*coefficient* = 0.05, *t(121)* = 0.87, $p = .388$) levels of cortisol reactivity, the impact of stress on eating decreased. Similar to the findings of AUCg, stress was significantly positively related to eating at low and mean levels of AUCi, but not to high levels of AUCi across the whole sample.

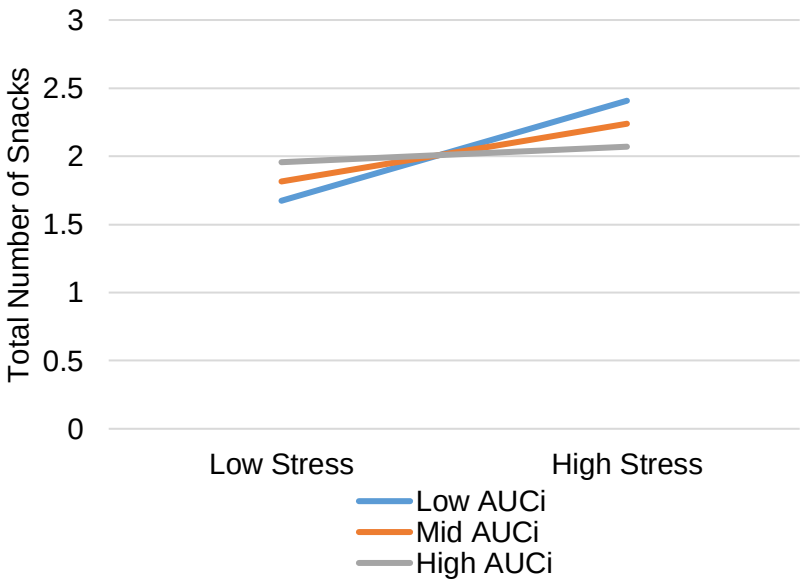


**Figure 4-11. Simple slopes for the moderating effect of AUCi on total stress and total snack intake (whole sample).**

The moderating effect of cortisol reactivity (AUCg and AUCi) on total stress and type of between meal snacks was investigated using cross-level models (see Table 4-19 and Table 4-20 for results).

The analyses indicated no main effects of AUCg or group size on total stress and the type of snack intake across the whole sample. A moderating effect was found for AUCg on total stress and snacks which were low-to-medium in fat and sugar content ($\beta < -0.001$, $p = .032$). No moderating effects were found on total stress and snacks high in fat only, high in sugar only, high in fat and sugar, or portions of fruit and vegetables.

Similarly, analyses indicated no main effects of AUCi on type of between meal snacks across the whole sample. A moderating effect for AUCi on total stress and snacks high in both fat and sugar ($\beta$ < - 0.001, $p$ = .011). No moderating effects were found on total stress and snacks high in fat only, high in sugar only, low-to-medium in fat and sugar, or portions of fruit and vegetables.

**Table 4-19. Summary of results for the moderating effect of stress reactivity (AUCg) on total stress and type of snack intake (whole sample).**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| High fat snacks | $\beta_{00}$ | 0.377 | 0.031 | <.001 |
| *L1 Slope*: Total stress and high fat snacks | $\beta_{10}$ | 0.010 | 0.023 | .664 |
| Group size – high fat snacks | $\beta_{01}$ | < -.001 | 0.024 | .997 |
| AUCg – high fat snacks | $\beta_{02}$ | < -.001 | <.001 | .502 |
| Group size x stress – high fat snacks | $\beta_{11}$ | -0.013 | 0.017 | .444 |
| AUCg x stress – high fat snacks | $\beta_{12}$ | <.001 | <.001 | .618 |
| High sugar snacks | $\beta_{00}$ | 0.274 | 0.025 | <.001 |
| *L1 Slope*: Total stress and high sugar snacks | $\beta_{10}$ | 0.028 | 0.015 | .065 |
| Group size – high sugar snacks | $\beta_{01}$ | < -.001 | 0.017 | .966 |
| AUCg – high sugar snacks | $\beta_{02}$ | <.001 | <.001 | .790 |
| Group size x stress – high sugar snacks | $\beta_{11}$ | 0.012 | 0.011 | .284 |
| AUCg x stress – high sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .192 |
| High fat & sugar snacks | $\beta_{00}$ | 0.566 | 0.032 | <.001 |
| *L1 Slope*: Stress and high fat & sugar snacks | $\beta_{10}$ | 0.039 | 0.020 | .059 |
| Group size – high fat & sugar snacks | $\beta_{01}$ | -0.005 | 0.028 | .870 |
| AUCg – high fat & sugar snacks | $\beta_{02}$ | <.001 | <.001 | .068 |
| Group size x stress – high fat & sugar snacks | $\beta_{11}$ | 0.006 | 0.023 | .777 |
| AUCg x stress – high fat & sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .249 |

***Table 4-19 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.812 | 0.065 | <.001 |
| *L1 Slope*: Total stress and low-to-medium snacks | $\beta_{10}$ | 0.098 | 9.026 | <.001 |
| Group size – low-to-medium snacks | $\beta_{01}$ | -0.016 | 0.046 | .732 |
| AUCg – low-to-medium snacks | $\beta_{02}$ | <.001 | <.001 | .223 |
| Group size x stress – low-to-medium snacks | $\beta_{11}$ | -0.032 | 0.026 | .221 |
| AUCg x stress – low-to-medium snacks | $\beta_{12}$ | < -.001 | <.001 | .032 |
| Fruit & vegetable intake | $\beta_{00}$ | 2.703 | 0.153 | <.001 |
| *L1 Slope*: Total stress and fruit & vegetable intake | $\beta_{10}$ | 0.016 | 0.041 | .700 |
| Group size - fruit & vegetable intake | $\beta_{01}$ | 0.180 | 0.122 | .141 |
| AUCg – fruit & vegetable intake | $\beta_{02}$ | < -.001 | <.001 | .430 |
| Group size x stress – fruit & vegetable intake | $\beta_{11}$ | -0.095 | 0.047 | .044 |
| AUCg x stress - fruit & vegetable intake | $\beta_{12}$ | < -.001 | <.001 | .649 |

**Table 4-20. Summary of results for the moderating effect of stress reactivity (AUCi) on total stress and type of snack intake (whole sample).**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| High fat snacks | $\beta_{00}$ | 0.376 | 0.031 | <.001 |
| *L1 Slope*: Total stress and high fat snacks | $\beta_{10}$ | 0.010 | 0.023 | .669 |
| Group size – high fat snacks | $\beta_{01}$ | -0.001 | 0.025 | .952 |
| AUCi – high fat snacks | $\beta_{02}$ | < -.001 | <.001 | .397 |
| Group size x stress – high fat snacks | $\beta_{11}$ | -0.007 | 0.015 | .649 |
| AUCi x stress – high fat snacks | $\beta_{12}$ | < -.001 | <.001 | .611 |
| High sugar snacks | $\beta_{00}$ | 0.274 | 0.026 | <.001 |
| *L1 Slope*: Total stress and high sugar snacks | $\beta_{10}$ | 0.026 | 0.016 | .106 |
| Group size – high sugar snacks | $\beta_{01}$ | 0.002 | 0.017 | .896 |
| AUCi – high sugar snacks | $\beta_{02}$ | < -.001 | <.001 | .886 |
| Group size x stress – high sugar snacks | $\beta_{11}$ | 0.010 | 0.011 | .374 |
| AUCi x stress – high sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .127 |
| High fat & sugar snacks | $\beta_{00}$ | 0.567 | 0.032 | <.001 |
| *L1 Slope*: Stress and high fat & sugar snacks | $\beta_{10}$ | 0.037 | 0.020 | .063 |
| Group size – high fat & sugar snacks | $\beta_{01}$ | 0.013 | 0.028 | .638 |
| AUCi – high fat & sugar snacks | $\beta_{02}$ | <.001 | <.001 | .599 |
| Group size x stress – high fat & sugar snacks | $\beta_{11}$ | 0.004 | 0.021 | .863 |
| AUCi x stress – high fat & sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .011 |

***Table 4-20 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.812 | 0.065 | <.001 |
| *L1 Slope*: Total stress and low-to-medium snacks | $\beta_{10}$ | 0.093 | 0.027 | <.001 |
| Group size – low-to-medium snacks | $\beta_{01}$ | 0.008 | 0.047 | .857 |
| AUCi – low-to-medium snacks | $\beta_{02}$ | < -.001 | <.001 | .998 |
| Group size x stress – low-to-medium snacks | $\beta_{11}$ | -0.044 | 0.025 | .078 |
| AUCi x stress – low-to-medium snacks | $\beta_{12}$ | < -.001 | <.001 | .227 |
| Fruit & vegetable intake | $\beta_{00}$ | 2.701 | 0.153 | <.001 |
| *L1 Slope*: Total stress and fruit & vegetable intake | $\beta_{10}$ | 0.015 | 0.040 | .705 |
| Group size - fruit & vegetable intake | $\beta_{01}$ | 0.171 | 0.116 | .144 |
| AUCi – fruit & vegetable intake | $\beta_{02}$ | < -.001 | <.001 | .295 |
| Group size x stress – fruit & vegetable intake | $\beta_{11}$ | -0.100 | 0.044 | .025 |
| AUCi x stress - fruit & vegetable intake | $\beta_{12}$ | < -.001 | <.001 | .957 |

The simple slopes for the relationship between stress and low-to-medium snack intake at low (-237.39), mean (0) and high (237.39) levels of AUCg are illustrated in Figure 4-12.

The slopes indicated that as AUCg increased from low (*coefficient* = 0.18, *t(121)* = 4.89, *p* < .001), to the mean (*coefficient* = 0.10, *t(121)* = 3.70, *p* < .001), to high (*coefficient* = 0.03, *t(121)* = 0.67, *p* = .505) levels of cortisol reactivity, the impact of stress on eating decreased. Stress was significantly positively related to low-to-medium snack intake at low and mean levels of AUCg, but not to high levels of AUCg across the whole sample.

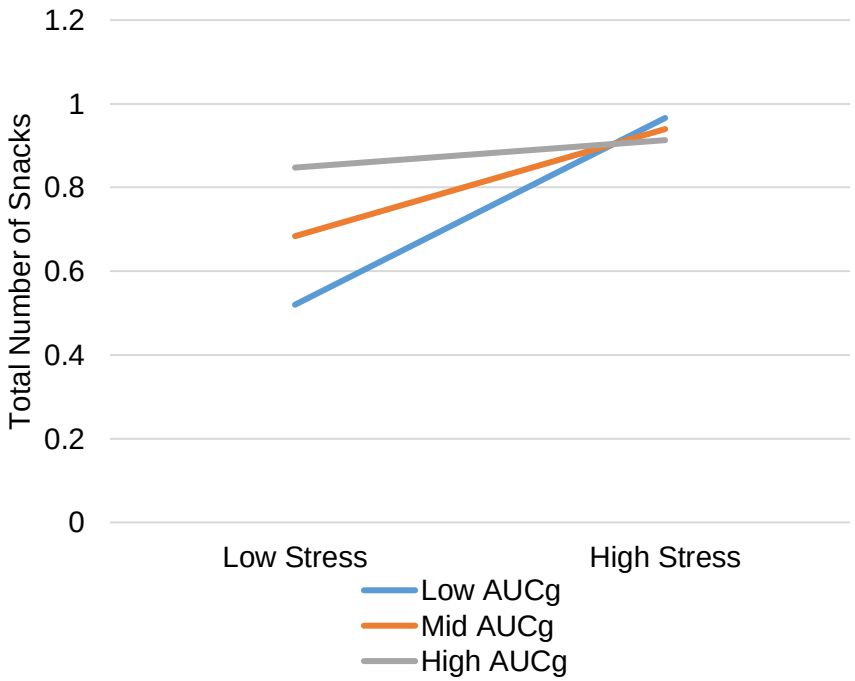


**Figure 4-12. Simple slopes for the moderating effect of AUCg on total stress and low-to-medium snacks (whole sample).**

The simple slopes for the relationship between stress and high fat and sugar snack intake at low (-230.49), mean (0) and high (230.49) levels of AUCi are illustrated in Figure 4-13. The slopes indicated that as AUCi increased from low (*coefficient* = 0.08, *t(121)* = 2.68, *p* = .008), to the mean (*coefficient* = 0.04, *t(121)* = 1.81, *p* = .073), to high (*coefficient* = -0.001, *t(121)* = -0.04, *p* = .966) levels of cortisol reactivity, the impact of stress on eating decreased. Stress was significantly positively related to high fat and sugar snack intake at low levels of AUCi, but not at mean or high levels of AUCi across the whole sample.

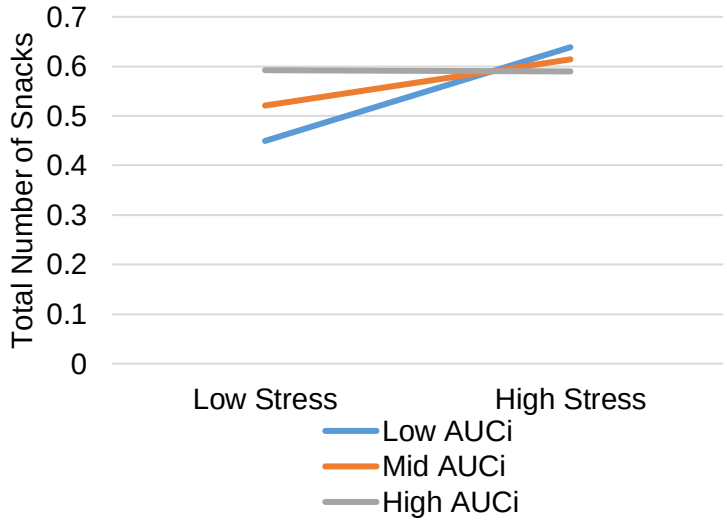


**Figure 4-13. Simple slopes for the moderating effect of AUCi on total stress and snacks high in fat and sugar (whole sample).**

Furthermore, the moderating effect of total cortisol (AUCg) and cortisol reactivity in relation to the stress task (AUCi) on type of stress and total snacks was investigated using cross-level models (see Table 4-21 and Table 4-22 for results).

The analyses indicated no main effects of stress reactivity (AUCg) on total snack intake across the whole sample. A moderating effect was found for AUCg on work/academic stress and total snack intake (*β* <-.001, *p* = .007). No moderating effects of AUCg were found on ego-threatening, interpersonal, physical or other stressors on total snack intake. Similarly, analyses indicated no main effects of AUCi on total snack intake across the whole sample. A moderating effect was found for AUCi on work/academic stress (*β* <-.001, *p* = .007) and ego-

threatening stressors on total snack intake ($\beta$ =-0.001, $p$ = .013). AUCi did not moderate interpersonal, physical or other stressors on total snack intake.

**Table 4-21. Summary of results for the moderating effect of stress reactivity (AUCg) on type of stress and total snack intake (whole sample).**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.031 | 0.093 | <.001 |
| *L1 Slope*: Ego-threat and snacks | $\beta_{10}$ | 0.242 | 0.090 | .008 |
| Group size - snacks | $\beta_{01}$ | -0.024 | 0.069 | .732 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .141 |
| Group size x ego-threat –snacks | $\beta_{11}$ | -0.150 | 0.087 | .089 |
| AUCg x ego-threat -snacks | $\beta_{12}$ | <-.001 | <.001 | .307 |
| Snacks | $\beta_{00}$ | 2.032 | 0.093 | <.001 |
| *L1 Slope*: Interpersonal and snacks | $\beta_{10}$ | 0.098 | 0.074 | .189 |
| Group size - snacks | $\beta_{01}$ | -0.025 | 0.069 | .719 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .137 |
| Group size x interpersonal –snacks | $\beta_{11}$ | 0.016 | 0.081 | .846 |
| AUCg x interpersonal -snacks | $\beta_{12}$ | <-.001 | <.001 | .759 |
| Snacks | $\beta_{00}$ | 2.032 | 0.093 | <.001 |
| *L1 Slope*: Work stress and snacks | $\beta_{10}$ | 0.187 | 0.050 | <.001 |
| Group size - snacks | $\beta_{01}$ | -0.023 | 0.069 | .737 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .138 |
| Group size x work stress –snacks | $\beta_{11}$ | -0.019 | 0.042 | .656 |
| AUCg x work stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .007 |

***Table 4-21 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.031 | 0.093 | <.001 |
| *L1 Slope*: Physical stress and snacks | $\beta_{10}$ | 0.097 | 0.054 | .073 |
| Group size - snacks | $\beta_{01}$ | -0.024 | 0.069 | .727 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .138 |
| Group size x physical stress –snacks | $\beta_{11}$ | -0.032 | 0.044 | .459 |
| AUCg x physical stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .843 |
| Snacks | $\beta_{00}$ | 2.031 | 0.093 | <.001 |
| *L1 Slope*: Other stress and snacks | $\beta_{10}$ | 0.084 | 0.068 | .219 |
| Group size - snacks | $\beta_{01}$ | -0.024 | 0.069 | .726 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .139 |
| Group size x other stress –snacks | $\beta_{11}$ | -0.102 | 0.070 | .148 |
| AUCg x other stress -snacks | $\beta_{12}$ | <.001 | <.001 | .868 |

**Table 4-22. Summary of results for the moderating effect of stress reactivity (AUCi) on type of stress and total snack intake (whole sample).**

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Ego-threat and snacks | $\beta_{10}$ | 0.238 | 0.086 | .007 |
| Group size - snacks | $\beta_{01}$ | 0.024 | 0.073 | .746 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .801 |
| Group size x ego-threat –snacks | $\beta_{11}$ | -0.147 | 0.083 | .080 |
| AUCi x ego-threat -snacks | $\beta_{12}$ | -0.001 | <.001 | .013 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Interpersonal and snacks | $\beta_{10}$ | 0.097 | 0.075 | .202 |
| Group size - snacks | $\beta_{01}$ | 0.023 | 0.074 | .756 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .804 |
| Group size x interpersonal –snacks | $\beta_{11}$ | 0.020 | 0.071 | .886 |
| AUCi x interpersonal -snacks | $\beta_{12}$ | <-.001 | <.001 | .837 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Work/academic stress and snacks | $\beta_{10}$ | 0.185 | 0.050 | <.001 |
| Group size - snacks | $\beta_{01}$ | 0.024 | 0.073 | .740 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .803 |
| Group size x work/academic stress –snacks | $\beta_{11}$ | -0.039 | 0.044 | .378 |
| AUCi x work/academic stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .007 |
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Physical stress and snacks | $\beta_{10}$ | 0.098 | 0.056 | .084 |
| Group size - snacks | $\beta_{01}$ | 0.024 | 0.074 | .784 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .802 |
| Group size x physical stress –snacks | $\beta_{11}$ | -0.037 | 0.041 | .360 |
| AUCi x physical stress -snacks | $\beta_{12}$ | <.001 | <.001 | .833 |

***Table 4-22 continued.***

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.032 | 0.094 | <.001 |
| *L1 Slope*: Other stress and snacks | $\beta_{10}$ | 0.085 | 0.070 | .226 |
| Group size - snacks | $\beta_{01}$ | 0.023 | 0.074 | .751 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .803 |
| Group size x other stress –snacks | $\beta_{11}$ | -0.099 | 0.061 | .111 |
| AUCi x other stress -snacks | $\beta_{12}$ | <.001 | <.001 | .909 |

The interactions between AUCg and AUCi on the type of stress and total snacks were decomposed using simple slopes analysis. The simple slopes for the relationship between work/academic stress and eating at low (-237.39), mean (0) and high (237.39) levels of AUCg are illustrated in Figure 4-14. The slopes demonstrated that as AUCg increased from low (*coefficient* = 0.36, *t(121)* = 4.87, *p* < .001), to the mean (*coefficient* = 0.19, *t(121)* = 3.75, *p* < .001), to high (*coefficient* = 0.01, *t(121)* = 0.09, *p* = .925) levels of cortisol reactivity, the impact of work/academic stress on eating decreased. Work/academic stress was significantly positively related to eating at low and mean levels of AUCg, but not to high levels of AUCg across the whole sample.

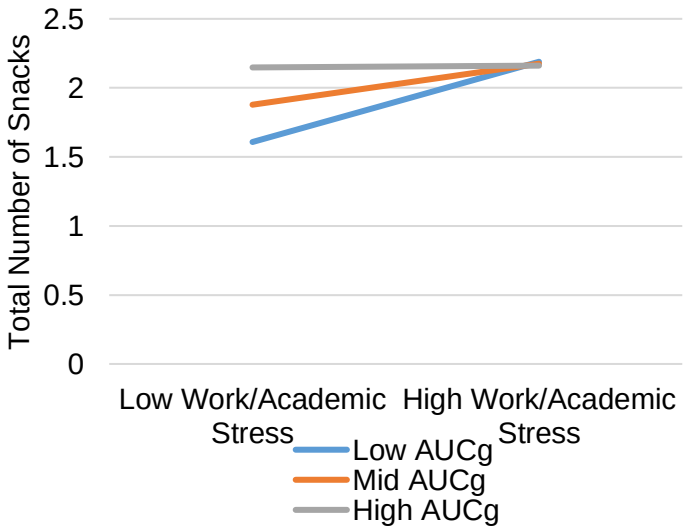


**Figure 4-14. Simple slopes for the moderating effect of AUCg on work/academic stress and total snack intake across the whole sample.**

Similarly, the simple slopes for the relationship between work/academic stress and eating at low (-237.39), mean (0) and high (237.39) levels of AUCi are illustrated in Figure 4-15 (note that the slope for low AUCi is not visible due to the slope for high AUCi).

The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.37, *t(121)* = 5.06, *p* < .001) to the mean (*coefficient* = 0.18, *t(121)* = 3.68, *p* < .001) levels of cortisol reactivity, the impact of work/academic stress on eating decreased. As AUCi increased from the mean to high (*coefficient* = 0.37, *t(121)* = 5.06, *p* < .001) levels of cortisol reactivity, the impact of work/academic stress on eating increased. Work/academic stress was significantly positively related to eating across all levels of AUCi.

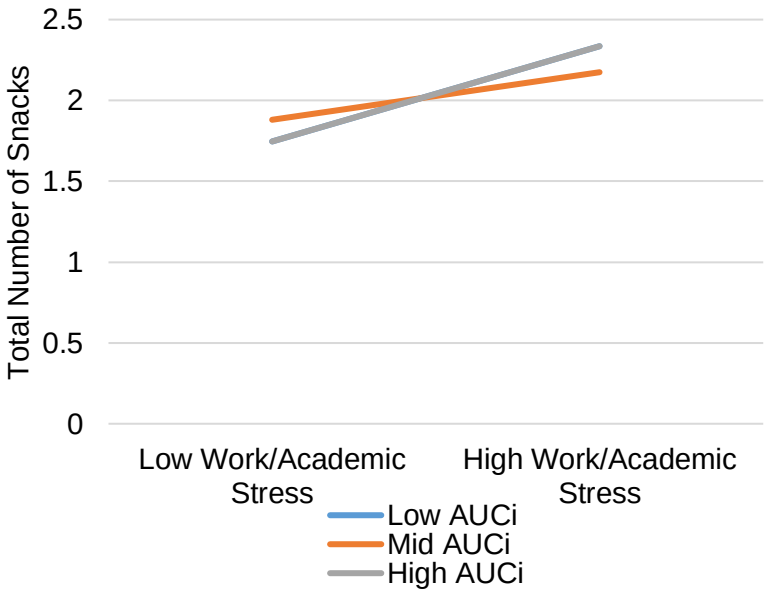


**Figure 4-15. Simple slopes for the moderating effect of AUCi on work/academic stress and total snack intake across the whole sample.**

Finally, the simple slopes for the relationship between ego-threatening stress and eating at low (-237.39), mean (0) and high (237.39) levels of AUCi are illustrated in Figure 4-16.

The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.52, *t(121)* = 4.45, *p* < .001), to mean (*coefficient* = 0.24, *t(121)* = 2.67, *p* = .008) to high (*coefficient* = -0.04, *t(121)* = -0.28, *p* = .782) levels of cortisol reactivity, the impact of ego-threatening stress on eating decreased. Ego-threatening stress was significantly, positively associated with eating at low and mean levels of AUCi, but not at high levels of AUCi across the whole sample.

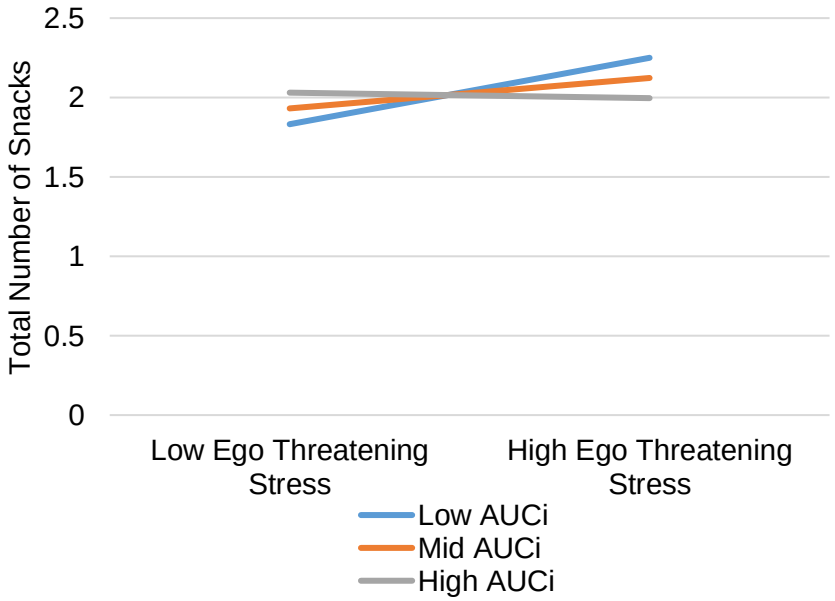


**Figure 4-16. Simple slopes for the moderating effect of AUCi on ego threatening stress and total snack intake across the whole sample.**

#### 4.4.7.1 Stress reactivity in adolescents

AUCg was on average lower in adolescents (mean = 426.15 nmol/L) compared to young adults indicating that adolescents experienced reduced activation of the HPA axis across the stress task. In contrast, AUCi was greater in adolescents than young adults (mean = 138.41 nmol/L), indicating that adolescents experienced greater activation of the HPA axis in response to the stress task. Cortisol levels (nmol/L) showed an increase following the stress task which returned to baseline levels by the final sampling point at +40 minutes

following completion of the TSST-G; baseline sample mean = 4.56nmol/L, sample 2 (+00 minutes) mean = 7.72nmol/L, sample 3 (+10 minutes) mean = 8.14nmol/L, sample 4 (+40 minutes) mean = 5.13 nmol/L.

Cross-level models were used to investigate the moderating effect of stress reactivity on total stress and total snack intake in adolescents (see Table 4-23 for results). Analyses indicated no main effect of trier group size, AUCg or AUCi on total snack intake in adolescents. A moderating effect was found for AUCi on total stress and total snacks in adolescents ($\beta$ <-.001, $p$ = .045), but not for AUCg.

**Table 4-23. Summary of results for the moderating effect of stress reactivity (AUCg and AUCi) on total stress and total snack intake in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.020 | 0.150 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.216 | 0.062 | <.001 |
| Group size - snacks | $\beta_{01}$ | -0.109 | 0.100 | .281 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .435 |
| Group size x stress –snacks | $\beta_{11}$ | -0.016 | 0.062 | .791 |
| AUCg x stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .156 |
| Snacks | $\beta_{00}$ | 2.021 | 0.150 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.216 | 0.060 | <.001 |
| Group size - snacks | $\beta_{01}$ | -0.067 | 0.107 | .537 |
| AUCi – snacks | $\beta_{02}$ | <.001 | <.001 | .886 |
| Group size x stress –snacks | $\beta_{11}$ | -0.005 | 0.060 | .940 |
| AUCi x stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .045 |

The simple slopes for the relationship between stress and eating at low (-238.37), mean (0) and high (238.37) levels of AUCi are illustrated in Figure 4-24. The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.34, *t(57)* = 4.15, *p* < .001), to the mean (*coefficient* = 0.22, *t(57)* = 3.67, *p* < .001), to high (*coefficient* = 0.10, *t(57)* = 1.19, *p* = .240) levels of cortisol reactivity, the impact of stress on eating in adolescents decreased. Stress was significantly positively related to eating across low and mean levels of AUCi in adolescents, but not high levels of AUCi.

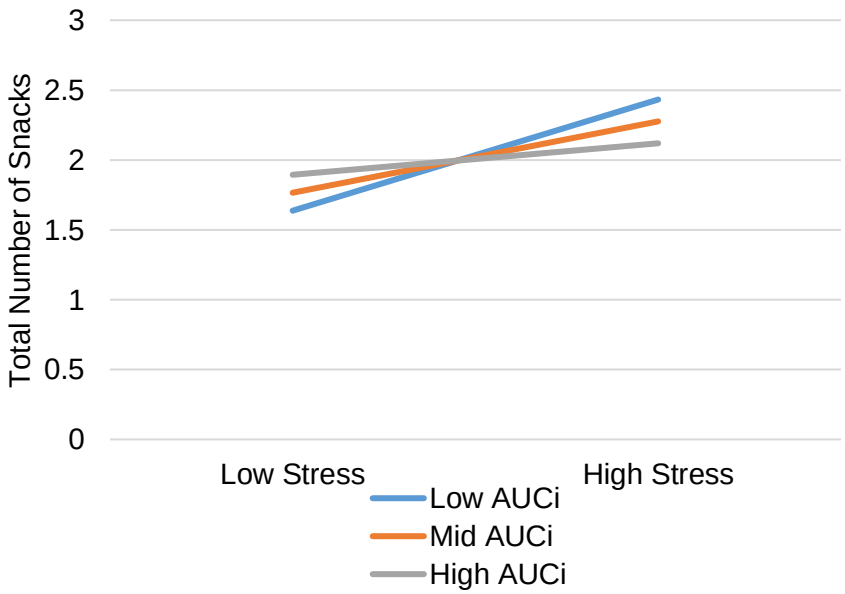


**Figure 4-17. Simple slopes for the moderating effect of AUCi on total stress and total snack intake in adolescents.**

The moderating effect of cortisol reactivity (AUCg and AUCi) on total stress and type of between meal snacks was investigated using cross-level models (see Table 4-24 and Table 4-25 for results). The analyses indicated no main effects of AUCg or group size on total stress and the type of snack intake in adolescents, although the effect of AUCg on high sugar snacks was trending towards significant ($\beta$ < 0.001, *p* = .067). A moderating effect was found for AUCg on total stress and snacks which were low-to-medium in fat and sugar content ($\beta$ < - 0.001, *p* = .020). No moderating effects were found on total stress and snacks high in fat only, high in sugar only, high in fat and sugar, or portions of fruit and vegetables.

Similarly, analyses indicated no main effect of AUCi on type of between meal snacks in adolescents, although the effect of AUCi on high sugar snacks was trending towards significant ($\beta$ < 0.001, $p$ = .072). A moderating effect was found for AUCi on total stress and snacks low-to-medium in fat and sugar content ($\beta$ < - 0.001, $p$ = .021). No moderating effects were found on total stress and snacks high in fat only, high in sugar only, high in both fat and sugar, or portions of fruit and vegetables.

**Table 4-24. Summary of results for the moderating effect of stress reactivity (AUCg) on total stress and type of snack intake in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| High fat snacks | $\beta_{00}$ | 0.416 | 0.048 | <.001 |
| *L1 Slope*: Total stress and high fat snacks | $\beta_{10}$ | 0.029 | 0.042 | .491 |
| Group size – high fat snacks | $\beta_{01}$ | -0.021 | 0.038 | .587 |
| AUCg – high fat snacks | $\beta_{02}$ | < -.001 | <.001 | .155 |
| Group size x stress – high fat snacks | $\beta_{11}$ | -0.020 | 0.029 | .486 |
| AUCg x stress – high fat snacks | $\beta_{12}$ | <.001 | <.001 | .820 |
| High sugar snacks | $\beta_{00}$ | 0.289 | 0.039 | <.001 |
| *L1 Slope*: Total stress and high sugar snacks | $\beta_{10}$ | 0.017 | 0.030 | .562 |
| Group size – high sugar snacks | $\beta_{01}$ | -0.005 | 0.026 | .847 |
| AUCg – high sugar snacks | $\beta_{02}$ | <.001 | <.001 | .067 |
| Group size x stress – high sugar snacks | $\beta_{11}$ | -0.005 | 0.024 | .829 |
| AUCg x stress – high sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .405 |
| High fat & sugar snacks | $\beta_{00}$ | 0.575 | 0.050 | <.001 |
| *L1 Slope*: Stress and high fat & sugar snacks | $\beta_{10}$ | 0.045 | 0.033 | .180 |
| Group size – high fat & sugar snacks | $\beta_{01}$ | 0.006 | 0.040 | .887 |
| AUCg – high fat & sugar snacks | $\beta_{02}$ | <.001 | <.001 | .320 |
| Group size x stress – high fat & sugar snacks | $\beta_{11}$ | -0.006 | 0.035 | .870 |
| AUCg x stress – high fat & sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .678 |

***Table 4-24 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.738 | 0.110 | <.001 |
| *L1 Slope*: Total stress and low-to-medium snacks | $\beta_{10}$ | 0.102 | 0.037 | .008 |
| Group size – low-to-medium snacks | $\beta_{01}$ | -0.089 | 0.069 | .205 |
| AUCg – low-to-medium snacks | $\beta_{02}$ | <.001 | <.001 | .588 |
| Group size x stress – low-to-medium snacks | $\beta_{11}$ | 0.035 | 0.036 | .332 |
| AUCg x stress – low-to-medium snacks | $\beta_{12}$ | < -.001 | <.001 | .020 |
| Fruit & vegetable intake | $\beta_{00}$ | 2.030 | 0.200 | <.001 |
| *L1 Slope*: Total stress and fruit & vegetable intake | $\beta_{10}$ | -0.051 | 0.049 | .305 |
| Group size - fruit & vegetable intake | $\beta_{01}$ | 0.225 | 0.206 | .280 |
| AUCg – fruit & vegetable intake | $\beta_{02}$ | -0.001 | <.001 | .177 |
| Group size x stress – fruit & vegetable intake | $\beta_{11}$ | -0.145 | 0.048 | .004 |
| AUCg x stress - fruit & vegetable intake | $\beta_{12}$ | <.001 | <.001 | .417 |

**Table 4-25. Summary of results for the moderating effect of stress reactivity (AUCi) on total stress and type of snack intake in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| High fat snacks | $\beta_{00}$ | 0.416 | 0.048 | <.001 |
| *L1 Slope*: Total stress and high fat snacks | $\beta_{10}$ | 0.028 | 0.042 | .506 |
| Group size – high fat snacks | $\beta_{01}$ | -0.011 | 0.039 | .777 |
| AUCi – high fat snacks | $\beta_{02}$ | < -.001 | <.001 | .072 |
| Group size x stress – high fat snacks | $\beta_{11}$ | -0.031 | 0.027 | .268 |
| AUCi x stress – high fat snacks | $\beta_{12}$ | <.001 | <.001 | .397 |
| High sugar snacks | $\beta_{00}$ | 0.290 | 0.040 | <.001 |
| *L1 Slope*: Total stress and high sugar snacks | $\beta_{10}$ | 0.016 | 0.031 | .595 |
| Group size – high sugar snacks | $\beta_{01}$ | 0.023 | 0.029 | .435 |
| AUCi – high sugar snacks | $\beta_{02}$ | <.001 | <.001 | .899 |
| Group size x stress – high sugar snacks | $\beta_{11}$ | 0.005 | 0.025 | .830 |
| AUCi x stress – high sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .200 |
| High fat & sugar snacks | $\beta_{00}$ | 0.575 | 0.050 | <.001 |
| *L1 Slope*: Stress and high fat & sugar snacks | $\beta_{10}$ | 0.044 | 0.031 | .168 |
| Group size – high fat & sugar snacks | $\beta_{01}$ | 0.020 | 0.029 | .600 |
| AUCi – high fat & sugar snacks | $\beta_{02}$ | <.001 | <.001 | .649 |
| Group size x stress – high fat & sugar snacks | $\beta_{11}$ | 0.003 | 0.034 | .932 |
| AUCi x stress – high fat & sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .260 |

***Table 4-25 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.738 | 0.107 | <.001 |
| *L1 Slope*: Total stress and low-to-medium snacks | $\beta_{10}$ | 0.097 | 0.038 | .013 |
| Group size – low-to-medium snacks | $\beta_{01}$ | -0.113 | 0.070 | .111 |
| AUCi – low-to-medium snacks | $\beta_{02}$ | <.001 | <.001 | .244 |
| Group size x stress – low-to-medium snacks | $\beta_{11}$ | 0.040 | 0.037 | .290 |
| AUCi x stress – low-to-medium snacks | $\beta_{12}$ | < -.001 | <.001 | .021 |
| Fruit & vegetable intake | $\beta_{00}$ | 2.027 | 0.202 | <.001 |
| *L1 Slope*: Total stress and fruit & vegetable intake | $\beta_{10}$ | -0.050 | 0.047 | .294 |
| Group size - fruit & vegetable intake | $\beta_{01}$ | 0.097 | 0.215 | .655 |
| AUCi – fruit & vegetable intake | $\beta_{02}$ | <.001 | <.001 | .748 |
| Group size x stress – fruit & vegetable intake | $\beta_{11}$ | -0.147 | 0.051 | .005 |
| AUCi x stress - fruit & vegetable intake | $\beta_{12}$ | <.001 | <.001 | .405 |

Simple slopes analysis was used to determine the moderating effect of cortisol reactivity (AUCg and AUCi) on stress and low-to-medium snack intake in adolescents.

The simple slopes for the relationship between total stress and low-to-medium fat and sugar snacks at low (-255.75), mean (0) and high (255.75) levels of AUCg are illustrated in Figure 4-18. The slopes demonstrated that as AUCg increased from low (*coefficient* = 0.19, *t(57)* = 4.08, *p* < .001), to the mean (*coefficient* = 0.10, *t(57)* = 2.82, *p* = .007) to high (*coefficient* = 0.02, *t(57)* = 0.28, *p* = .783) levels of cortisol reactivity, the impact of total stress on low-to-medium fat and sugar snacks decreased. Total stress was significantly positively related to low-to-medium snack intake at low and mean levels of AUCg, but not high levels of AUCg.

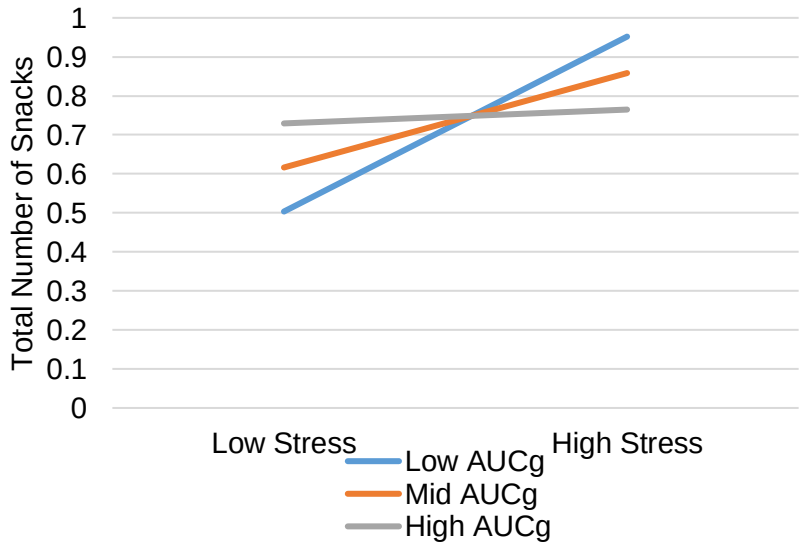


**Figure 4-18. Simple slopes for the moderating effect of AUCg on total stress and snacks low-to-medium in fat and sugar snacks (adolescents).**

The simple slopes for the relationship between stress and low-to-medium fat and sugar snacks at low (-238.37) mean (0) and high (238.37) levels of AUCi are illustrated in Figure 4-19. The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.18, *t(57)* = 4.02, *p* < .001), to the mean (*coefficient* = 0.10, *t(57)* = 2.65, *p* = .010), to high (*coefficient* = 0.02, *t(57)* = 0.33, *p* = .746) levels of cortisol reactivity, the impact of stress on eating in adolescents

decreased. Stress was significantly positively related to low-to-medium snack intake across low and mean levels of AUCi in adolescents, but not high levels of AUCi.

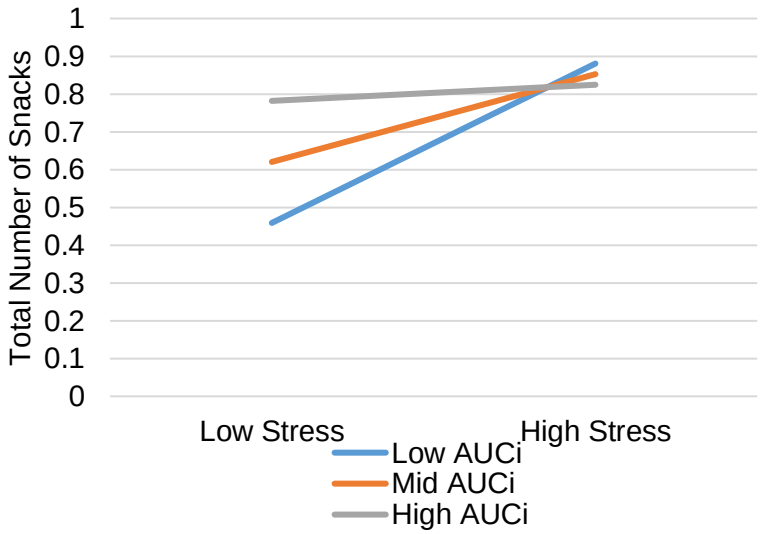


**Figure 4-19. Simple slopes for the moderating effect of AUCi on total stress and snacks low-to-medium in fat and sugar snacks (adolescents).**

Finally, the moderating effect of cortisol reactivity (AUCg and AUCi) on type of stress and total snacks in adolescents was investigated using cross-level models (see Table 4-26 and Table 4-27 for results).

The analyses indicated no main effects for stress reactivity (AUCg) on total snack intake in adolescents. A moderating effect was found for AUCg for ego-threatening ($\beta$ =-0.001, $p$ = .048) and work/academic stress on total snack intake ($\beta$ =-0.001, $p$ = .002). No moderating effects of AUCg were found on interpersonal, physical or other stressors on total snack intake in adolescents.

Similarly, no main effects were found for AUCi on type of stressors and total snack intake in adolescents. A moderating effect was also found for AUCi on ego-threatening ($\beta$ = -0.002, $p$ = .003) and work/academic stress ($\beta$ = -0.001, $p$ <.001) on total snack intake. AUCi did not moderate interpersonal, physical or other stressors on total snack intake in adolescents.

**Table 4-26. Summary of results for the moderating effect of stress reactivity (AUCg) on type of stress and total snack intake in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.020 | 0.150 | <.001 |
| *L1 Slope*: Ego-threat and snacks | $\beta_{10}$ | 0.274 | 0.143 | .061 |
| Group size - snacks | $\beta_{01}$ | -0.109 | 0.100 | .279 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .436 |
| Group size x ego-threat –snacks | $\beta_{11}$ | -0.180 | 0.156 | .255 |
| AUCg x ego-threat -snacks | $\beta_{12}$ | -0.001 | <.001 | .048 |
| Snacks | $\beta_{00}$ | 2.020 | 0.150 | <.001 |
| *L1 Slope*: Interpersonal and snacks | $\beta_{10}$ | 0.196 | 0.133 | .145 |
| Group size - snacks | $\beta_{01}$ | -0.110 | 0.100 | .276 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .434 |
| Group size x interpersonal -snacks | $\beta_{11}$ | 0.056 | 0.105 | .597 |
| AUCg x interpersonal -snacks | $\beta_{12}$ | <.001 | <.001 | .529 |
| Snacks | $\beta_{00}$ | 2.022 | 0.150 | <.001 |
| *L1 Slope*: Work/academic stress and snacks | $\beta_{10}$ | 0.170 | 0.100 | .096 |
| Group size - snacks | $\beta_{01}$ | -0.106 | 0.100 | .292 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .432 |
| Group size x work/academic stress –snacks | $\beta_{11}$ | 0.065 | 0.085 | .444 |
| AUCg x work/academic stress -snacks | $\beta_{12}$ | -0.001 | <.001 | .002 |

***Table 4-26 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.020 | 0.150 | <.001 |
| *L1 Slope*: Physical stress and snacks | $\beta_{10}$ | 0.260 | 0.116 | .029 |
| Group size - snacks | $\beta_{01}$ | -0.109 | 0.100 | .278 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .432 |
| Group size x physical stress –snacks | $\beta_{11}$ | -0.035 | 0.126 | .784 |
| AUCg x physical stress -snacks | $\beta_{12}$ | <.001 | <.001 | .244 |
| Snacks | $\beta_{00}$ | 2.020 | 0.150 | <.001 |
| *L1 Slope*: Other stress and snacks | $\beta_{10}$ | 0.184 | 0.139 | .191 |
| Group size - snacks | $\beta_{01}$ | -0.109 | 0.100 | .277 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .436 |
| Group size x other stress –snacks | $\beta_{11}$ | -0.098 | 0.138 | .481 |
| AUCg x other stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .990 |

**Table 4-27. Summary of results for the moderating effect of stress reactivity (AUCi) on type of stress and total snack intake in adolescents.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.021 | 0.150 | <.001 |
| *L1 Slope*: Ego-threat and snacks | $\beta_{10}$ | 0.285 | 0.137 | .041 |
| Group size - snacks | $\beta_{01}$ | -0.067 | 0.107 | .533 |
| AUCi – snacks | $\beta_{02}$ | <.001 | <.001 | .883 |
| Group size x ego-threat –snacks | $\beta_{11}$ | -0.157 | 0.149 | .296 |
| AUCi x ego-threat -snacks | $\beta_{12}$ | -0.002 | <.001 | .003 |
| Snacks | $\beta_{00}$ | 2.021 | 0.150 | <.001 |
| *L1 Slope*: Interpersonal and snacks | $\beta_{10}$ | 0.193 | 0.136 | .160 |
| Group size - snacks | $\beta_{01}$ | -0.069 | 0.107 | .522 |
| AUCi – snacks | $\beta_{02}$ | <.001 | <.001 | .870 |
| Group size x interpersonal –snacks | $\beta_{11}$ | 0.062 | 0.123 | .613 |
| AUCi x interpersonal -snacks | $\beta_{12}$ | <.001 | <.001 | .643 |
| Snacks | $\beta_{00}$ | 2.023 | 0.150 | <.001 |
| *L1 Slope*: Work/academic stress and snacks | $\beta_{10}$ | 0.170 | 0.097 | .088 |
| Group size - snacks | $\beta_{01}$ | -0.063 | 0.108 | .561 |
| AUCi – snacks | $\beta_{02}$ | <.001 | <.001 | .894 |
| Group size x work/academic stress –snacks | $\beta_{11}$ | 0.074 | 0.087 | .398 |
| AUCi x work/academic stress -snacks | $\beta_{12}$ | -0.002 | <.001 | <.001 |

***Table 4-27 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.021 | 0.150 | <.001 |
| *L1 Slope*: Physical stress and snacks | $\beta_{10}$ | 0.265 | 0.121 | .032 |
| Group size - snacks | $\beta_{01}$ | -0.067 | 0.107 | .533 |
| AUCi – snacks | $\beta_{02}$ | <.001 | <.001 | .883 |
| Group size x physical stress –snacks | $\beta_{11}$ | -0.011 | 0.118 | .929 |
| AUCi x physical stress -snacks | $\beta_{12}$ | <.001 | <.001 | .387 |
| Snacks | $\beta_{00}$ | 2.021 | 0.150 | <.001 |
| *L1 Slope*: Other stress and snacks | $\beta_{10}$ | 0.184 | 0.144 | .207 |
| Group size - snacks | $\beta_{01}$ | -0.069 | 0.107 | .524 |
| AUCi – snacks | $\beta_{02}$ | <.001 | <.001 | .874 |
| Group size x other stress –snacks | $\beta_{11}$ | -0.090 | 0.133 | .502 |
| AUCi x other stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .921 |

The simple slopes for the relationship between ego-threatening stress and total snacks at low (-255.75), mean (0) and high (255.75) levels of AUCg are illustrated above in Figure 4-20.

The slopes demonstrated that as AUCg increased from low (*coefficient* = 0.702, *t(57)* = 3.391, *p* = .001), to the mean (*coefficient* = 0.278, *t(57)* = 1.807, *p* = .076) to high (*coefficient* = -0.147, *t(57)* = -0.576, *p* = .567) levels of cortisol reactivity, the impact of ego-threatening stress on snack intake decreased. Ego-threatening stress was significantly associated with total snack intake at low levels of AUCg, but not at mean or high levels of AUCg.

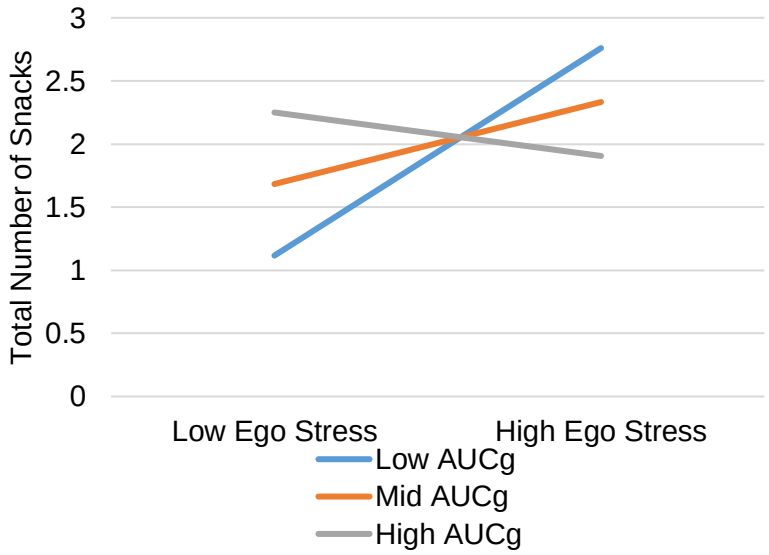


**Figure 4-20. Simple slopes for the moderating effect of AUCg on ego-threatening stress and total snack intake in adolescents.**

The simple slopes for the relationship between work/academic stress and total snacks at low (-255.75), mean (0) and high (255.75) levels of AUCg are illustrated above in Figure 4-21. The slopes demonstrated that as AUCg increased from low (*coefficient* = 0.503, *t(57)* = 3.424, *p* = .001), to the mean (*coefficient* = 0.172, *t(57)* = 1.729, *p* = .089) to high (*coefficient* = -0.158, *t(57)* = -0.987, *p* = .328) levels of cortisol reactivity, the impact of work/academic stress on snack intake decreased. Work/academic stress was significantly associated with total snack intake at low levels of AUCg, but not at mean or high levels of AUCg.

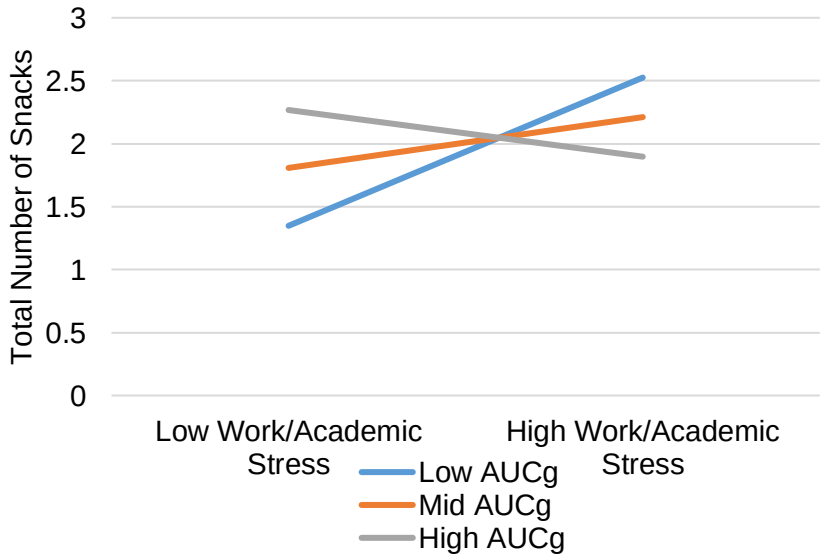


**Figure 4-21. Simple slopes for the moderating effect of AUCg on work/academic stress and total snack intake in adolescents.**

The simple slopes for the relationship between ego-threatening stress and total snacks at low (-238.37), mean (0) and high (238.37) levels of AUCi are illustrated above in Figure 4-22.

The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.788, *t(57)* = 4.066, *p* < .001), to the mean (*coefficient* = 0.294, *t(57)* = 1.987, *p* = .052) to high (*coefficient* = -0.201, *t(57)* = -0.834, *p* = .408) levels of cortisol reactivity, the impact of ego-threatening stress on snack intake decreased. Ego-threatening stress was significantly associated with total snack intake at low levels of AUCi, but not at mean or high levels of AUCi.

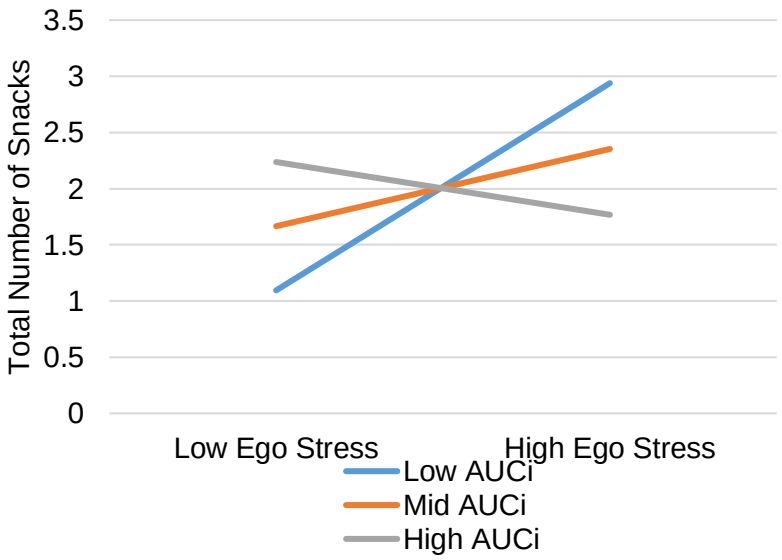


**Figure 4-22. Simple slopes for the moderating effect of AUCi on ego-threatening stress and total snack intake in adolescents.**

The simple slopes for the relationship between work/academic stress and total snacks at low (-238.37), mean (0) and high (238.37) levels of AUCi are illustrated above in Figure 4-23.

The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.516, *t(57)* = 3.382, *p* < .001), to the mean (*coefficient* = 0.173, *t(57)* = 1.776, *p* = .081) to high (*coefficient* = -0.170, *t(57)* = -1.068, *p* = .290) levels of cortisol reactivity, the impact of work/academic stress on snack intake decreased.

Work/academic stress was significantly associated with total snack intake at low levels of AUCi, but not at mean or high levels of AUCi.

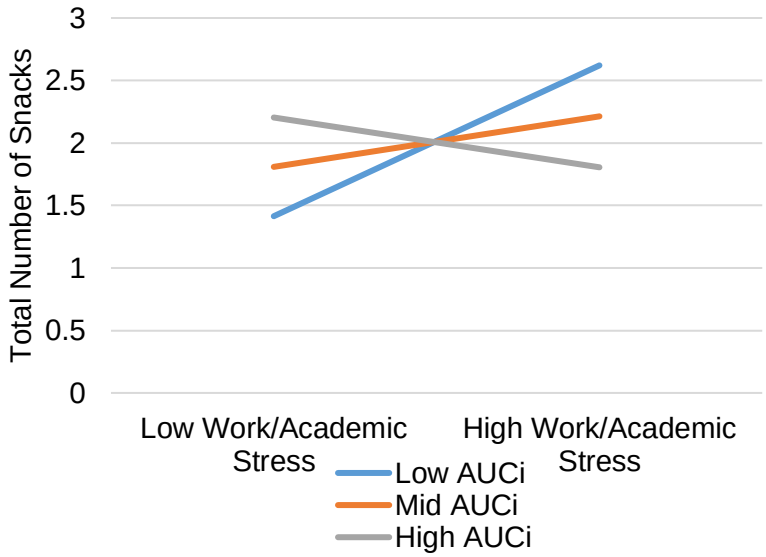


**Figure 4-23. Simple slopes for the moderating effect of AUCi on work/academic stress and total snack intake in young adults.**

#### 4.4.7.2 Stress reactivity in young adults

AUCg was on average higher in young adults compared to adolescents (mean = 453.38 nmol/L), whilst AUCi was lower in young adults compared to adolescents (mean = 55.81 nmol/L). Cortisol levels (nmol/L) showed an increase following the stress task which returned to baseline levels by the final sampling point at +40 minutes following completion of the TSST-G; baseline sample mean = 6.10 nmol/L, sample 2 (+00 minutes) mean = 7.77 nmol/L, sample 3 (+10 minutes) mean = 7.86 nmol/L, sample 4 (+40 minutes) mean = 5.42 nmol/L.

Cross-level models were used to investigate the moderating effect of stress reactivity on total stress and total snack intake in young adults (see Table 4-28 for results). Analyses indicated no main effects of trier group size, AUCg or AUCi on total snack intake, although AUCg was trending towards significant ($\beta$ < .001, $p$ = .063). A moderating effect was found for both AUCg ($\beta$ < -.001, $p$ = .030) and AUCi ($\beta$ < -.001, $p$ < .001) on total stress and total snacks in young adults.

**Table 4-28. Summary of results for the moderating effect of stress reactivity (AUCg and AUCi) on total stress and total snack intake in young adults.**

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.044 | 0.115 | <.001 |
| *L1 Slope*: Stress and Snacks | $\beta_{10}$ | 0.156 | 0.049 | .002 |
| Group size - snacks | $\beta_{01}$ | 0.051 | 0.092 | .580 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .063 |
| Group size x stress –snacks | $\beta_{11}$ | -0.005 | 0.051 | .921 |
| AUCg x stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .030 |
| Snacks | $\beta_{00}$ | 2.044 | 0.116 | <.001 |
| *L1 Slope*: Stress and Snacks | $\beta_{10}$ | 0.145 | 0.047 | .003 |
| Group size - snacks | $\beta_{01}$ | 0.096 | 0.101 | .348 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .742 |
| Group size x stress –snacks | $\beta_{11}$ | -0.030 | 0.048 | .536 |
| AUCi x stress -snacks | $\beta_{12}$ | <-.001 | <.001 | <.001 |

The simple slopes for the relationship between stress and eating at low (-220.35), mean (0) and high (220.35) levels of AUCg are illustrated in Figure 4-24. The slopes demonstrated that as AUCg increased from low (*coefficient* = 0.28, *t(62)* = 4.04, *p* < .001), to the mean (*coefficient* = 0.16, *t(62)* = 3.15, *p* = .003), to high (*coefficient* = 0.04, *t(62)* = 0.58, *p* = .562) levels of cortisol reactivity, the impact of stress on eating in young adults decreased. Stress was significantly positively related to eating across low and mean levels of AUCg, but not high levels of AUCg.

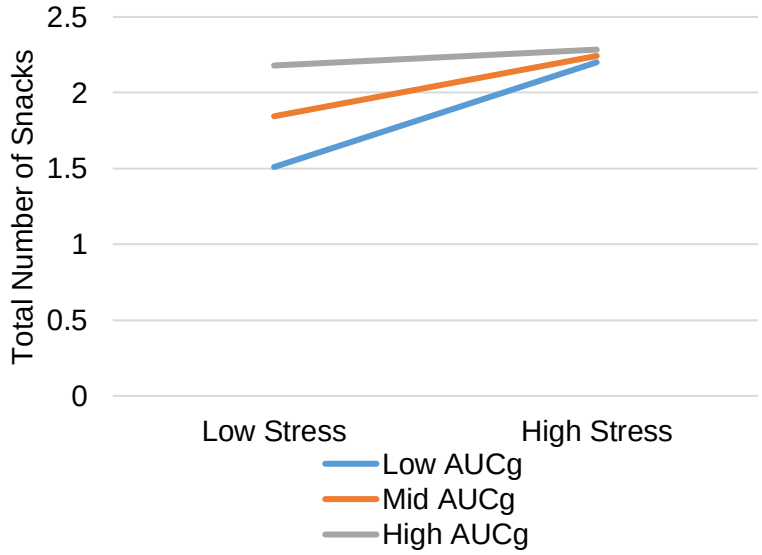


**Figure 4-24. Simple slopes for the moderating effect of AUCg on total stress and total snack intake in young adults.**

The simple slopes for the relationship between stress and eating at low (-217.37), mean (0) and high (217.37) levels of AUCi are illustrated in Figure 4-25.

The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.29, *t(62)* = 4.49, *p* < .001), to the mean (*coefficient* = 0.15, *t(62)* = 3.07, *p* = .003), to high (*coefficient* = 0.01, *t(62)* = 0.16, *p* = .871) levels of cortisol reactivity, the impact of stress on eating in young adults decreased. Stress was significantly positively related to eating across low and mean levels of AUCi, but not high levels of AUCi.

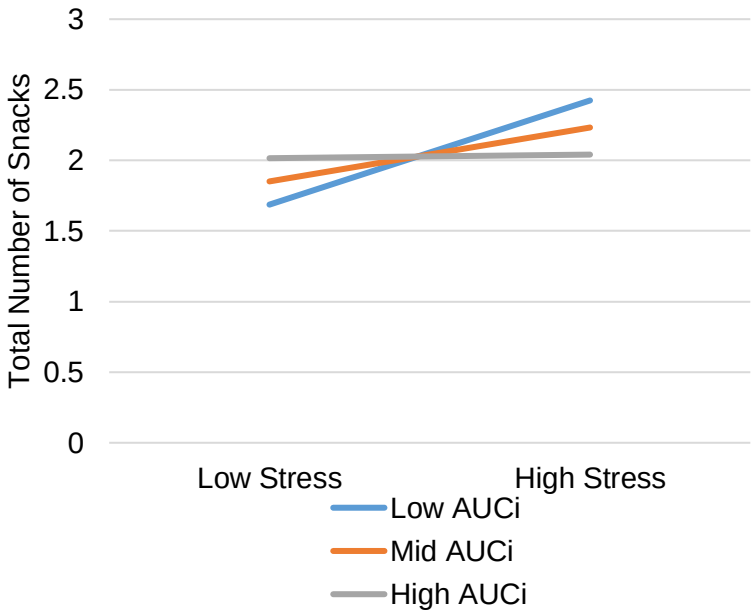


**Figure 4-25. Simple slopes for the moderating effect of AUCi on total stress and total snack intake in young adults.**

The moderating effect of cortisol reactivity (AUCg and AUCi) on total stress and type of between meal snacks was investigated using cross-level models (see Table 4-29 and Table 4-30 for results).

The analyses indicated a main effect of AUCg on snacks high in sugar in young adults ($\beta$ < -.001, $p$ = .011). No main effects were found on high fat, high fat and sugar, low-to-medium snacks or portions of fruit and vegetables, although the effect of AUCg on snacks low-to-medium in fat and sugar was trending towards significant ($\beta$ < 0.001, $p$ = .053).

A moderating effect was found for AUCg on total stress and snacks high in sugar ($\beta$ < - 0.001, $p$ = .047). No moderating effects were found on total stress and snacks high in fat only, high in fat and sugar, low-to-medium in fat and sugar, or portions of fruit and vegetables.

Similarly, analyses indicated no main effects for AUCi on type of between meal snacks in young adults. A moderating effect was found for AUCi on total stress and snacks high in fat and sugar content ($\beta$ < - 0.001, $p$ = .008). Furthermore, AUCi moderated total stress and snacks high in fat ($\beta$ < - 0.001, $p$ = .005), and snacks high in sugar ($\beta$ < - 0.001, $p$ = .007). No moderating effects

were found on snacks low-to-medium in fat and sugar content, or portions of fruit and vegetables.

**Table 4-29. Summary of results for the moderating effect of stress reactivity (AUCg) on total stress and type of snack intake in young adults.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| High fat snacks | $\beta_{00}$ | 0.349 | 0.040 | <.001 |
| *L1 Slope*: Total stress and high fat snacks | $\beta_{10}$ | -0.003 | 0.023 | .901 |
| Group size – high fat snacks | $\beta_{01}$ | 0.032 | 0.031 | .314 |
| AUCg – high fat snacks | $\beta_{02}$ | <.001 | <.001 | .494 |
| Group size x stress – high fat snacks | $\beta_{11}$ | -0.003 | 0.017 | .872 |
| AUCg x stress – high fat snacks | $\beta_{12}$ | < -.001 | <.001 | .977 |
| High sugar snacks | $\beta_{00}$ | 0.259 | 0.031 | <.001 |
| *L1 Slope*: Total stress and high sugar snacks | $\beta_{10}$ | 0.030 | 0.016 | .070 |
| Group size – high sugar snacks | $\beta_{01}$ | < -.001 | 0.024 | .968 |
| AUCg – high sugar snacks | $\beta_{02}$ | < -.001 | <.001 | .011 |
| Group size x stress – high sugar snacks | $\beta_{11}$ | 0.019 | 0.012 | .132 |
| AUCg x stress – high sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .047 |
| High fat & sugar snacks | $\beta_{00}$ | 0.561 | 0.042 | <.001 |
| *L1 Slope*: Stress and high fat & sugar snacks | $\beta_{10}$ | 0.037 | 0.025 | .141 |
| Group size – high fat & sugar snacks | $\beta_{01}$ | -0.009 | 0.041 | .825 |
| AUCg – high fat & sugar snacks | $\beta_{02}$ | <.001 | <.001 | .113 |
| Group size x stress – high fat & sugar snacks | $\beta_{11}$ | 0.017 | 0.031 | .582 |
| AUCg x stress – high fat & sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .229 |

***Table 4-29 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.878 | 0.075 | <.001 |
| *L1 Slope*: Total stress and low-to-medium snacks | $\beta_{10}$ | 0.085 | 0.035 | .019 |
| Group size – low-to-medium snacks | $\beta_{01}$ | 0.034 | 0.055 | .543 |
| AUCg – low-to-medium snacks | $\beta_{02}$ | <.001 | <.001 | .053 |
| Group size x stress – low-to-medium snacks | $\beta_{11}$ | -0.056 | 0.032 | .086 |
| AUCg x stress – low-to-medium snacks | $\beta_{12}$ | < -.001 | <.001 | .219 |
| Fruit & vegetable intake | $\beta_{00}$ | 3.291 | 0.204 | <.001 |
| *L1 Slope*: Total stress and fruit & vegetable intake | $\beta_{10}$ | 0.074 | 0.056 | .196 |
| Group size - fruit & vegetable intake | $\beta_{01}$ | -0.035 | 0.145 | .808 |
| AUCg – fruit & vegetable intake | $\beta_{02}$ | < -.001 | 0.001 | .896 |
| Group size x stress – fruit & vegetable intake | $\beta_{11}$ | -0.079 | 0.060 | .195 |
| AUCg x stress - fruit & vegetable intake | $\beta_{12}$ | < -.001 | <.001 | .188 |

**Table 4-30. Summary of results for the moderating effect of stress reactivity (AUCi) on total stress and type of snack intake in young adults.**

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| High fat snacks | $\beta_{00}$ | 0.349 | 0.040 | <.001 |
| *L1 Slope*: Total stress and high fat snacks | $\beta_{10}$ | -0.005 | 0.022 | .823 |
| Group size – high fat snacks | $\beta_{01}$ | 0.036 | 0.034 | .288 |
| AUCi – high fat snacks | $\beta_{02}$ | <.001 | <.001 | .579 |
| Group size x stress – high fat snacks | $\beta_{11}$ | -0.001 | 0.016 | .948 |
| AUCi x stress – high fat snacks | $\beta_{12}$ | < -.001 | <.001 | .005 |
| High sugar snacks | $\beta_{00}$ | 0.259 | 0.032 | <.001 |
| *L1 Slope*: Total stress and high sugar snacks | $\beta_{10}$ | 0.028 | 0.015 | .065 |
| Group size – high sugar snacks | $\beta_{01}$ | -0.012 | 0.025 | .620 |
| AUCi – high sugar snacks | $\beta_{02}$ | < -.001 | <.001 | .187 |
| Group size x stress – high sugar snacks | $\beta_{11}$ | 0.014 | 0.012 | .248 |
| AUCi x stress – high sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .007 |
| High fat & sugar snacks | $\beta_{00}$ | 0.561 | 0.043 | <.001 |
| *L1 Slope*: Stress and high fat & sugar snacks | $\beta_{10}$ | 0.034 | 0.024 | .170 |
| Group size – high fat & sugar snacks | $\beta_{01}$ | 0.008 | 0.040 | .847 |
| AUCi – high fat & sugar snacks | $\beta_{02}$ | <.001 | <.001 | .871 |
| Group size x stress – high fat & sugar snacks | $\beta_{11}$ | 0.010 | 0.030 | .749 |
| AUCi x stress – high fat & sugar snacks | $\beta_{12}$ | < -.001 | <.001 | .008 |
| Low-to-medium fat & sugar snacks | $\beta_{00}$ | 0.877 | 0.076 | <.001 |
| *L1 Slope*: Total stress and low-to-medium snacks | $\beta_{10}$ | 0.080 | 0.035 | .026 |
| Group size – low-to-medium snacks | $\beta_{01}$ | 0.066 | 0.059 | .265 |
| AUCi – low-to-medium snacks | $\beta_{02}$ | < -.001 | <.001 | .440 |
| Group size x stress – low-to-medium snacks | $\beta_{11}$ | -0.066 | 0.031 | .039 |
| AUCi x stress – low-to-medium snacks | $\beta_{12}$ | < -.001 | <.001 | .562 |

***Table 4-30 continued.***

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Fruit & vegetable intake | $\beta_{00}$ | 3.289 | 0.204 | <.001 |
| *L1 Slope*: Total stress and fruit & vegetable intake | $\beta_{10}$ | 0.066 | 0.057 | .248 |
| Group size - fruit & vegetable intake | $\beta_{01}$ | -0.028 | 0.132 | .831 |
| AUCi – fruit & vegetable intake | $\beta_{02}$ | < -.001 | 0.001 | .612 |
| Group size x stress – fruit & vegetable intake | $\beta_{11}$ | -0.099 | 0.058 | .094 |
| AUCi x stress - fruit & vegetable intake | $\beta_{12}$ | <.001 | <.001 | .926 |

Simple slopes analysis was used to determine the moderating effect of cortisol reactivity (AUCg and AUCi) on stress and type of snacks in young adults.

The simple slopes for the relationship between total stress and high sugar snacks at low (-220.35), mean (0) and high (220.35) levels of AUCg are illustrated in Figure 4-26. The slopes demonstrated that as AUCg increased from low (*coefficient* = 0.04, *t(62)* = 1.84, *p* = .070), to the mean (*coefficient* = 0.02, *t(62)* = 1.53, *p* = .131) to high (*coefficient* < .001, *t(62)* = 0.31, *p* = .755) levels of cortisol reactivity, the impact of total stress on high sugar snacks decreased. However, total stress was not significantly related to high sugar snack intake at low, mean or high levels of AUCg in young adults.

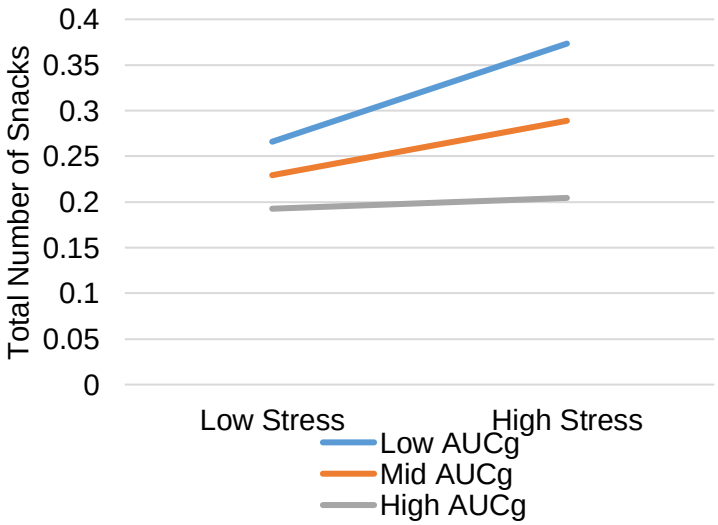


**Figure 4-26. Simple slopes for the moderating effect of AUCg on total stress and high sugar snack intake in young adults.**

The simple slopes for the relationship between total stress and high sugar snacks at low (-217.37), mean (0) and high (217.37) levels of AUCi are illustrated in Figure 4-27. The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.05, *t(62)* = 2.68, *p* = .009), to the mean (*coefficient* = 0.02, *t(62)* = 1.58, *p* = .119) to high (*coefficient* = -0.004, *t(62)* = -0.24, *p* = .815) levels of cortisol reactivity, the impact of total stress on high sugar snacks decreased. Total stress was significantly positively related to eating at low levels of AUCi in young adults, but not at mean or high levels of AUCi.

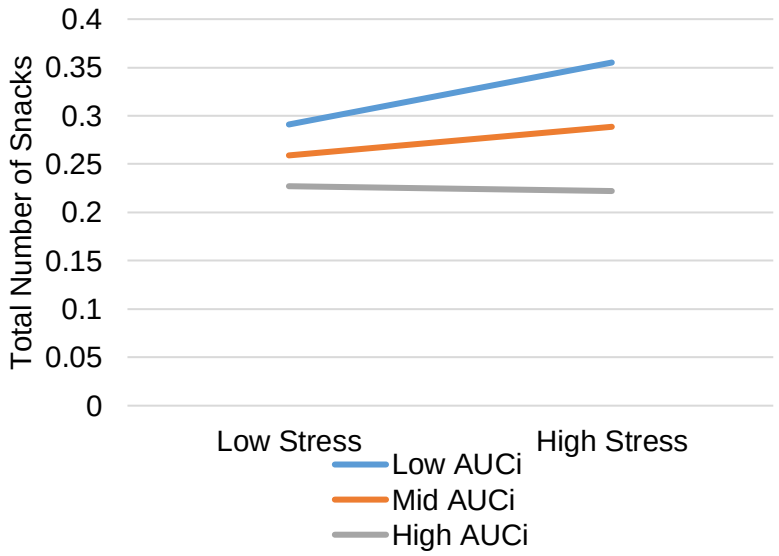


**Figure 4-27. Simple slopes for the moderating effect of AUCi on total stress and high sugar snack intake in young adults.**

The simple slopes for the relationship between total stress and high fat snacks at low (-217.37), mean (0) and high (217.37) levels of AUCi are illustrated in Figure 4-28.

The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.04, *t(62)* = 1.53, *p* = .132), to the mean (*coefficient* = -0.004, *t(62)* = -0.17, *p* = .865) to high (*coefficient* = -0.051, *t(62)* = -2.09, *p* = .041) levels of cortisol reactivity, the impact of total stress on high fat snacks decreased. Total stress was significantly positively related to eating at high AUCi in young adults, but not at low and mean levels of AUCi.

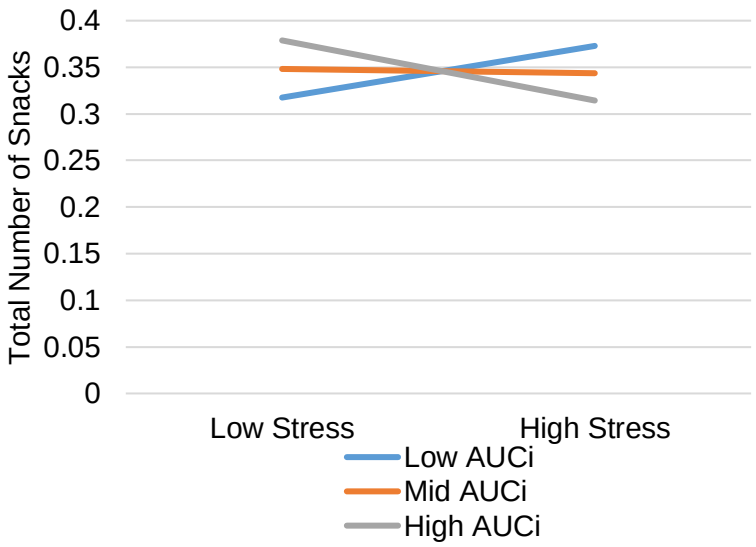


**Figure 4-28. Simple slopes for the moderating effect of AUCi on total stress and high fat snack intake in young adults.**

Finally, the simple slopes for the relationship between total stress and snacks high in both fat and sugar at low (-217.37), mean (0) and high (217.37) levels of AUCi are illustrated in Figure 4-29. The slopes demonstrated that as AUCi increased from low (*coefficient* = 0.08, *t(62)* = 2.51, *p* = .015), to the mean (*coefficient* = 0.032, *t(62)* = 1.21, *p* = .232) to high (*coefficient* = -0.013, *t(62)* = -0.40, *p* = .690) levels of cortisol reactivity, the impact of total stress on high fat and sugar snacks decreased. Total stress was significantly positively related to eating at low levels of AUCi in young adults, but not at mean and high levels of AUCi.

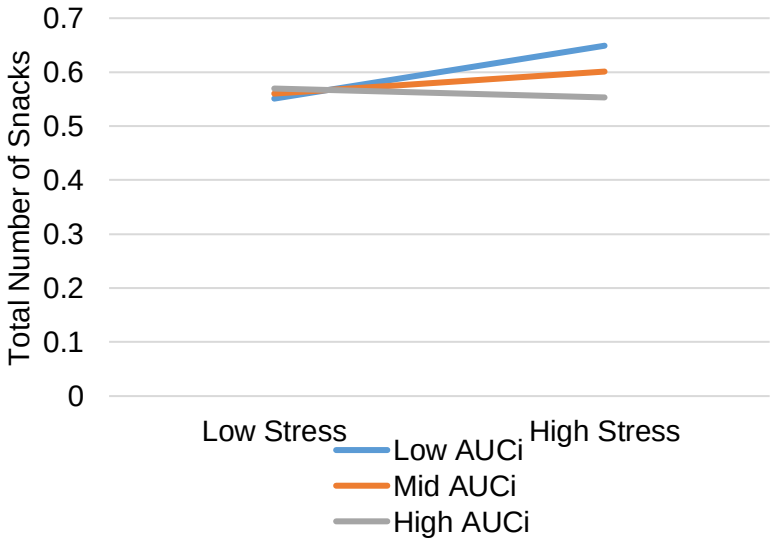


**Figure 4-29. Simple slopes for the moderating effect of AUCi on total stress and high fat and sugar snack intake in young adults.**

Finally, the moderating effect of stress reactivity (AUCg and AUCi) on type of stress and snack intake in young adults was investigated using cross-level models (see Table 4-31 and Table 4-32 for results).

The analyses indicated no main effects of stress reactivity (AUCg) on total snack intake in young adults, although findings were trending towards significant, ($\beta$ = -0.001, $p$ = .065). Similarly, no moderating effects were found on AUCg on the type of stress and total snack intake. No main effects were found for AUCi on total snack intake in young adults, although the effect of AUCg on physical stress and total snack intake was trending towards significant ($\beta$ < -.001, $p$ = .074). Furthermore, AUCi did not moderate the type of stress and total snack intake in young adults.

**Table 4-31. Summary of results for the moderating effect of stress reactivity (AUCg) on type of stress and total snack intake in young adults.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.045 | 0.115 | <.001 |
| *L1 Slope*: Ego-threat and Snacks | $\beta_{10}$ | 0.256 | 0.101 | .013 |
| Group size - snacks | $\beta_{01}$ | 0.051 | 0.092 | .582 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .065 |
| Group size x ego-threat –snacks | $\beta_{11}$ | -0.148 | 0.109 | .181 |
| AUCg x ego-threat -snacks | $\beta_{12}$ | <.001 | <.001 | .328 |
| Snacks | $\beta_{00}$ | 2.045 | 0.115 | <.001 |
| *L1 Slope*: Interpersonal and Snacks | $\beta_{10}$ | 0.052 | 0.084 | .539 |
| Group size - snacks | $\beta_{01}$ | 0.050 | 0.092 | .591 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .063 |
| Group size x interpersonal –snacks | $\beta_{11}$ | <-.001 | 0.096 | .996 |
| AUCg x interpersonal -snacks | $\beta_{12}$ | <-.001 | <.001 | .191 |

***Table 4-31 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.045 | 0.115 | <.001 |
| *L1 Slope*: Work/academic stress and Snacks | $\beta_{10}$ | 0.191 | 0.046 | <.001 |
| Group size - snacks | $\beta_{01}$ | 0.051 | 0.092 | .581 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .064 |
| Group size x work/academic stress –snacks | $\beta_{11}$ | -0.060 | 0.036 | .095 |
| AUCg x work/academic stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .556 |
| Snacks | $\beta_{00}$ | 2.044 | 0.115 | <.001 |
| *L1 Slope*: Physical stress and Snacks | $\beta_{10}$ | 0.011 | 0.049 | .820 |
| Group size - snacks | $\beta_{01}$ | 0.052 | 0.091 | .578 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .064 |
| Group size x physical stress –snacks | $\beta_{11}$ | -0.022 | 0.039 | .576 |
| AUCg x physical stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .074 |
| Snacks | $\beta_{00}$ | 2.045 | 0.115 | <.001 |
| *L1 Slope*: Other stress and Snacks | $\beta_{10}$ | 0.033 | 0.074 | .655 |
| Group size - snacks | $\beta_{01}$ | 0.051 | 0.092 | .585 |
| AUCg – snacks | $\beta_{02}$ | <.001 | <.001 | .064 |
| Group size x other stress –snacks | $\beta_{11}$ | -0.091 | 0.083 | .278 |
| AUCg x other stress -snacks | $\beta_{12}$ | <.001 | <.001 | .825 |

**Table 4-32. Summary of results for the moderating effect of stress reactivity (AUCi) on type of stress and total snack intake in young adults.**

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.044 | 0.116 | <.001 |
| *L1 Slope*: Ego-threat and Snacks | $\beta_{10}$ | 0.248 | 0.098 | .014 |
| Group size - snacks | $\beta_{01}$ | 0.096 | 0.101 | .348 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .735 |
| Group size x ego-threat –snacks | $\beta_{11}$ | -0.115 | 0.103 | .272 |
| AUCi x ego-threat -snacks | $\beta_{12}$ | <-.001 | <.001 | .134 |
| Snacks | $\beta_{00}$ | 2.044 | 0.116 | <.001 |
| *L1 Slope*: Interpersonal and Snacks | $\beta_{10}$ | 0.046 | 0.084 | .583 |
| Group size - snacks | $\beta_{01}$ | 0.094 | 0.101 | .355 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .733 |
| Group size x interpersonal –snacks | $\beta_{11}$ | -0.025 | 0.086 | .773 |
| AUCi x interpersonal -snacks | $\beta_{12}$ | <-.001 | <.001 | .116 |
| Snacks | $\beta_{00}$ | 2.044 | 0.116 | <.001 |
| *L1 Slope*: Work/academic stress and Snacks | $\beta_{10}$ | 0.192 | 0.046 | <.001 |
| Group size - snacks | $\beta_{01}$ | 0.096 | 0.101 | .348 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .735 |
| Group size x work/academic stress –snacks | $\beta_{11}$ | -0.062 | 0.037 | .094 |
| AUCi x work/academic stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .252 |
| Snacks | $\beta_{00}$ | 2.044 | 0.116 | <.001 |
| *L1 Slope*: Physical stress and Snacks | $\beta_{10}$ | 0.006 | 0.049 | .909 |
| Group size - snacks | $\beta_{01}$ | 0.096 | 0.101 | .347 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .734 |
| Group size x physical stress –snacks | $\beta_{11}$ | -0.036 | 0.036 | .329 |
| AUCi x physical stress -snacks | $\beta_{12}$ | <-.001 | <.001 | .129 |

***Table 4-32 continued.***

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 2.045 | 0.116 | <.001 |
| *L1 Slope*: Other stress and Snacks | $\beta_{10}$ | 0.033 | 0.075 | .660 |
| Group size - snacks | $\beta_{01}$ | 0.095 | 0.101 | .350 |
| AUCi – snacks | $\beta_{02}$ | <-.001 | <.001 | .733 |
| Group size x other stress –snacks | $\beta_{11}$ | -0.087 | 0.072 | .229 |
| AUCi x other stress -snacks | $\beta_{12}$ | <.001 | <.001 | .898 |

### 4.4.8 Moderating Effect of Hair Cortisol Concentrations on Total Stress and Total Snacks

Hair samples were obtained for 37 participants (14 adolescents and 23 young adults) and were analysed against 364 daily diaries. Hair sampling weight ranged from 2.1mg to 25.2mg. Average HCC over the previous month was higher in young adults (*mean* = 8.05pg/mg; range = 4.72pg/mg to 16.58pg/mg) compared to adolescents (*mean* = 6.52pg/mg; range = 3.20pg/mg to 12.59pg/mg).

Prior to analyses, ANOVA's were conducted to determine potential confounding effects of frequency of hair washing, smoking status and use of medications on HCCs. Analyses indicated that frequency of hair washing, $F(5, 31) = 0.48$, $p = .788$, smoking status, $F(1, 35) = 0.53$, $p = .473$, and use of medications were not associated with HCCs, $F(1, 35) = 5.02$, $p = .125$. Therefore, these variables were not controlled for in subsequent analyses. Finally, analyses were conducted to investigate associations between HCCs and stress reactivity measures. Pearson's correlations indicated that HCC was not associated with AUCg ($r = .292$, $p = .080$) or AUCi ($r = -.234$, $p = .161$).

Cross-level models were used to investigate the moderating effect of HCC on total stress and total snack intake, and type of snacks, across the 37 participants (see Table 4-33 for results). Analyses indicated no main effects of

HCC on total snack intake across the whole sample (*β* = 0.047, *p* = .457). Similarly, no main effects were found for HCC on the type of snacks.

HCC did not moderate the association between total stress and total snack intake (*β* = -0.003, *p* = .905), nor were any moderating effects found for total stress on the types of snacks.

**Table 4-33. Cross-level model for the moderating effect of hair cortisol on total stress and total snack intake, including types of snacks.**

| Model and Variables | β | Coefficient | SE | p |
|---|---|---|---|---|
| Snacks | $\beta_{00}$ | 1.994 | 0.139 | <.001 |
| *L1 Slope*: Stress and snacks | $\beta_{10}$ | 0.015 | 0.074 | .841 |
| HCC - snacks | $\beta_{01}$ | 0.047 | 0.062 | .457 |
| HCC x stress -snacks | $\beta_{11}$ | -0.003 | 0.029 | .905 |
| High fat snacks | $\beta_{00}$ | 0.308 | 0.040 | <.001 |
| *L1 Slope*: Stress and high fat snacks | $\beta_{10}$ | 0.022 | 0.029 | .370 |
| HCC – high fat snacks | $\beta_{01}$ | -0.022 | 0.013 | .099 |
| HCC x stress – high fat snacks | $\beta_{11}$ | -0.006 | 0.012 | .617 |
| High sugar snacks | $\beta_{00}$ | 0.214 | 0.026 | <.001 |
| *L1 Slope*: Stress and high sugar snacks | $\beta_{10}$ | -0.013 | 0.020 | .533 |
| HCC – high sugar snacks | $\beta_{01}$ | -0.001 | 0.009 | .889 |
| HCC x stress – high sugar snacks | $\beta_{11}$ | -0.002 | 0.008 | .846 |
| High fat & sugar snacks | $\beta_{00}$ | 0.524 | 0.056 | <.001 |
| *L1 Slope*: Stress and high fat & sugar snacks | $\beta_{10}$ | < -.001 | 0.031 | .990 |
| HCC – high fat & sugar snacks | $\beta_{01}$ | 0.017 | 0.018 | .356 |
| HCC x stress – high fat & sugar snacks | $\beta_{11}$ | 0.007 | 0.009 | .459 |

***Table 4-33 continued.***

| Model and Variables | $\beta$ | Coefficient | SE | p |
|---|---|---|---|---|
| Low-to-medium fat and sugar snacks | $\beta_{00}$ | 0.929 | 0.096 | <.001 |
| *L1 Slope*: Stress and low-to-medium snacks | $\beta_{10}$ | -0.002 | 0.055 | .971 |
| HCC – low-to-medium snacks | $\beta_{01}$ | 0.058 | 0.049 | .245 |
| HCC x stress – low-to-medium snacks | $\beta_{11}$ | -0.004 | 0.022 | .841 |
| Fruit & vegetable intake | $\beta_{00}$ | 3.497 | 0.298 | <.001 |
| *L1 Slope*: Stress and fruit & vegetable intake | $\beta_{10}$ | 0.009 | 0.094 | .923 |
| HCC – fruit & vegetable intake | $\beta_{01}$ | 0.049 | 0.080 | .546 |
| HCC x stress – fruit & vegetable intake | $\beta_{11}$ | 0.029 | 0.027 | .306 |

#### 4.4.8.1 Motivations and Barriers of Hair Sampling

Feedback was obtained via a brief questionnaire regarding potential motivations and barriers to providing hair samples in research. Of the 123 participants who took part in the study, 106 completed the hair feedback questionnaire (86.18%).

Using a 5-point Likert scale (from '*Very Unlikely'* to *'Very Likely'*), participants were asked how likely they would be to provide a hair sample for research. The majority of participants (*N* = 46; 43%) indicated that they would be likely or very likely to provide hair samples as part of research. Following this response, participants responded positively, commenting that they were willing because *"it is for research and could benefit people in the future", "it is unlikely to be noticeable"* and because *"it will grow back".* It is important to note that whilst participants responded positively towards providing hair samples, these responses did not translate to consenting to provide hair samples in the current study.

35% of participants said they were very unlikely or unlikely to provide hair samples. The main concerns for these participants were that they *"didn't realise how much hair is taken", "it will take ages to grow back"* and *"hair growing back at a different rate to the rest"*.

Finally, 22% of participants were undecided about providing hair samples for research. These participants commented that *"you may be able to see where the hair has been taken from", "the samples seem quite large to what I expected"* and *"only thought a few strands would be taken".* Taken together, these findings indicate that participants were predominately concerned with the aesthetic appearance following hair samples being taken, opposed to concerns regarding the physical process of taking samples or concerns regarding the use of biological samples as part of a research project. Finally, most participants (97%) found the hair information sheet helpful in making their decision on whether to provide hair samples in the current study.

## 4.5 Discussion

This study aimed to investigate the role of cortisol reactivity on stress and eating behaviours in adolescents and young adults. Similar to the findings of Chapter 3, daily stress was positively associated with the amount of between-meal snacks consumed per day across emerging adulthood. This effect was mainly on total daily snacks consumed, and snacks which were low-to-medium in fat and sugar content. This is in line with previous research, as the meta-analyses in Chapter 2 found that stress was associated with an increase in the amount, and type of foods consumed in both adolescents and adults.

Across the whole sample, no main effects were found for level 2 variables on total snack intake, however main effects were identified when analysing adolescents and young adults separately. In adolescents, a main effect of emotional and external eating styles was found on total snack intake, where adolescents scoring higher in these traits reported eating more between-meal snacks per day than individuals scoring lower in emotional and external eating styles. In contrast, no main effects were found for eating styles on total snack intake in young adults. Instead, main effects were found for age, expressive suppression, total conscientiousness and three lower order facets (virtue, industriousness and responsibility) on total snack intake. These main effects indicated that younger adults, and individuals who were lower in expressive suppression, ate more between-meal snacks whilst younger adults who scored

highly in total conscientiousness, virtue, industriousness and responsibility ate more between-meal snacks than younger adults who scored lower in these personality measures. Finally, no main effects were found for cortisol reactivity (AUCg and AUCi) on total snack intake across the whole sample, or in each age group separately. Similarly, no main effects were found for cortisol reactivity (AUCg and AUCi) on the type of snacks consumed across the whole sample, or in adolescents. A main effect was found for AUCg on high sugar snacks in young adults, where lower AUCg was associated with greater intake of high sugar snacks than higher AUCg in this age group. No other main effects of cortisol reactivity on type of snacks were identified in young adults.

More relevantly, cortisol reactivity was found to differentially influence stress-eating associations in adolescents and young adults i.e., a cross-level interaction. Across the whole sample, AUCg significantly, negatively moderated the impact of total daily stress on total daily snack intake. The simple slopes analysis indicated that as AUCg increased, the effect of stress on snack intake decreased. Furthermore, stress was significantly, positively associated with snack intake at low and mean levels of AUCg across the whole sample, but not at high levels of AUCg. These findings suggest that, in high reactors, merely the experiencing a stressor (and not the number of stressors) influences eating behaviours, as snack intake was similar across both low and high stress for these individuals. In mean and low reactors, snack intake significantly increased from low to high stress. Further analyses indicated that the moderating effect of AUCg on the daily stress to daily snack intake relationship was specific to young adults and was not found to moderate stress-eating relations in adolescents.

Similarly, the change in cortisol levels (from baseline measures) as a result of the stress-induction task (AUCi) also moderated the daily stress to between-meal snack intake relationship across the whole sample, and in adolescents and young adults separately. The simple slopes analysis indicated a consistent pattern across all group analyses, where the impact of stress on eating decreased as AUCi increased in a similar pattern to AUCg. These findings demonstrate that cortisol reactivity is differentially associated with stress-related eating behaviours across emerging adulthood. Specifically, this study found that stress-eating

associations were greatest in adolescents and young adults who had lower cortisol reactivity to a stress-induction task compared to individuals who had a greater physiological response to the stress-induction task.

Individual differences in cortisol reactivity across the two age groups were also identified in the types of snacks consumed. Across the whole sample, AUCg moderated total stress and low-to-medium snack intake, whilst AUCi moderated total stress and high fat and sugar snacks. The analyses indicated that the impact of stress on eating behaviours was significant at low levels of cortisol reactivity (AUCg and AUCi).

Interestingly, differences were found between adolescents and young adults for the moderating effect of cortisol reactivity on stress and type of snacks. In adolescents, both AUCg and AUCi moderated total stress and low-to-medium snack intake, where stress-eating associations were greatest at low levels of cortisol reactivity. In young adults, AUCg moderated total stress and high sugar snacks. However, this effect was not observed in simple slopes analyses, suggesting that the moderating effect of AUCg was only present when controlling for group size of the stress task. Furthermore, AUCi moderated stress-eating associations specifically for snacks high in sugar, high in fat, and high in both sugar and fat in young adults. The simple slopes highlighted that the impact of total stress on these unhealthy snacks was greatest at low levels of AUCi, with the exception of high fat snacks (where stress-eating associations were greatest at high levels of AUCi).

Taken together, these findings highlight the moderating effect of cortisol reactivity on daily stress and between meal snack intake, for both the amount and type of snacks consumed, where moderating effects were found on healthier snacks in adolescents, while AUCi moderated stress-eating relations on unhealthier snacks in young adults. More specifically, these findings indicate that, for high reactors, the occurrence of stress (and not the amount) can trigger eating to a higher degree than in individuals lower in cortisol reactivity who instead showed a hyperphagic response under conditions of stress.

These results are broadly in line with previous research on cortisol response to acute stress, where individuals with higher cortisol reactivity to an

acute stressor are more susceptible to stress-related eating compared to individuals who experience lower levels of cortisol reactivity (Epel et al., 2001; Newman et al., 2007).

The findings of the current study highlight important differences in stress-eating associations across emerging adulthood and may suggest that the effect of cortisol on the stress-eating relationship is curvilinear, where cortisol reactivity above a particular level (i.e., greater than low levels in the current study) does not continue to influence eating behaviours. This is generally consistent with the stress-eating paradox outlined by Stone and Brownell (1994) who found that eating less occurred more frequently at higher levels of stress, while eating more was reported more frequently under lower stress. Nevertheless, these findings support previous research studies which have found that differences in cortisol reactivity to a stressor are associated with changes to eating habits (Appelhans et al., 2010; Epel et al., 2001; Newman et al., 2007). Future research ought to replicate the effects found in the current study within larger samples of adolescents and young adults.

Previous studies have primarily used ad libitum food intake following a stressor in laboratory environments which, although useful, can increase participants' awareness of their eating behaviours and so do not present an accurate picture of eating habits (Robinson et al., 2015). Furthermore, laboratory based nutrition studies lack ecological validity unlike alternative methods (such as daily dairies) which capture eating habits away from the confines of an experimental environment (Best, Barsalou & Papies, 2018; Stelick & Dando, 2018). Combining objective and subjective measures of stress can shed light on individual variability of the HPA axis by providing insights into day-to-day variations in stress and eating habits (O'Connor et al., 2008) than either method used in isolation (Stalder et al., 2017).

Interestingly, stress reactivity (both AUCg and AUCi) was associated with group size of the TSST-G, suggesting that participating in the stress task as part of larger groups (i.e., groups of 6) elicited a stronger cortisol response compared to completing the task in smaller groups. This is in line with previous research which has found that inclusion of social evaluation in stress-induction tasks are

effective in eliciting a stronger response of the HPA axis compared to tasks that did not include an element of social evaluation (Dickerson & Kemeny, 2004). These findings support the use of the TSST-G as a method of inducing stress in group settings (Von Dawans et al., 2011) where increasing the number of participants within a group setting provides an additional source of social evaluation to the TSST-G.

Furthermore, the moderating effect of stress reactivity was specific to some types of stress. Across the whole sample, total cortisol response (AUCg) moderated work/academic stressors and total snack intake, while stress reactivity (AUCi) moderated work/academic stressors, and ego threatening stressors on total snack intake. Further analyses found that these effects were different in adolescents and young adults. Both measures of stress response (AUCg and AUCi) were found to moderate work/academic stressors and ego threatening stressors in adolescents. In contrast, total cortisol response (AUCg) was found to moderate physical stressors in young adults, however stress reactivity (AUCi) did not moderate the type of stress on total snack intake in this age group.

Although an effect was found between total stress and total snack intake, the current study did not find an effect of daily stress on unhealthy snack foods (i.e., those high in fat and/or sugar) nor on healthy foods (i.e., portions of fruit and vegetables). This is contrary to previous research in adolescents, which has found that stress is typically associated with increased consumption of unhealthy foods (Jeong & Kim, 2007; Shank et al., 2017; Son et al., 2014), and decreased consumption of healthy foods (Austin et al., 2009; De Vriendt et al., 2012; Son et al., 2014). This may be due to the low numbers of snacks reported overall and consequently fewer snacks falling into one of the four categories used in the current study. Similarly, it is likely that an effect was not found on daily stress and healthy food intake in the current study as adolescents and young adults ate on average 2-3 portions fewer than the recommended daily intake per day, which, although low, is typical for this age group (Huang et al., 2019).

Furthermore, the current study found that ego-threatening stressors were positively associated with total snack consumption across emerging adulthood. Further analyses revealed that this effect was specific to young adults. This is in

line with previous research (O'Connor et al., 2008; Wallis & Hetherington, 2009) which has suggested that ego-threatening stressors can have the greatest impact on health behaviours due to individuals attempting to alter negative appraisals of the self through a change in focus towards an external stimulus such as food (Wallis & Hetherington, 2009).

Interestingly, work/academic stressors also predicted total snack intake in young adults, but not adolescents, which was also found in Chapter 3. In adolescents, only physical stressors were associated with total snack intake, which is contrary to the findings of the daily diary study in Chapter 3 which found no differences on snack intake by the type of stressor in this age group. In line with previous research (O'Connor et al., 2004), these findings indicate that individual differences in the type of stress experienced can result in changes in different eating behaviours in adolescents and young adults. Furthermore, these findings suggest that the type of stress may be a contributory factor to maladaptive, stress-related eating behaviours differently in adolescents and young adults.

Other than cortisol reactivity, this study identified several moderating variables on stress and snack intake throughout emerging adulthood. Across the whole sample, only emotional and external eating styles were found to moderate total stress and total snack intake, where the stress-eating association was greater in emotional and external eaters compared to individuals who scored lower in these eating styles. When investigating these effects by each age group separately, the moderating effect of external eating was not found in either age group in isolation. Previous research has found mixed results regarding the moderating role of external eating on stress and food intake, with some studies finding higher external eating is associated with more daily snacks consumed when experiencing stress (Conner et al., 1999; O'Connor et al., 2008) and others reporting no effects of this eating style (Newman et al., 2007; Royal & Kurtz, 2010).

The current study also found that emotional eating style moderated stress-related eating, however this effect was specific to young adults. Previous studies have reported a moderating effect of emotional eating style on stress and food

intake across both children and young adults (Michels et al., 2012; Oliver et al., 2000; Wallis & Hetherington, 2004; Wilson et al., 2015), although research in adolescents is currently limited. O'Connor et al. (2008) suggest that, of the three eating styles (emotional, external and restrained eating), emotional eating has been suggested to be the pre-eminent eating style in stress-induced eating.

Similarly, the emotion regulation strategy of expressive suppression was found to moderate stress-eating associations, however, contrary to the effect of emotional eating, this was only found in adolescents. This is supported by previous research, which has found that emotions, and their underlying strategies, can strongly predict eating behaviours (Evers et al., 2010). In adolescents, expressive suppression may be used as an emotional avoidance strategy when facing challenging situations and has been previously associated with greater stress-related eating behaviours in this age group (Young & Limbers, 2017). In the current study, emotion regulation was included as a secondary measure of emotional eating, as research has suggested that the underlying strategies of emotion regulation are more important when considering individual differences in eating behaviours, compared to differences in emotional eating style more broadly (Evers et al., 2010). Considering the different effects of emotion regulation and emotional eating style between adolescents and young adults, it may be suggested that maladaptive emotion regulation strategies (i.e., high levels of expressive suppression) during adolescence may be a pre-eminent factor to emotional eating more generally into adulthood. Finally, these emotion-oriented stress-related eating habits can result in overweight and obesity (Richardson et al., 2015) through chronically occurring positive energy balance.

Conscientiousness did not moderate stress-eating associations across the whole sample, nor by either age group independently. This contrasts with the findings of the daily diary study (Chapter 3) which found a moderating effect of total conscientiousness on total stress and total snack intake, although this effect was specific to young adults. Similarly, the six lower order facets of conscientiousness were not associated with stress and snack intake. Previous studies have found that conscientiousness is associated with differences in health behaviours (Bogg & Roberts, 2004; Hagger-Johnson et al., 2012), and has

been found to moderate stress-eating associations (O'Connor et al., 2009; O'Connor & O'Connor, 2004). Furthermore, the present study aimed to build on the findings of Chapter 3 by investigating the lower order facets of conscientiousness on stress-related eating habits across emerging adulthood. Previous research suggests that the lower order facets of conscientiousness may be more predictive of health behaviours compared to measures of overall conscientiousness (Kern & Friedman, 2008; Sutin et al., 2018). For example, in a sample of adolescents, Macchi et al. (2017) found that higher impulsivity (a factor within conscientiousness) was associated with more unhealthy eating habits. However, Mõttus, Kandler, Bleidorn, Riemann, and McCrae (2017) argue that facets themselves are not as insightful as they could be. They propose instead that even more specific aspects of personality (coined nuances) may provide better indications on associations with other variables.

Nevertheless, the moderating effect of conscientiousness on stress-related eating habits in adolescents and young adults appears to be inconsistent across the two studies in this thesis. One possible explanation for this difference in findings between the two studies was the type of questionnaires used. A short, 10-item scale of overall conscientiousness was used in the daily diary study (Chapter 3) which was taken from the International Personality Item Pool (Goldberg et al., 2006), whereas a longer, 60-item questionnaire (Chernyshenko et al., 2007) was used in the experimental study (Chapter 4) in order to capture the six lower order facets. It may be that the shorter questionnaire was better able to capture conscientiousness compared to the 60-item Chernyshenko scale, which due to its length, may have resulted in participant fatigue when completing the initial questionnaire. Despite these methodological differences, the moderating effect of conscientiousness on stress-eating associations across emerging adulthood remains unclear.

Finally, the current study aimed to determine the role of chronically occurring stress on eating behaviours using hair cortisol. HCCs over the past month did not moderate the associations between total stress and total snack across the whole sample. Similarly, HCC did not moderate total daily stress and the type of between meal snacks. Due to the limited number of samples available,

analyses were not conducted in each age group separately. HCCs have previously been associated with differences in health behaviours, including physical activity and smoking (Wosu et al., 2013), as well as differences in health outcomes such as depression (Abell et al., 2016) and body adiposity (Jackson et al., 2017). Although HCC has been negatively associated with fruit and vegetable intake (Steptoe et al., 2017), research on the role of HCCs in eating behaviours is currently limited. Furthermore, research has suggested that HCCs may not be strongly associated with perceived stress. In a study of 99 undergraduate students, Karlén, Ludvigsson, Frostell, Theodorsson, and Faresjö (2011) found that serious life events were most strongly associated with HCCs. In contrast, perceived stress was only weakly (and negatively) associated with HCCs. Similarly, in a meta-analysis Staufenbiel, Penninx, Spijker, Elzinga, and van Rossum (2013) found moderate-to-strong associations between HCCs and chronic stress. These findings suggest that HCCs may not be sensitive enough to correlate with daily stressors and may provide insights only into chronically occurring stress-eating associations, opposed to those occurring on a daily level.

In the current study, there were several methodological issues regarding HCCs. Firstly, few participants were willing to provide hair samples due to concerns over how much hair was required and how noticeable the sampling area would be on the scalp. Furthermore, the hair sample weight was generally quite low. During assay of the samples, hair weight was accounted for when calculating HCCs, however it is likely that on average the low hair weight is a contributory factor to the results for the current study. Finally, in a meta-analysis, Steptoe et al. (2017) found that HCCs were not reliably associated with self-reported stress. It may be that HCC as a moderator of perceived stress and eating behaviours is less informative than its predictive effect on daily eating behaviours across emerging adulthood. Hair samples are useful predictors of chronically occurring stress due to their stability in providing retrospective cortisol levels over previous weeks or months (Stalder et al., 2017). However, in the current study, data on HCC were limited and were not found to moderate stress-eating associations across emerging adulthood. Future research ought to replicate this study in larger samples to determine whether HCCs are associated with stress-eating relations in adolescents and young adults.

## 4.6 Conclusions

This study aimed to develop the findings of Chapter 3 and address current gaps in the literature identified in Chapter 2 by combining objective and subjective measures of stress. Analyses indicated a similar pattern of stress-eating associations in adolescents and young adults to those found in Chapter 3.

Eating style and emotion regulation were found to moderate stress-related eating habits differently in adolescents and young adults. More specifically, higher levels of expressive suppression were associated with reduced stress-eating in adolescents. Similar to these findings, emotional eating was found to moderate daily stress and snack intake in young adults, where higher levels of emotional eating were associated with more stress-related eating compared to lower levels of this eating style. It is possible that adolescents who use expressive suppression as an emotion regulation strategy develop emotional eating behaviours as they develop into adulthood. External eating was also found to moderate total stress and total snack intake across the whole sample, although this effect was not observed in either age group alone.

In contrast, conscientiousness did not moderate total stress and total snack intake in adolescents and young adults. Furthermore, no moderating effects were found for any of the six lower order facets of conscientiousness on stress-eating associations. These findings differ to the daily diary study (Chapter 3) which found a moderating effect of total conscientiousness in young adults. These contrasting results may, in part, be explained by different methodological approaches used across the two studies to measure conscientiousness.

Furthermore, the current study aimed to understand the role of cortisol reactivity to a stress-induction task on stress-eating associations across emerging adulthood. Days with low levels of stress were associated with significant differences in total snacks consumed across AUC (i.e., cortisol reactivity) groups. However, in contrast, on high stress days, there were no differences in total snack intake across the AUCg groups. The study found moderating effects of AUCi on the stress-snack relationship, however these effects differed depending on the type of daily stress and snack intake across

adolescents and young adults. These findings are broadly in line with previous research which has found that higher cortisol reactivity to an acute stressor can lead to increased food intake compared to lower stress levels of cortisol reactivity.

Differences were also found on the types of snacks consumed. In adolescents, the moderating effect of cortisol reactivity on stress-eating was specific to healthier snacks (i.e., low-to-medium fat and sugar snacks). In contrast, cortisol reactivity was found to moderate stress-eating relations for unhealthy snacks (i.e., snacks high in fat and/or sugar) in young adults. These findings highlight the differential, and complex, interactions between cortisol reactivity and stress-eating associations in adolescents and young adults. Further research is warranted to replicate this effect.

Finally, this study found that chronically occurring stress (measured using hair cortisol) was not associated with daily stress-eating associations across emerging adulthood. HCCs were obtained on a small number of participants due to concerns over visual appearance following samples being taken. Further research is needed using larger samples sizes to determine the role of chronically occurring stress on eating behaviours in adolescents and young adults.

# Chapter 5
# General Discussion

## 5.1 Thesis Aims and Overview

The overall aim of this thesis was to develop current understanding of stress-related eating habits in adolescents and young adults and identify potential moderating variables of this relationship. Through two reviews and two studies, this thesis aimed to determine whether stress-eating associations were similar in adolescents and young adults.

More specifically, this thesis aimed to synthesize previous research on stress-related eating behaviours in adolescents and young adults. This aim was addressed in Chapter 1, which provides a summary of the literature on the associations between stress and eating behaviours, as well as moderating variables on the stress-eating relationship. The combined findings of two meta-analyses (Chapter 2) quantified the strength of stress-eating associations in adults and adolescents and identified current gaps in the literature.

Secondly, this thesis aimed to determine stress-related eating behaviours in adolescents and young adults using daily diaries (Chapter 3). This study identified stress-eating relationships in adolescents (15-18 years old) and young adults (18 – 24 years old) to determine whether stress-eating associations were similar across emerging adulthood. Furthermore, this study aimed to investigate the role of moderating variables, mainly conscientiousness and eating styles (emotional, restrained and external eating), on stress and eating behaviours across the whole sample, and in each age group separately.

Thirdly, this thesis aimed to investigate the role of cortisol reactivity on stress-eating associations across emerging adulthood (Chapter 4). A stress-induction task was used to assess cortisol reactivity to stress using saliva samples. This study also used hair samples as a measure of chronically occurring stress over the previous month. The study combined these objective measures of stress with subjective, daily diaries to investigate acute and chronically occurring stress on daily eating behaviours across emerging adulthood. Similar

to the study presented in (Chapter 3), this study also aimed to determine the role of moderating variables, in this case conscientiousness (and its six lower order facets), eating style and emotion regulation (expressive suppression and cognitive reappraisal), on stress-related eating habits in adolescents and young adults.

Finally, this thesis aimed to synthesize and discuss the findings from the two meta-analyses, and two studies within the wider context of the literature in the general discussion (Chapter 5). This discussion chapter will summarise the key findings from this thesis, outline the novelty of this research and address potential limitations of this thesis. Additionally, the discussion aims to highlight current patterns of stress-related eating in adolescents and young adults, and individual differences in the moderating variables on this association. Based on these findings, the discussion will suggest directions for future research on stress-related eating behaviours in adolescents and young adults.

## 5.2 Summary of Key Findings

The findings of two meta-analyses and two studies identified that stress is associated with a change in the amount, and type, of food consumed across emerging adulthood. Furthermore, this association is moderated by several key variables, which differ between adolescents and young adults.

The meta-analyses outlined in Chapter 2 found that stress is associated with increased food intake overall in adults, however stress was not associated with overall food intake in adolescents. The meta-analyses identified differential effects of stress on the type of foods consumed. A small, positive effect was found between stress and unhealthy food consumption in both adolescents and adults. In contrast, a small, negative effect was found between stress and healthy food intake, however this effect was only significant in studies using adult samples and was not found in adolescents.

The moderating effects of mean age, sample size, gender and study quality were investigated in both meta-analyses. Sample source (i.e., samples recruited from higher education settings or from wider populations), dietary restraint, mean BMI, proportion of healthy / overweight participants and stress

measurement were also investigated in the meta-analysis in adults. Study quality was the only variable found to moderate stress-eating associations in adults, where stronger effects were observed in studies lower in quality. In contrast, only gender (% female) was found to moderate stress-eating associations in adolescents.

Finally, the meta-analyses identified several gaps in the literature. Firstly, there is a clear gap in the literature for studies investigating stress-related eating behaviours in adolescents. Due to the limited research currently available in adolescents, few moderating variables could be investigated on stress-eating associations. Similarly, few studies using samples of adults included sufficient data to conduct moderation analyses on variables other than those stemming from the review (such as stress measurement and study quality). Previous studies have placed emphasis on the moderating role of eating style on stress-induced eating behaviours (Adam & Epel, 2007; Greeno & Wing, 1994), however data on these variables is not consistently reported in the studies included in the two reviews, meaning that the strength of associations could not be quantified in this thesis. Although the number of females and males across the two reviews was similar, there was a greater number of studies which had used exclusively female samples, which may result in an under-representation of stress-eating associations in male samples.

Based on the findings from the meta-analyses, two studies were conducted to determine whether stress-related eating habits were similar in adolescents and young adults.

To determine whether stress was associated with eating habits across emerging adulthood, a daily diary study was initially conducted (Chapter 3). A total of 176 participants (78 adolescents and 98 young adults) completed up to 10 online daily diaries (total of 1,318 diaries) to measure daily stress and between-meal snack intake. The results indicated that daily stress was positively associated with daily snack intake in both adolescents and young adults, specifically for snacks which were high in sugar, and snacks which were low-to-medium in fat and sugar content. However, these effects were not observed in either age group in isolation.

Contrary to previous research, stress was not associated with a change in consumption of LEHN foods (specifically daily portions of fruit and vegetables). The average number of portions of fruit and vegetables consumed per day was below the recommended 5-a-day for both adolescents and young adults, which may explain the lack of association between daily stress and healthy food consumption in this study. This is consistent with other studies which have found that fruit and vegetable consumption is often reported to be less than recommended guidelines in this age group with as many as 30% of adolescents not eating any portions of fruit or vegetables daily (Huang et al., 2019).

Individual differences were observed for the type of stress on total snack intake. Work/academic and ego threatening stressors were associated with snack intake across the whole sample. However, differences were found between adolescents and young adults on these associations. In young adults, work/academic stressors positively predicted daily snack intake, while only the number of daily stressors predicted snack intake in adolescents. These findings indicate that the type of stressor is an important predictor of eating habits in young adults, whilst in adolescents, the number of stressors (and not the type) is associated with a change in daily eating habits.

Finally, conscientiousness was found to significantly moderate stress and snack intake across the whole sample, where highly conscientious individuals experienced more stressors and reported a greater number of between meal snacks compared to individuals who were lower in this personality trait. Further analyses revealed that this moderating effect was specific to young adults and was not observed in adolescents.

Following the daily diary study, this thesis aimed to combine objective and subjective measures of stress to investigate the role of cortisol reactivity on stress-eating associations in adolescents and young adults (Chapter 4). Associations between stress and eating habits (between meal snacks and portions of fruit and vegetables) were similar to those reported in Chapter 3. Stress was positively associations with snacks which were low-to-medium in fat and sugar content across the whole sample, and for the two age groups independently. Similarly, stress was not associated with a change in fruit and

vegetable consumption. Although previous research has found negative associations between stress and healthy food consumption in adults (Lyzwinski et al., 2018; Torres & Nowson, 2007), it is evident from the findings of the two studies in this thesis that stress does not influence healthy eating habits in the same way across adolescents and young adults (Hill et al., 2018), possibly due to the low intake of these healthy foods across emerging adulthood.

Similar to the findings of the daily diary study, differences between adolescents and young adults were observed on the type of stressor and between-meal snack intake. Work/academic and ego threatening stressors were associated with greater intake in young adults only. In contrast, only physical stressors were associated with increased snack intake in adolescents. These findings across the two studies indicate that the type of stressors which are experienced in adolescents are qualitatively different to those in young adults, and that the type of stress may elicit stress-induced eating behaviours, especially in young adults.

This study also identified several key moderating variables on stress-eating associations across emerging adulthood. Across the whole sample, emotional and external eating styles were found to moderate total stress and total snack intake. The effect of external eating was not seen in either age group separately. The moderating effect of emotional eating style was only found in young adults. In contrast, the emotion regulation strategy of expressive suppression was found to significantly moderate total stress and total snack intake only in adolescents. These findings indicate that emotions play an important role in stress-eating associations across emerging adulthood.

Furthermore, the study found that conscientiousness did not moderate stress-eating associations across the whole sample, nor by either age group independently. Similarly, no moderating effects were found on the six lower order facets of conscientiousness on total stress and total snack intake across emerging adulthood. This is contrary to the daily diary study (Chapter 3) which found a moderating effect of total conscientiousness which was specific to young adults. However, the differences between these two studies may be a result of methodological differences in the measurement of trait conscientiousness, where

a short 10-item questionnaire was used in the daily diary study (Chapter 3) whilst the 60-item Chernyshenko questionnaire (Chernyshenko, 2003) was used in Chapter 4.

Aside from daily diaries, this study investigated cortisol reactivity to stress using a group stress-induction task (TSST-G). Analyses revealed that cortisol reactivity (AUC) moderated stress and snack intake under conditions of low stress, whereas eating habits were similar across cortisol reactivity levels under conditions of high stress. Specifically, high reactors ate a similar number of snacks on both low and high stress days, whereas individuals who were mean or low in cortisol reactivity demonstrated a hyperphagic response (i.e., significantly increased snack intake from low to high stress days).

Furthermore, differences were found on type of snacks consumer between adolescents and young adults. The results indicated that cortisol reactivity moderated stress-eating associations on healthier snacks in adolescents, while AUCi was found to moderate stress-eating relations on unhealthier snacks in young adults. However, inconsistencies were identified with AUCi, where the moderating effect of AUCi differentially influenced the stress-eating relationship depending on the type of stress and snacks, as well as the age group.

Finally, the study aimed to investigate the role of hair cortisol (as a measure of chronically occurring stress) on daily stress and snack intake across emerging adulthood. Analyses found that hair cortisol was not associated with total daily stress and total daily snack intake across adolescents and young adults. Similarly, no effects of HCCs were found on stress and the type of between meal snacks. This may be due to low power in the data set, as relatively few participants consented to provide hair samples for the current study. Data from qualitative open questions highlighted some motivations and barriers to providing hair samples for research. Participants' main concern was the amount of hair taken for each sample, and the degree of noticeability once the sample had been taken. In contrast, motivations for providing hair samples in research related to helping advance science and ultimately help others through their participation in the hair sampling procedure. Although most participants responded that they would be likely to provide hair samples as part of a research

project, this did not translate into consenting to provide hair samples in the current study. The findings from the qualitative responses indicate a gap between intentions and behaviours (i.e., consenting) to providing hair samples for research.

In summary, the findings from this thesis indicate that stress is associated with a change in eating habits in adolescents, which are comparable to stress-eating relations in young adults. Eating styles (specifically emotional and external), conscientiousness and emotion regulation (expressive suppression) influence the strength of stress-eating associations differently in adolescents and young adults. In contrast, cortisol reactivity to stress moderates the effect of daily stress and daily eating habits across emerging adulthood. Chronically occurring stress (HCCs) did not moderate stress-eating associations.

## 5.3 Unique Contribution of the Current Research

This thesis has combined findings from two novel meta-analyses and two research projects to improve current understanding of stress-related eating habits across emerging adulthood.

Firstly, two meta-analyses were conducted to determine the strength of the association between stress and eating behaviours in adults and adolescents. Previous literature reviews have synthesized findings on stress-related eating habits (Adam & Epel, 2007; Araiza & Lobel, 2018; O'Connor, 2018), in addition to the effect of stress on the type of foods consumed, mainly changes to the consumption of healthy and unhealthy foods (Lyzwinski et al., 2018; Torres & Nowson, 2007). Although these reviews have provided succinct and informative summaries of stress-eating associations, the strength of reported associations between stress and eating behaviours had not been quantified. This thesis provided two novel meta-analyses which quantified the strength of the association between stress and food intake in both adults and adolescents. Combined with the findings of a previous meta-analysis (Hill et al., 2018), current research suggests that stress-related eating behaviours may be present in children as young as 8 years old and can continue throughout childhood into adolescence and adulthood. More specifically, stress is associated with

increased consumption of unhealthy foods, and decreased consumption of healthy foods, although the effect on healthy foods was not found in adolescents. Finally, the meta-analyses investigated moderating variables of this association, highlighting that future studies should consider variables such as eating style to understand the complex associations between stress and eating behaviours.

The findings from these meta-analyses highlighted gaps in the literature, some of which have been addressed in this thesis through two daily diary studies. Although well researched in adult samples, there is limited research on stress and eating behaviours in adolescents. Similarly, research on stress-related eating behaviours in samples of adults have identified key moderating variables on this association, including conscientiousness, eating styles and emotion regulation. However, there is a lack of research on these moderating variables on stress-eating associations across emerging adulthood. This thesis provided a unique contribution to the current research by implementing two studies which aimed to determine the role of moderating variables on stress-related eating behaviours in adolescents and young adults.

Finally, research is yet to determine whether stress-eating associations formed in adolescence may continue into adulthood by comparing stress-eating associations of adolescents with those of young adults. Therefore, this thesis aimed to address this gap in the literature with two unique studies which compared stress-eating associations between adolescents and young adults.

The daily diary study (Chapter 3) was developed based on current gaps in research, both in literature on adolescents (of which there is a paucity) and based on findings from adults (for the effects of moderating variables on stress-eating associations). The findings of the meta-analyses (Chapter 2) highlighted a need for more robust methodologies to investigate stress-related eating habits, such as daily diaries, which can document within and between-person variability in daily stress and eating habits (O'Connor et al., 2009). Furthermore, research is yet to determine the effect of moderating variables on stress-related eating habits in adolescents. Therefore, the daily diary study provided novel insights into;

1) Stress-related eating habits in adolescents and young adults independently

2) Differences in stress-eating associations between these two age groups and,

3) Differential effects of moderating variables on stress-eating associations in adolescents and young adults.

Finally, the research presented in Chapter 4 provided a unique contribution to the current research through its design, methodology and findings. Building on the results from the daily diary study (Chapter 3), this study aimed to determine the role of cortisol reactivity to stress on daily stress and eating habits across emerging adulthood. To do this, a novel group stress-induction task (the TSST-G) was used in school and university settings. Four saliva samples were taken (one before and three after the stress task) to determine total cortisol response (AUCg), and cortisol reactivity in response to the stress task (AUCi). This objective measure of stress was combined with data from daily diaries to determine the moderating effect of stress reactivity on daily stress and daily eating habits. The combination of objective and subjective measures of stress provided insights into stress-eating associations which cannot be gained when using either method in isolation (Stalder et al., 2017). This study was unique in its contribution to the current research as it determined associations between physiological reactivity to stress on daily stress-eating behaviours in adolescents and young adults. More specifically, the study determined that cortisol reactivity to stress plays an important role in daily stress and eating habits across emerging adulthood.

Furthermore, this study employed a novel method of assessing chronically occurring stress via hair sampling. At present, there is limited research available on the role of chronic stress on eating habits, with no studies currently investigating this objective measure of stress in adolescents. Although hair cortisol did not moderate stress-eating associations across emerging adulthood, qualitative data identified key motivations and barriers to providing hair samples for research purposes.

In summary, the findings of this study have identified differences in stress-eating associations in adolescents and young adults. More specifically, this study has highlighted moderating variables, including cortisol reactivity, of this association in an age group which is currently under researched.

This thesis has combined novel reviews and studies to address gaps in the literature regarding stress-eating associations across emerging adulthood. This thesis has provided a unique contribution to research in both its methodology and findings, which have been discussed in the context of previous research and suggestions made for future directions.

## 5.4 Limitations

There were several practical and methodological limitations to the current research, of which the main shortcomings are discussed below.

### 5.4.1 Role of Palatability in Stress-Eating

A limitation of the current research is the potential confounding effect of food palatability on eating behaviours made under conditions of stress. In the meta-analyses and two research projects included in this thesis, food intake was categorised based on nutrient content into HELN (i.e., unhealthy) and LEHN foods (i.e., healthy) as research has indicated that seeking for unhealthier foods increases under conditions of high stress (Lyzwinski et al., 2018; Torres & Nowson, 2007). However, the palatability of foods eaten when experiencing stress should also be considered in the context of stress-eating associations.

Reward theories posit that, under conditions of stress, changes in glucocorticoids (including cortisol) and CRF sensitize areas of the brain associated with reward (e.g., nucleus accumbens), increasing the drive to eat HELN and highly palatable foods (Cottone et al., 2009, Sinha & Jastreboff 2013). Consequently, eating habits are maintained through a positive feedback loop where highly palatable foods are perceived as being rewarding under conditions of stress which in turn enhances the salience of these foods (Nieuwenhuizen & Rutters, 2008; Sominsky & Spencer, 2014). As such, consumption of palatable foods (regardless of their nutritional content) may attenuate the physiological effects of acute stress (Morris et al., 2015).

Although palatability of foods should be considered in the stress-eating paradigm, it is difficult to disentangle whether the changes in food intake under conditions of stress found in this thesis results from consumers seeking highly

palatable foods that happened to have particular nutritional content (e.g., high fat) or from consumers specifically seeking foods that have specific nutritional content based on specific sensory cues (e.g., mouth feel) or learning processes linked to post-ingestional effects of the foods. Future research should reflect on the interactive effect of palatability and reward in stress-eating associations.

### 5.4.2 Participant Recruitment and Retention

A key shortcoming with the current research was the recruitment of participants, specifically adolescents, from local schools and sixth form colleges. Participants were recruited from local schools and sixth form colleges which proved difficult to access, particularly for the cortisol study (Chapter 4) as this had to be carried out at school, and required sufficient resources (mainly time and classroom space) to conduct the stress-induction task and cortisol sampling. Therefore, the recruitment of adolescents was restricted to schools that were keen to take part and were able to accommodate resources to conduct the two studies within classroom environments. For example, one school which took part in the daily diary study (Chapter 3) was a girls' high school, and so contributed to the over representation of females in the study (see section 5.4.4 for details).

Similarly, difficulties were encountered recruiting adolescents once in a school/college. Drop-out rates were particularly high in adolescents across both studies, where large numbers of those recruited failed to complete any daily diaries on time, resulting in their exclusion from the study. This may be partly due to the limited incentives available for adolescents to take part and engage with the studies fully. Both studies were incentivised with monetary vouchers, although this was limited due to funding availability. Similarly, the two studies differed in incentives, as the daily diary study (Chapter 3) used a prize-draw and the cortisol study (Chapter 4) used monetary vouchers for each participant. Previous research has suggested that prize-draws, although useful in facilitating high response rates compared to no incentives (Laguilles, Williams, & Saunders, 2011), are less effective in encouraging response rates compared to pre-paid cash incentives in online surveys (LaRose & Tsai, 2014). Therefore, drop-out rates may have been reduced if all participants had received a monetary incentive, opposed to entry into a prize-draw.

However, to encourage (and maintain) engagement in the two studies, additional incentives were utilised (i.e., other than financial rewards). For example, adolescents were encouraged to report their participation on UCAS university applications which, for some students, was more appealing than the monetary incentive. Nevertheless, drop-out rates remained high in adolescents. In contrast, the drop-out rate was less problematic in the sample of young adults. This is likely due to the difference in incentives used, as the young adults could receive up to 14 course credits as part of the undergraduate Psychology BSc for the completion of the study, based on their level of engagement. Therefore, completion of the daily diaries (across both studies) was high in the young adults as they were more motivated to receive the full incentive of 14 course credits, opposed to a reduced which was given where participants did not complete the required number of daily diaries.

Furthermore, the length of the study period may have resulted in high drop-out rates amongst adolescents for the two studies. Although useful in documenting day-to-day fluctuations in stress and eating habits (O'Connor et al., 2008), the predominant reason for drop-out across both studies was due to participants (specifically adolescents) completing no daily diaries on time. Response rates can be low for online surveys for a multitude of design and practical factors, including the length of the survey (Fan & Yan, 2010). In contrast, all participants who consented to take part in the study completed the initial questionnaires, demonstrating that drop-out rates were during the daily diary periods.

The duration of the diary period for the two studies was chosen to capture stress-eating behaviours across both weekdays and weekends. Similarly, the cortisol study diary period (Chapter 4) was slightly longer (an additional 4 diary days) than the diary study (Chapter 3) to enable a greater amount of time to be captured retrospectively with the hair samples (i.e., two weeks of daily diaries out of the previous 4 weeks which were reflected in the HCCs). Drop-out rates may have reduced with shorter diary periods, or through a different methodology for delivering the daily diaries.

Interval-contingent methods (such as end-of day-daily diaries) are thought to improve compliance on self-reported daily measures (Palmier-Claus, Haddock, & Varese, 2019), however, even with daily reminders to participants, drop-out rates were high amongst adolescents in the current research. Instead, continuous sampling methods using bespoke applications (such as a mobile phone application) may be more appropriate to document stress and health behaviours. Similarly, event or notification-based sampling, such as scheduled questionnaires on smartphones, have been found to improve response rates (van Berkel et al., 2019).

Recruiting and retaining adolescent participants in daily diary studies proved difficult in the current research. Future studies should consider incentives for participants and alternative methodologies to encourage and maintain participation in this age group.

### 5.4.3 Age

Continuing from the limitation outlined above regarding participant recruitment, a second shortcoming with the current research was the limited age range of adolescents who were recruited for the studies, particularly for the daily diary study (Chapter 3). Very few younger adolescents (i.e., those aged 13 to 15 years old) participated in the daily diary study which was predominantly as a result of difficulties in recruiting schools to take part in the daily diary study. This restriction in access to recruit younger adolescents was further compounded by the need to obtain parental consent for adolescents under the age of 16 years. This resulted in very few questionnaire packs being returned for the daily diary study.

Although the daily diary study aimed to address the gap in the literature regarding stress-eating associations in adolescents, the findings were specific to adolescents aged on average 16 years. Therefore, a gap still exists for research to understand stress-eating associations in younger adolescents less than 16 years old. This would enable comparisons to be made across adolescence to determine at what age stress-induced eating habits are formed. This age is important to consider in the stress and health context, as previous research has

suggested that stress-related eating habits may be established in children as young at 8 years old (Hill et al., 2018). A larger sample balanced across ages between 13 to 18 years old is needed to determine whether stress-related eating patterns are present in young adolescents, and to investigate at what age potential moderating variables such as conscientiousness influence stress-eating associations.

Similarly, both studies utilised undergraduate samples to compare stress-eating associations across adolescence and into adulthood. Although useful for obtaining large numbers of participants, data obtained exclusively from undergraduate samples are not representative of young adults more broadly (Hanel & Vione, 2016). Reliance on WEIRD studies (i.e., samples which are Western, Educated, Industrialised, Rich and Democratic) is an ongoing issue in psychology research which can limit generalisability of findings (Henrich et al., 2010). As a result, the findings of the current research are limited to adolescents and young adults who are in full-time education.

### 5.4.4 Gender

A limitation of this thesis is potential gender bias across the two studies. In both the daily diary (Chapter 3) and cortisol study (Chapter 4), most of the participants were female (95% and 83% respectively). Previous research has suggested that the effect of stress on eating habits influences men and women differently. For example, some studies have found that females are more likely to change their normal eating behaviours when experiencing stress compared to males (Mikolajczyk et al., 2009; Sims et al., 2008; Stone & Brownell, 1994; Weinstein et al., 1997) although this difference has not been consistently found (Barrington et al., 2014; Conner et al., 1999; El Ansari & Berg-Beckhoff, 2015; Reichenberger et al., 2018). Although no difference was found between males and females in the meta-analyses in adults (Chapter 2), a moderating effect of gender was found in the meta-analyses in adolescents, where stress-eating associations were greater in studies with more females. Therefore, there may be gender differences in stress-eating associates in adolescents.

However, due to the predominately female sample, the findings from this thesis may not present an accurate reflection of stress-related eating habits in

adolescent males. For example, research has found that females report greater stress on average compared to males (Cohen & Janicki-Deverts, 2012), which has also been found in young adults (Garett, Liu, & Young, 2017). Similarly, Jääskeläinen et al. (2014) found that stress-induced eating behaviours were common particularly in females (43%) compared to males (15%). Furthermore, those who identified as eating in response to stress were more likely to be overweight or obese.

Aside from gender differences on stress-eating associations, differences may also be present between females and males on moderating variables. For example, the effect of eating styles (particularly restrained and emotional eating) on stress and food intake is thought to be greater in women than men (Conner, Johnson, & Grogan, 2004; O'Connor et al., 2008), although some studies have used female only samples (Raspopow et al., 2010; Spoor, Bekker, Van Strien, & van Heck, 2007; Tomiyama et al., 2011).

Finally, gender differences have also been found in hair cortisol concentrations. In a meta-analysis, Stalder et al. (2017) found that men have on average approximately 21% more HCC in hair samples compared to women. However, similar to the effect of gender on stress-eating associations, gender differences in hair cortisol have not been consistently reported. For example, Dettenborn, Tietze, Kirschbaum, and Stalder (2012) found no differences in gender and hair cortisol concentrations in adolescents. It may be useful for future research to recruit samples which are equal in females and males to determine whether differences exist in HCCs between genders.

Although research has suggested that females are more susceptible to stress-induced eating than males (Gibson, 2012; Greeno & Wing, 1994; Zellner et al., 2006), findings remain unclear. Based on the findings from the meta-analysis in Chapter 2, gender differences may exist in stress-eating associations in adolescents. However, as the samples using in this research were mainly female, the influence of gender on stress-eating associations could not be fully investigated in the current research.

### 5.4.5 Group Size Variation of the TSST-G

Whilst the TSST-G proved useful in delivering a stress-induction task to groups of participants, the differences in the duration of the TSST-G was found to influence the magnitude of cortisol reactivity. The results outlined in Chapter 4 found a positive association between group size and AUC measures. Although this potential confounding effect of group size was managed statistically in the current study, it is advised that future research should endeavour to use a consistent number of participants when using the TSST-g in a similar context (i.e., measuring cortisol reactivity to an acute stressor).

When a stressor is experienced, cortisol secretion increases and typically reaches peak levels between 21 and 40 minutes following the onset of a stressor (Dickerson & Kemeny, 2004). In the current study, duration of the stress task ranged from 10 minutes to 35 minutes. Consequently, the four sampling points used in the current study are likely to have either captured or missed peak cortisol depending group size for each participant, specifically participants who formed either a small (between 1 and 3 participants) or a larger group (5 or 6 participants).

Therefore, as evidenced by the results in Chapter 4, increasing the duration of the stress task may result in a mismatch with the sampling points and the expected time course for HPA activation (Dickerson & Kemeny, 2004). Although Von Dawnas et al., (2011) recommend using groups of up to 6 participants in their group adaptation of the Trier Social Stress Task, this may not be appropriate when using the TSST-G in the context of cortisol reactivity in a similar manner to the current study. Based on these findings, the TSST-G should be conducted with consistent groups of either 3 or 4 participants when studies investigating cortisol reactivity in order to capture peak cortisol reactivity at the sampling point immediately after the termination of the task. Controlling for group size in this way will reduce ambiguity and noise with cortisol sampling points as well as aid the interpretation of the study findings.

### 5.4.6 Hair Sampling

Finally, a limitation to the current research was the availability of data on hair cortisol across adolescents and young adults (Chapter 4). The study initially intended to obtain hair samples on 150 participants, however very few participants were willing to provide hair samples in the current study.

Data from qualitative responses highlighted that participants were concerned over the amount of hair taken, and the noticeability of where the samples were taken. Obtaining biological samples in this age group can be difficult, and research has suggested that minimising burden can improve rates of providing blood or saliva samples in research (Storr, Or, Eaton, & Ialongo, 2014). However, as hair samples are taken from the scalp, the burden of taking the sample outweighed decisions for providing the hair samples in the current sample.

Although efforts were made to keep sampling procedures consistent, the hair samples obtained for the current research were generally underweight (i.e., < 25 mg). This was partly due to the environment in which samples were taken, particularly for the adolescents. Following the daily diary period, the adolescents were followed-up as a group within school, at which point participants were asked whether they wished to provide hair samples as part of the study. Often, the adolescents would base their decision on whether to provide hair samples on the choices of the other adolescents in the group. This often led to a whole group declining to provide hair samples. It is likely that the rate of adolescents providing hair samples may have increased slightly had the follow-up sessions been conducted on an individual basis although this could not be achieved due to time and resource restrictions within schools.

Sampling procedures were more consistent with the young adults, who were followed up individually at the University of Leeds. Although samples were underweight, these differences were accounted for at assay. Similarly, HCCs were well correlated against the two sampling points indicating consistency across the two samples for each participant.

Furthermore, HCCs can be influenced by a range of factors, some of which were not considered in the current study. For example, exercise is thought to have a protecting effect on HPA functioning, where individuals who are physically fitter have lower cortisol responses compared to those who are less physically fit (Huang, Webb, Zourdos, & Acevedo, 2013; Rimmele et al., 2009; Traustadóttir, Bosch, & Matt, 2005). Similarly, due to the destructive nature of analysing hair samples, HCCs can vary due to methodological differences, from taking the sample to cleaning and assay (Greff et al., 2019).

Finally, as the hair samples were taken at the end of the daily diary period, the average HCCs included the stress-induction task within the one-month retrospective period. Therefore, future research should consider potential confounding effects of the study design when using hair sampling methods as an objective measure of stress. Additionally, it would be useful for future research to determine how comparable HCCs are with self-reported stress levels, as previous research has found HCCs are more strongly associated with life events opposed to perceived stress (Karlén et al., 2011; Staufenbiel et al., 2013).

## 5.5 Implications of Findings and Future Directions

Taken together with previous research, the findings from this thesis indicate that stress-related eating habits are consistent throughout adolescence and into adulthood. Adolescence presents a unique period for the establishment of health behaviours, particularly dietary habits (Albani et al., 2018; Todd et al., 2015), as adolescents are given increased autonomy over their eating behaviours due to decreased dependence on the family home environment (Bassett et al., 2008). Previous research has highlighted the importance of understanding health behaviours in emerging adulthood (Ames et al., 2018; Boyce & Kuijer, 2015; Hu et al., 2016; Watts et al., 2016), where increased autonomy over food choice and maintaining norms within peer groups around eating habits (Koehn et al., 2016) may facilitate choices towards unhealthy foods when stressed, rather than healthier choices.

The stress-induced changes to eating habits identified in this thesis may result in poorer health behaviours being established during adolescence which

can continue into adulthood (Mikkilä et al., 2005), increasing the risk of ill health and obesity in later life (Ebbeling et al., 2002). More specifically, changes to daily snack intake as a result of stress can have long lasting effects on health. For example, small changes in daily food intake by 50 to 100 kcal can result in weight gain through chronic, positive energy intake (Mozaffarian et al., 2011) and contribute to high levels of overweight and obesity (Jauch-Chara & Oltmanns, 2014; Sinha & Jastreboff, 2013). Understanding patterns and moderators of stress-related eating behaviours in emerging adulthood can inform future research to reduce this maladaptive eating behaviour.

Although stress was not associated with changes to healthy food consumption, the findings from this thesis demonstrate that intake of fruit and vegetables is below recommended levels in adolescents and young adults. Fruit and vegetable consumption are often lower than recommendations within this age group, where as many as 70% of adolescents eat less than the recommended 5 portions of fruit and vegetables a day (Huang et al., 2019). In young people aged 11-16 years old, barriers to healthy eating involved the relative cheapness and palatability of fast food as well as its ease of access (Shepherd et al., 2006). Research has also found that stress itself may present a barrier to healthy eating (Unusan, 2006), increasing seeking behaviours for unhealthy foods instead, which are seen as being rewarding and pleasurable (Ulrich-Lai et al., 2010). These findings highlight the need to encourage healthier dietary behaviours in adolescents and young adults.

Theories have posited that stress-related eating is used as a coping mechanism when experiencing stress (Dallman et al., 2003; Torres & Nowson, 2007; Wethington et al., 2015) where food is used to alleviate symptoms of stress such as negative affect and anxiety (Adam & Epel, 2007; Tryon et al., 2013) and is appraised as being rewarding (Jauch-Chara & Oltmanns, 2014). Reward systems can have a significant effect on weight-related outcomes through increased sensitivity towards foods which are perceived as being rewarding, even when, cognitively, an individual is aware of the food choices they should be making to be healthy (Lowe, Reichelt, & Hall, 2019). Changing these maladaptive health behaviours is not straightforward, however, is it important to note that

stress-induced eating is a modifiable behaviour and, as such, interventions can be developed to facilitate health promoting behaviours and improve health outcomes across the lifespan.

Although the direct and indirect effects of stress on health outcomes are well established in the literature, stress is often overlooked when considering prevention strategies to reduce obesity, with greater focus placed instead on increasing exercise or developing healthy eating initiatives (Tomiyama, 2019). There are schemes that exist which aim to improve health outcomes, such as Change4Life national campaign, which are effective in increasing awareness of obesity and unhealthy eating behaviours. However, such prevention schemes do not always result in attitudinal changes towards health or changes to health behaviours themselves (Croker, Lucas, & Wardle, 2012). Instead, understanding motivations which facilitate eating behaviour is needed to develop effective interventions (Ulrich-Lai et al., 2010).

Furthermore, understanding individual differences in stress-eating associations can provide insights into why individuals may be more susceptible to changes to normal eating habits when experiencing stress. Concurrent with previous research (Greeno & Wing, 1994; O'Connor & Conner, 2011), the findings of this thesis demonstrate that individual differences play a crucial role in understanding stress-induced eating in adolescents, and how these behaviours may persist into adulthood.

Across the moderators investigated in this thesis, cortisol reactivity to stress was found to moderate stress-eating associations across both adolescents and young adults. Differences in cortisol reactivity have been associated with differential effects on the experience of stress and subsequent eating behaviours (for reviews see Klatzkin et al., 2019; O'Connor, 2018). This direct effect of stress on this biological pathway is likely to increase wear and tear on important internal systems (Aschbacher et al., 2013; McEwen, 2004) leading to poorer health outcomes (Chida & Steptoe, 2010). Worryingly, the effect of cortisol reactivity on stress-eating associations has also been found in children, where higher cortisol has been associated with increased food intake following a stress-induction task

(Francis et al., 2013), and increased consumption of sweet foods in children under 10 years (Michels et al., 2013).

This effect of cortisol reactivity on stress-eating associations was particularly evident in work/academic and ego threatening stressors in adolescents, whilst in young adults, cortisol reactivity only moderated stress-eating associations on the total number of daily stressors. These findings suggest that, while cortisol response may moderate daily stress and total snack intake across the whole sample, the type of stressor experienced is especially relevant in adolescents. Future research using cortisol sampling should consider associations with the types of stressors experienced as this can provide useful insights into stress-eating associations beyond merely the experience of a stressor. Understanding these individual differences in cortisol reactivity to stress can help to develop effective interventions to reduce maladaptive coping methods when stress such as changes to normal eating behaviours.

Conversely, chronically occurring stress over the past month did not moderate any stress-eating associations across emerging adulthood. Whist saliva samples provided insights into stress reactivity, findings of previous research (as well as the findings in the current research) indicate that HCCs may not be sensitive enough to compare against daily stress and eating habits across emerging adulthood, as instead, HCCs are thought to be better predictors of chronic stress or life events opposed to perceived stress (Karlén et al., 2011; Staufenbiel et al., 2013). Gundersen, Mahatmya, Garasky, and Lohman (2011) suggest that chronic stress, particularly in low income families, can predict incidence of childhood obesity and is a major contributory factor within this young age group. Further research is needed to determine the influence of chronically occurring stress on eating behaviours across emerging adulthood.

Individual differences in emotion regulation, and emotional eating, were found to influence stress-eating associations differently in adolescents and young adults. Emotional eating tendencies are thought to be a learnt behaviour (Herle et al., 2018), rather than one stemming from a combination of genetic susceptibility and environmental factors (van Strien et al., 2010). However,

differences in emotional eating behaviours between adolescents and young adults may stem from the methodologies employed in the current study.

For example, in a review, Bongers and Jansen (2016) suggest that self-reported scales of emotional eating such as the DEBQ (Van Strien et al., 1986) lack both predictive and discriminative validity, resulting in inconsistent findings in previous research. Instead, they suggest that other descriptors of emotional eating should be adopted (such as uncontrolled eating or eating in response to a cue), or adopting a different methodology (e.g., ecological momentary assessments) which are able to capture emotions as they occur. Similarly, in a review on emotional eating and weight gain, Frayn and Knäuper (2018) concluded that as a construct, emotional eating is not well defined. This may explain why research findings on the role of eating styles in stress-eating associations are mixed.

Furthermore, the current research investigated emotional eating as a general trait, along with two strategies of emotion regulation. However, underlying traits of emotional eating may be more predictive of health behaviours than eating styles overall. For example, Van Blyderveen et al. (2016) looked at impulsivity and emotion control and found that both variables moderated negative affect and snack intake in individuals when experiencing stress.

Similarly, research has focused on the impact of negative emotions on eating behaviours. However, individual differences in positive emotions have also been found to influence stress-eating associations. For example, Evers, Adriaanse, de Ridder, and de Witt Huberts (2013) found that positive emotions were more predictive than negative emotions on food intake. This was also found in a meta-analysis, where both positive and negative mood was associated with increased food intake in healthy individuals (Cardi, Leppanen, & Treasure, 2015).

Individual differences in stress-eating associations were also investigated using the personality trait of conscientiousness, although findings were not consistent in the current research. Conscientiousness is unique in its application to health behaviours as it has been found to predict longevity (Friedman et al., 1993; Kern & Friedman, 2008) and risk of mortality (Taylor et al., 2009; Weiss & Costa Jr, 2005). Understanding the role of conscientiousness on stress-eating

associations is especially useful as higher levels of this personality trait can be protective against poor health outcomes, including obesity (Jokela et al., 2013). Future research should consider the role of conscientiousness on stress-eating associations, as individual differences in this trait can differentially influence eating habits when experiencing stress (O'Connor et al., 2009; O'Connor & O'Connor, 2004).

The relationship between stress and health behaviours is a complex, multifaceted behaviour involving behavioural, neural and endocrine systems (Finch et al., 2019). The findings of this thesis have highlighted that stress can differentially influence the amount, and type, of food consumed in adolescents and young adults. Furthermore, this relationship may be moderated by variables including cortisol reactivity, conscientiousness, eating style and emotion regulation, however findings were not consistent.

For example, conscientiousness was found to moderate stress and snacks intake in the daily diary study (Chapter 3), but not in the experimental study (Chapter 4). Similar differences were seen for eating style across adolescents and young adults. As there is limited research currently available on these moderators on stress-eating associations in adolescents, it is difficult to draw conclusions regarding moderators of stress-eating in this age group. Therefore, future research should consider the role of key moderating variables when researching stress and health behaviours in adolescents to provide greater insights into the individual differences of stress-eating associations.

## 5.6 Conclusions

Taken together, the findings from this thesis indicate that stress is associated with a change in the amount, and type, of foods consumed across emerging adulthood. These changes to normal eating behaviours may result in the formation of maladaptive coping methods when experiencing stress and, once established, can continue throughout adulthood. Consequently, changes to normal eating behaviours can result in poorer health outcomes, including obesity and subsequent weight-related illnesses. Evidence for the role of moderating variables (mainly conscientiousness, eating styles and emotional regulation) on stress and eating behaviours is inconsistent, and requires further investigation. Furthermore, cortisol reactivity to stress was found to moderate stress-eating associations across both adolescents and young adults. Conversely, chronically occurring stress did not moderate stress-eating relations across emerging adulthood. Currently, there is limited research regarding stress-eating associations in adolescents, and the long-term impact of these behaviours is unknown. Future research should endeavour to continue investigating stress-eating associations in adolescents to determine the role of moderating variables on this association.

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# Appendices

## Appendix Item 1. Example search strategy for meta-analysis on stress and eating behaviours in adults.

| Stress Terms | | Eating Terms | | |
|---|---|---|---|---|
| 1. Stress*.mp<br>2. Hyperphagi*<br>3. Daily adj2 (hassle* or stress*)<br>4. Hypophagi*<br>5. Cortisol<br>6. Saliva* adj5 cortisol<br>7. Hair adj5 cortisol<br>8. Stress reactiv* | 9. Worry* or distress*<br>10. cop? adj3 stress*<br>11. Perceive* stress<br>12. Life event*<br>13. Life adj2 stress*<br>14. Trier social stress t$*<br>15. Initiate* adj2 stress*<br>16. ((induce* adj3 stress) not oxidati*) | 18. Food intake.mp (food intake)<br>19. Snack*<br>20. Diet*<br>21. Eat* NOT disorder* adj2 eat*<br>22. Stress adj3 eat*<br>23. Diet* restrain*<br>24. Unhealthy adj5 diet<br>25. High calorie low nutrient OR HCLN<br>26. Low calorie high nutrient OR LCHN | 27. Healthy adj5 diet<br>28. Emotion* eat*<br>29. Healthy adj2 food*<br>30. Healthy adj eat*<br>31. Food habit*<br>32. Eat* behavio?r<br>33. Fat*<br>34. Main meal*<br>35. Fruit*<br>36. Unhealthy adj eat*<br>37. Overeat* | 38. Vegetable*<br>39. Undereat*<br>40. Fast adj food*<br>41. Food consum*<br>42. Junk adj food*<br>43. Calorie*<br>44. Kilocalorie*<br>45. Convenience adj3 food*<br>46. Unhealthy adj5 food*<br>47. Sugar* |
| **Combined Terms** | | | | |
| 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16. | | 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47. | | |
| **17 AND 48** | | | | |
| **Notes:** / = map to subject heading * = missing letter<br>adj = adjective .mp = title, abstract, subject heading exp = explode subject<br>? = wildcard | | | | |

**Appendix Item 2. Quality assessment tool adapted from the EPHPP (Effective Public Health Practice Project).**

## A. SELECTION BIAS

**Q1. Are the individuals selected to participate in the study likely to be representative of the target population?**

1 Very Likely
2 Somewhat Likely
3 Not Likely
4 Can't Tell

**Q2. What percentage of selected individuals agree to participate?**

1 80-100% agreement
2 60-79% agreement
3 Less than 60% agreement
4 Not applicable
5 Can't tell

| RATE THIS SECTION | STRONG | MODERATE | WEAK |
|---|---|---|---|
| | 1 | 2 | 3 |

## B. STUDY DESIGN

**Indicate the study design:**

1 Longitudinal
2 Stress induction (independent groups) with objective stress and/or eating measure.
3 Stress induction (single group) with objective stress and/or eating measure.
4 Objective stress or eating measures (1 time point)
5 Daily diary design
6 Subjective stress and eating measures (multiple time points)
7 Subjective stress and eating measures (single time point)
8 Other. Specify _____
9 Can't tell

**Does the study use:**

Independent groups Repeated measures Can't tell

**If independent groups, were all groups of equal size?**

No Yes

| RATE THIS SECTION | STRONG | MODERATE | WEAK |
|---|---|---|---|
| | 1 | 2 | 3 |

## C. CONFOUNDERS

**Q1. Were additional variables considered in the study?**

1 Yes 2 No 3 Can't tell

**Examples of confounders:**

Race, Sex, Marital status/family, Age, SES (income), Education, Health Status

**Q2. If yes, indicate the percentage of relevant confounds that were controlled (either in the design (e.g., matching) or analysis).**

1 80-100% (most) 2 60-79% (some)
3 Less than 60% (few or none) 4 Can't tell

| RATE THIS SECTION | STRONG | MODERATE | WEAK |
|---|---|---|---|
| | 1 | 2 | 3 |

## D. DATA COLLECTION METHODS

**Type of stress measure used:**

Objective Subjective

**Q1. Were data collection tools for stress measurements shown to be valid?**

1 Yes 2 No 3 Can't tell

**Q2. Were data collection tools for stress measurements shown to be reliable?**

1 Yes 2 No 3 Can't tell

**Type of eating behaviour measure used:**

Objective Subjective

**Q3. Were data collection tools for eating behaviours shown to be valid?**

1 Yes 2 No 3 Can't tell

**Q1. Were data collection tools for eating behaviours shown to be reliable?**

1 Yes 2 No 3 Can't tell

| RATE THIS SECTION | STRONG | MODERATE | WEAK |
|---|---|---|---|
| | 1 | 2 | 3 |

## E. WITHDRAWALS AND DROP OUTS

**Q1. Were withdrawals and drop-outs reported in terms of number and/or reasons per group?**

1 Yes 2 No 3 Can't tell 4 Not applicable (i.e., one time surveys)

**Q2. Indicate the percentage of participants completing the study. (if the percentage differs by groups, record the lowest).**

1 80-100% 2 60-79% 3 Less than 60% 4 Can't tell

| RATE THIS SECTION | STRONG | MODERATE | WEAK | |
|---|---|---|---|---|
| | 1 | 2 | 3 | Not applicable |

**Global Rating: Component Ratings**

Please transcribe the information from the grey boxes on pages 1-3 onto this page.

| | | | |
|---|---|---|---|
| **A SELECTION BIAS** | **STRONG** | **MODERATE** | **WEAK** |
| | 1 | 2 | 3 |
| **B STUDY DESIGN** | **STRONG** | **MODERATE** | **WEAK** |
| | 1 | 2 | 3 |
| **C CONFOUNDERS** | **STRONG** | **MODERATE** | **WEAK** |
| | 1 | 2 | 3 |
| **D DATA COLLECTION METHOD** | **STRONG** | **MODERATE** | **WEAK** |
| | 1 | 2 | 3 |
| **E WITHDRAWALS & DROP-OUTS** | **STRONG** | **MODERATE** | **WEAK** |
| | 1 | 2 | 3 |

**GLOBAL RATING FOR THIS PAPER (CIRCLE ONE):**

**1 STRONG** (no WEAK ratings)
**2 MODERATE** (one WEAK rating)
**3 WEAK** (two or more WEAK ratings)

With both reviewers discussing the ratings:

Is there a discrepancy between the two reviewers with respect to the component (A-E) ratings?

No Yes

If yes, indicate a reason for the discrepancy

1 Oversight 2 Differences in interpretation of criteria
3 Differences in interpretation of study

**Final decision of both reviewers (circle one):**

**1 STRONG 2 MODERATE 3 WEAK**

**Scoring Criteria Details**

### A. SELECTION BIAS

**Q1.** Participants are likely to be representative of the target population if they have been recruited from workplaces or from sources away from higher education environments. Studies score 1 (Very likely) if the population have been sourced at random from the population (e.g., selected through online advertisements). A study may be somewhat likely (score 2) if participants have been recruited from settings other than higher education environments. Studies may score 3 (Not Likely) if the participants are obtained from specific sources (such as undergraduate students, managers of a specific company ect). Not applicable should be selected for cross-sectional studies carried out at a single time point.

**Q2.** Refers to the number of participants who agreed to complete all parts of the study (i.e., did not drop out).

RATE SECTION:

1 strong = Both Q1 & Q2 are '1', OR Q1 is '1' % Q2 is '4'.
2 moderate = Q1 is '1' or '2', and Q2 is '1', '2' OR '5' Can't tell.
3 weak = Q1 is '3' and Q2 is '3' or '4'.

### A. STUDY DESIGN

This section aims to assess the quality of a study based on the type of design used. The overall study design should be indicated, with details on the type of design. If a study used independent groups, please indicate whether groups were of equal size. An allowance of +/-1 participant should be made where sample sizes are odd.

**Longitudinal:** Studies conducted over several months or years, with multiple measurement points across the time period.
**Stress induction (independent groups) with objective stress / eating:** Independent groups for the stress task, with either an objective measure of stress (e.g., blood pressure, cortisol) OR an objective measure of food intake (e.g., weighed food intake, consumption of a test meal).
**Stress induction (single group) with objective stress / eating:** Same as above criteria, only with the use of a repeated measures design (i.e., a single group of participants).
**Objective stress or eating measures (1 time point):** Study does not induce stress, however does include a measure of objective stress OR an objective eating behaviour. 24 hour dietary recall with a dietitian is included as an objective measure of eating behaviour within this category.
**Daily diary design:** Study adopts a diary design whereby participants are asked to record stress and/or eating habits over multiple days. Minimum number of diary entries required is 2, otherwise study is categorised using one of the below categories. Diaries may be recorded online or on paper.
**Subjective stress and eating measures (multiple time points):** Study records stress and eating measures at more than one time point (for example one month part) using the same participants at both/multiple time points.
**Subjective stress and eating measures (single time point):** Study is cross-sectional, and records stress and eating measures at only one time point.

RATE SECTION:

1 strong = Study design is ‘1’ to ‘3’.
2 moderate = Study design is ‘3’ to ‘6’.
3 weak = Study design is ‘7’ to ‘9’

### B. CONFOUNDERS

The authors should indicate whether any confounds have been investigated and/or controlled for in the study. Studies may include analyses to compare potential confounding variables (such as age, gender, SES, dietary restraint or BMI). Where there are differences between confounding variables, indicate the estimated percentage that were controlled for in the study (either in the study design, or study analyses).

RATE SECTION:
1 strong = Q1 is ‘2’ OR Q2 is ‘1’
2 moderate = Q1 is ‘1’ AND Q2 is ‘2’
3 weak = Q1 is ‘1’ AND Q2 is ‘3’. OR confounds are not described (Q1 is ‘3’ and Q2 is ‘4’).

### C. DATA COLLECTION METHODS

This section aims to determine whether the comparison and outcome measures are reliable and valid. For comparison (stress measure) and outcome measures (eating behaviour), indicate whether an objective or subjective method was employed. Reliability and validity may be reported in the study, or detailed in a previous study and cited in text. Where objective measures have been used, check whether the method is valid for the purpose of the study (for example, collection of cortisol as an indicator of stress), and assume reliability.
RATE SECTION:
1 strong = Data collection methods are valid (Q1 / Q3 are ‘1’) AND reliable (Q2 / Q4 are ‘1’). OR an objective measure is used (coded as valid and reliable).
2 moderate = Data collection methods have been shown to be valid (Q1 / Q3 are ‘1’) and have not been shown to be reliable (Q2 / Q4 are ‘2’) or not described (Q2/ Q4 are ‘3’). OR at least one measure (stress / eating) is both valid and reliable.
3 weak = Collection methods have not been shown to be valid (Q1/ Q3 are ‘2’) OR validity and reliability have not been described for both measures (responses are ‘3’ across all questions).

### D. WITHDRAWALS & DROPOUTS

Retention of participants may be reported in the study design (usually under participants) or in the results section. Score YES if the authors note attrition rates and number of drop outs. Score NO if no information is given regarding the number of drop outs or withdrawals in the study. Studies using a single time point should be coded as 4 (Not applicable), and counted as ‘strong’ in global rating on withdrawals and dropouts. The percentage of participants completing the study refers to the number of participants retained for data analysis.

1 strong = where retention is 80% or greater (Q1 is ‘1’ and Q2 is ‘1’).
2 moderate = where retention is no lower than 60% (Q1 is ‘1’ and Q2 is ‘2’).
3 weak = where follow up rates are less than 60% (Q1 is ‘1’ and Q2 is ‘3’, or if withdrawals / drop outs have not been described (Q1 is ‘3’ and Q2 is ‘4’).

**Appendix Item 3. Study characteristics summary table of studies included in meta-analysis of adults (*k*=58)**

| Author(s) and Year | Sample Size | Gender | Mean age and BMI | Stress Category | Eating Behaviour Measurement | Eating Behaviour Category |
|---|---|---|---|---|---|---|
| Appelhans (2010) | 34 | All female | 33.5 years<br>27.7 kg/m$^2$ | Induced | Objectively measured snack intake[5] | Other |
| Barker et al. (2015) | 20 | All male | 20 years (median age) | Induced | 24-hour dietary recall | Other |
| Barrington et al. (2014)[6] | 65,235 | 32,880 females (50.4%)<br>32,355 males | Not reported | Perceived | Food frequency[7] | Healthy and Unhealthy |
| Barrington et al. (2012)[8] | 621 | 357 females (57.49%)<br>264 males | Mean age not reported<br>29.2 kg/m$^2$ | Perceived | Food frequency[9] | Healthy and Unhealthy |

[5] Intake measured by total intake (kcal)
[6] Results adjusted for age, sex, race, education, marital status and perceived stress.
[7] Servings per week of high fat snacks, fast food items, fruits and vegetables.
[8] Results controlled for age, sex, race, education and worksite.
[9] Portions of fruit and vegetables per day, and number of fast food meals consumed per week.

| | | | | | | |
|---|---|---|---|---|---|---|
| Boggiano et al. (2015) | 169 | 106 females (62.72%)<br>63 males | 21.10 years<br>27.5 kg/m$^2$ | Daily diary | Food frequency[10] | Unhealthy |
| Boyce and Kuijer (2015) | 175 | 121 females (69%)<br>54 males | 18.20 years<br>23.83 kg/m$^2$ | Perceived | Food frequency[11] | Healthy and Unhealthy |
| Carson et al. (2015) | 355 | All female | 49.8 years<br>36.5 kg/m$^2$ | Perceived | 24-hour dietary recall[12] | Unhealthy and Other |
| Conner et al. (1999) | 60 | 33 females (55%)<br>27 males | 20 years<br>BMI not reported | Daily diary | Between-meal snacks[13] | Other |
| Crowther, Sanftner, Bonifazi, and Shepherd (2001) | 17 | All female | 18.8 years<br>20.2 kg/m$^2$ | Daily hassles | Food frequency[14] | Other |
| Dweck et al. (2014) | 64 | All female | 18.8 years<br>24.5 kg/m$^2$ | Induced | Objectively measured snack intake[15] | Other |

[10] Total number of unhealthy foods consumed over four days.
[11] Portions of fruit and vegetables per day, and number of days per week consumed fast/junk foods or overate when full.
[12] Intake of total fat (grams) categorised as unhealthy. Total energy intake (kcals), carbohydrates (grams) and protein (grams) categorised as other foods.
[13] Number of snacks consumed.
[14] Total energy intake per day (kcal).
[15] Total energy intake from healthy and unhealthy snack foods (kcal).

| | | | | | | |
|---|---|---|---|---|---|---|
| El Ansari, Adetunji, and Oskrochi (2014)[16] | 3,706 | 2,699 females (72.83%)<br>765 males<br>242 not reported | 24.9 years<br>BMI not reported | Perceived | Food frequency[17] | Healthy, unhealthy and other |
| El Ansari and Berg-Beckhoff (2015) | 2,810 | 1,483 females (52.78%)<br>1,327 males | 18 years<br>BMI not reported | Perceived | Food frequency[18] | Healthy and Unhealthy |
| El Ansari, Suominen, and Berg-Beckhoff (2015) | 1,076 | 762 females (70.8%)<br>314 males | 21 years (median age)<br>BMI not reported | Perceived | Food frequency[18] | Healthy and unhealthy |
| Epel et al. (2001) | 59 | All female | 36 years<br>25.4 kg/m$^2$ | Induced | Objectively measured food intake[19] | Unhealthy and other |
| Errisuriz et al. (2016) | 613 | 368 females (60%)<br>245 males | 18.9 years<br>23.0 kg/m$^2$ | Perceived | Food frequency[20] | Healthy, unhealthy and other |

[16] Controlled for University.

[17] Eating behaviour category was based on food groupings used e.g., fresh fruits (healthy), sweets (unhealthy) and snacks / products based on macronutrients (other).

[18] Composite food intake scores (healthy and unhealthy patterns) based on self-reported food frequency.

[19] Data obtained on total amount eaten for sweet and salty foods separately (unhealthy). Number of servings eaten across all foods was categorised as other.

[20] Portions per day of fruit and vegetables (healthy). Servings per week of fast foods, sweet / salty snacks (unhealthy) and frozen foods (other).

| | | | | | | |
|---|---|---|---|---|---|---|
| Geliebter et al. (2012) | 20 | All female | 35.9 years<br>37.0 kg/m$^2$ | Induced | Objectively measured food intake[21] | Other |
| Groesz et al. (2012)[22] | 457 | All female | 28.5 years<br>24.2 kg/m$^2$ | Perceived | Food frequency[23] | Healthy and unhealthy |
| Habhab et al. (2009) | 40 | All female | 21.35 years<br>23.17 kg/m$^2$ | Induced | Objectively measured food intake[24] | Other |
| Herhaus, Päßler, and Petrowski (2018) | 56 | 30 females (53.6%)<br>26 males | 32.86 years<br>32.76 kg/m$^2$ obese group<br>22.58 kg/m$^2$ healthy weight group | Induced | Objectively measured food intake[25] | Unhealthy |
| Järvelä-Reijonen et al. (2016) | 297 | 249 females (83.8%)<br>48 males | 48.9 years<br>31.3 kg/m$^2$ | Perceived | 48hr dietary recall (self-reported)[26] | Healthy, unhealthy and other |
| Kandiah et al. (2006) | 272 | All female | 21.5 years (median age)<br>BMI not reported | Perceived | Foods eaten when under stress & not under stress[27] | Unhealthy and other |

[21] Consumption of an ad libitum test meal (kcal).
[22] Results controlled for age, BMI, education and income.
[23] Consumption of nutritious foods (healthy) and palatable, non-nutritious foods (unhealthy).
[24] Total consumption (ounces) of high/low fat sweet and salty foods.
[25] Total intake (kcal) of unhealthy foods.
[26] Consumption of food groups e.g., vegetables (healthy), pastries (unhealthy) and rye bread (other) in grams per day.
[27] Types of foods consumed including sweet foods (unhealthy) and mixed dishes (other)

| | | | | | | |
|---|---|---|---|---|---|---|
| Klatzkin et al. (2018) | 34 | All female | 19 years<br>24 kg/m$^2$ | Induced; Objective & perceived | Objectively measured food intake[28] | Unhealthy |
| Kwan and Gordon (2016) | 156 | All female | 19.27 years<br>BMI not reported | Induced | Objectively measured food intake[29] | Unhealthy |
| Lai et al. (2012) | 48 | All female | 19.9 years<br>20.74 kg/m$^2$ | Induced | 3-day food diary[30] | Other |
| Lattimore (2001)[31] | 9 | All female | 24 years<br>22 kg/m$^2$ | Induced | Objectively measured food intake[32] | Unhealthy |
| Lemmens et al. (2011) | 42 | 26 females (61.9%)<br>16 males | 30.7 years<br>25.4 kg/m$^2$ | Induced | Objectively measured food intake[33] | Other |
| Levine and Marcus (1997) | 20 | All female | 18.4 years<br>22.2 kg/m$^2$ | Induced | Objectively measured food intake[25] | Unhealthy |

[28] Consumption in grams of high fat/sugar snack foods.
[29] Total energy from high fat snacks (kcal).
[30] Energy intake per day (kcal).
[31] Mean age and BMI for whole sample (N=20). Meta-analysis included only none binge eating participants from the study (N=9).
[32] Total energy intake from full fat ice cream (kcal).
[33] Total energy intake as a percentage of daily energy requirements.

| | | | | | | |
|---|---|---|---|---|---|---|
| Liu et al. (2007) | 2,541 | 1,071 females (42.1%)<br>1,470 males | 20.4 years<br>BMI not reported | Perceived | Food frequency[34] | Healthy, unhealthy and other |
| McKinzie, Burgoon, Altamura, and Bishop (2006) | 65 | 49 females (75.38%)<br>16 males | 27.0 years<br>BMI not reported | Perceived | Eating habits[35] | Other |
| Mouchacca et al. (2013) | 1,382 | All female | 35.7 years<br>26.2 kg/m$^2$ | Perceived | Food frequency[36] | Unhealthy |
| Newman et al. (2007) | 50 | All female | 33.96 years<br>23.34 kg/m$^2$ | Induced & daily diary (perceived) | Between-meal snacks[13] | Other |
| Ng and Jeffery (2003)[37] | 12,110 | 6,620 females (54.6%)<br>5,490 males | 40.0 years<br>BMI not reported | Perceived | Food frequency[38] | Unhealthy |
| O'Connor et al. (2008) | 422 | 229 females (54.27%)<br>193 males | 40.32 years<br>25.61 kg/m$^2$ | Daily diary | Between meal snacks[39] | Healthy, unhealthy and other |
| O'Connor and O'Connor (2004) | 155 | All female | 21.12 years<br>22.8 kg/m$^2$ | Daily diary | Between meal snacks[40] | Unhealthy and other |

[34] Consumption of food groups including fruit (healthy), fast food (unhealthy) and snack food (other).
[35] Measured as a change in eating habits (eating more or less than usual).
[36] Consumption of unhealthy food groups including pizza and chocolates (unadjusted data obtained).
[37] Results controlled for age, education, ethnicity and marital status.
[38] Consumption of high fat foods only.
[39] Daily consumption of fruit/vegetables (healthy), high fat/sugar snacks (unhealthy) and total snacks (other).
[40] Consumption of unhealthy snacks (chocolate/savoury/biscuits) and mean snack consumption (other).

| | | | | | | |
|---|---|---|---|---|---|---|
| Oliver et al. (2000) | 68 | 41 females (60.29%)<br>27 males | 26.1 years<br>BMI not reported | Induced | Objectively measured food intake[41] | Other |
| Pak, Olsen, and Mahoney (1999) | 207 | 137 females (66.2%)<br>70 males | Females 44 years<br>Males 52 years<br>BMI not reported | Perceived | Food frequency[42] | Healthy and other |
| Papier, Ahmed, Lee, and Wiseman (2015)[43] | 728 | 397 females (54.53%)<br>331 males | 21.35 years<br>Mean BMI not reported | Perceived | Food frequency[44] | Healthy, unhealthy and other |
| Peker and Bermek (2011) | 111 | 56 females (50.5%)<br>55 males | 19.43 years<br>BMI not reported | Perceived | Diet quality[45] | Healthy |
| Pelletier, Lytle, and Laska (2016) | 441 | 298 females (67.6%)<br>143 males | Mean age and BMI not reported | Perceived | Food frequency[46] | Unhealthy and other |

[41] Total energy intake (kcal) of high and low fat sweet, salty and bland foods.
[42] Frequency of meals/fruit consumption (healthy) and eating out/snacks/caffeine (other).
[43] Data were adjusted for academic group, marital status, working hours, living situation, BMI, dieting, frequency of exercise and smoking status.
[44] Consumption of food groups e.g., vegetables and fruit (healthy), highly processed foods (unhealthy) and cereal foods (other).
[45]Diet quality measured through food habits (e.g., eating 33-5 servings of fruit/vegetables per day). Higher scores reflect better diet quality.
[46] Consumption of fast food per week (unhealthy) and snacks per day (other).

| | | | | | | |
|---|---|---|---|---|---|---|
| Pollard, Steptoe, Canaan, Davies, and Wardle (1995) | 115 | 51 females (44.35%)<br>64 males | 22.25 years<br>24.1 kg/m$^2$ | Induced | 24-hour dietary recall[47] | Other |
| Raspopow et al. (2010) | 48 | All female | 19.28 years<br>BMI not reported | Induced | Objectively measured food intake[48] | Other |
| Raspopow, Abizaid, Matheson, and Anisman (2014) | 66 | All female | 20.47 years<br>BMI not reported | Induced | Objectively measured food intake[49] | Unhealthy |
| Roberts et al. (2014) | 38 | All female | 42.0 years<br>24.9 kg/m$^2$<br>BMI not reported | Perceived | Food frequency[50] | Unhealthy and other |
| Roohafza et al. (2007)[51] | 5,892 | 2,915 females (49.47%)<br>2,917 males<br>60 not reported | 40.5 years<br>BMI not reported | Perceived | Food frequency[52] | Healthy |

[47] Total energy intake (kcal).
[48] Consumption of high and low-fat snacks (kcal).
[49] Consumption of a high fat snack (brownies) in grams.
[50] Food frequency categorised into macronutrients e.g., fat (unhealthy) and protein (other). Also included total energy intake in kcal (other).
[51] Results adjusted for age, gender, education and marriage.
[52] Fruit and vegetable consumption per day.

| | | | | | | |
|---|---|---|---|---|---|---|
| Rutledge and Linden (1998) | 77 | All female | 20.3 years<br>BMI not reported | Induced | Objectively measured food intake[53] | Unhealthy |
| Steptoe et al. (2017) | 2,428 | 1,374 females (59.3%)<br>944 males<br>110 not reported | 66.2 years<br>27.49 kg/m$^2$ | Objective (hair cortisol) | Food frequency[54] | Healthy |
| Steptoe, Lipsey, and Wardle (1998) | 44 | 28 females (63.63%)<br>16 males | 41.8 years<br>BMI not reported | Daily diary | Food frequency[55] | Healthy, unhealthy and other |
| Stone and Brownell (1994) | 158 | 79 females (50% female)<br>79 males | 43.2 years<br>BMI not reported | Daily diary | Food frequency[35] | Other |
| Tseng and Fang (2011) | 426 | All female | 43.9 years<br>BMI not reported | Perceived | 48-hour dietary recall[56] | Unhealthy and other |
| van Strien, Roelofs, and de Weerth (2013) | 46 | All female | 19.68 years<br>21.27 kg/m$^2$ | Induced | Objectively measured food intake[48] | Other |

[53] Consumption of high fat snacks in grams.
[54] Portions of fruit and vegetables per day (unadjusted data).
[55] Daily consumption of food groups over 8 weeks e.g., fresh fruit (healthy), sweet foods (unhealthy) and red meat (other).
[56] Two 48-hour recalls used to measure food consumption including percentage of energy from fat (unhealthy) and total energy intake in grams (other).

| | | | | | | |
|---|---|---|---|---|---|---|
| Vicennati et al. (2011)[57] | 127 | All female | 44.8 years<br>38.9 kg/m$^2$ | Objective (urinary cortisol) | Food frequency[58] | Unhealthy and other |
| Vidal et al. (2018) | 523 | 272 females (52%)<br>251 males | 19.0 years<br>BMI not reported | Perceived | Food frequency[59] | Unhealthy |
| Wallis and Hetherington (2004) | 38 | All female | 24.4 years<br>24.05 kg/m$^2$ | Induced | Objectively measured food intake[28] | Unhealthy |
| Wallis and Hetherington (2009) | 26 | All female | 27.4 years<br>BMI not reported | Induced | Objectively measured food intake[28] | Unhealthy |
| Wardle et al. (2000) | 82 | 53 females (64.4%)<br>29 males | 35.0 years<br>25.03 kg/m$^2$ | Perceived | 24-hour dietary recall[60] | Unhealthy and other |
| Zellner et al. (2006) | 34 | All female | 22.0 years<br>BMI not reported | Induced | Objectively measured food intake[61] | Healthy, unhealthy and other |

[57] Data adjusted for BMI.
[58] Consumption of fat (unhealthy), starch and total energy intake (other).
[59] Fat intake measured through the Block Screening Questionnaire for Fat Intake (Thompson & Byers, 1994).
[60] Consumption of macronutrients e.g., saturated fat in grams (unhealthy), carbohydrates and total energy intake in kcal (other).
[61] Total intake (grams) of high and low-fat snacks.

| | | | | | | |
|---|---|---|---|---|---|---|
| Zellner, Saito, and Gonzalez (2007) | 36 | All male | 20 years<br>BMI not reported | Induced | Objectively measured food intake[62] | Healthy, unhealthy and other |
| Zenk et al. (2014) | 100 | All female | 44.3 years<br>BMI not reported | Perceived | Between-meal snacks[13] | Other |

[62] Total intake (grams) of high and low-fat snacks.

**Appendix Item 4. Individual study findings for stress and food consumption overall arranged by Hedges' g value (lowest to highest). Values significant at the p <.05 level have been marked with an asterisk (*).**

| Authors, Year | Stress Measure | Eating Behaviour | Hedges' g | Variance | Z - Value | Lower Limit | Upper Limit | p - Value |
|---|---|---|---|---|---|---|---|---|
| Peker & Bermek (2011) | Perceived | Healthy | -0.766 | 0.042 | -3.741 | -1.168 | -0.365 | <.001 * |
| Rutledge & Linden (1998) | Induced | Unhealthy | -0.591 | 0.058 | -2.457 | -1.062 | -0.120 | .014* |
| Zellner et al., (2007) | Induced | Combined | -0.546 | 0.126 | -1.536 | -1.242 | 0.151 | .125 |
| Epel et al., (2001) | Induced | Combined | -0.440 | 0.075 | -1.606 | -0.976 | 0.097 | .108 |
| Kwan & Gordon (2016) | Induced | Unhealthy | -0.385 | 0.027 | -2.350 | -0.706 | -0.064 | .019* |
| van Strien et al., (2013) | Induced | Other | -0.293 | 0.059 | -1.207 | -0.769 | 0.183 | .228 |
| Roohafza et al., (2007) | Perceived | Healthy | -0.242 | 0.001 | -9.209 | -0.293 | -0.190 | <.001 * |
| El Ansari & Berg-Beckhoff (2015) | Perceived | Combined | -0.166 | 0.003 | -3.096 | -0.272 | -0.061 | .002* |
| Raspopow et al., (2010) | Induced | Other | -0.155 | 0.064 | -0.612 | -0.651 | 0.341 | .541 |
| El Ansari et al., (2015) | Perceived | Combined | -0.134 | 0.009 | -1.396 | -0.323 | 0.054 | .163 |
| Boyce & Kuijer (2015) | Perceived | Combined | -0.121 | 0.023 | -0.793 | -0.421 | 0.178 | .428 |
| Geliebter et al., (2012) | Induced | Other | -0.116 | 0.218 | -0.249 | -1.032 | 0.799 | .803 |
| Crowther et al., (2001) | Daily diary | Other | -0.101 | 0.054 | -0.436 | -0.555 | 0.353 | .663 |
| Tseng & Fang (2011) | Perceived | Combined | -0.096 | 0.010 | -0.982 | -0.288 | 0.096 | .326 |
| Stone & Brownell (1994) | Daily diary | Other | -0.042 | 0.000 | -2.640 | -0.074 | -0.011 | .008* |
| Papier et al., (2015) | Perceived | Combined | -0.039 | 0.003 | -0.738 | -0.143 | 0.065 | .460 |
| Järvelä-Reijonen et al., (2016) | Perceived | Combined | -0.027 | 0.021 | -0.187 | -0.307 | 0.254 | .852 |
| Herhaus et al., (2018) | Induced | Unhealthy | -0.026 | 0.069 | -0.099 | -0.543 | 0.490 | .921 |
| Klatzkin et al., (2018) | Combined | Unhealthy | -0.015 | 0.226 | -0.032 | -0.947 | 0.916 | .974 |
| Barrington et al., (2012) | Perceived | Combined | -0.013 | 0.040 | -0.323 | -0.092 | 0.066 | .747 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| El Ansari et al., (2014) | Perceived | Combined | -0.008 | 0.003 | -0.133 | -0.121 | 0.106 | .894 |
| Steptoe et al., (2017) | Objective | Healthy | -0.006 | 0.002 | -0.136 | -0.085 | 0.074 | .891 |
| Pak et al., (1999) | Perceived | Combined | 0.000 | 0.019 | 0.000 | -0.273 | 0.273 | 1.00 |
| Barrington et al., (2014) | Perceived | Combined | 0.008 | 0.000 | 2.022 | 0.000 | 0.016 | .043* |
| Pelletier et al., (2016) | Perceived | Combined | 0.011 | 0.009 | 0.115 | -0.176 | 0.198 | .908 |
| Carson et al., (2015) | Perceived | Combined | 0.013 | 0.003 | 0.242 | -0.091 | 0.117 | .809 |
| Mouchacca et al., (2013) | Perceived | Unhealthy | 0.016 | 0.003 | 0.297 | -0.090 | 0.121 | .766 |
| Liu et al., (2007) | Perceived | Combined | 0.026 | 0.000 | 1.297 | -0.013 | 0.065 | .195 |
| O'Connor et al., (2008) | Daily Diary | Combined | 0.032 | 0.000 | 1.685 | -0.005 | 0.068 | .092 |
| Pollard et al., (1995) | Induced | Other | 0.052 | 0.009 | 0.562 | -0.130 | 0.234 | .574 |
| Steptoe et al., (1998) | Perceived | Combined | 0.073 | 0.022 | 0.491 | -0.218 | 0.364 | .624 |
| Groesz et al., (2012) | Perceived | Combined | 0.077 | 0.009 | 0.811 | -0.109 | 0.262 | .417 |
| Levine & Marcus (1997) | Induced | Unhealthy | 0.078 | 0.046 | 0.363 | -0.343 | 0.500 | .716 |
| Zenk et al., (2014) | Perceived | Other | 0.095 | 0.041 | 0.473 | -0.300 | 0.491 | .636 |
| Errisuriz et al., (2016) | Perceived | Combined | 0.097 | 0.007 | 1.197 | -0.062 | 0.256 | .231 |
| McKinzie et al., (2006) | Perceived | Other | 0.099 | 0.063 | 0.394 | -0.394 | 0.591 | .694 |
| Oliver et al., (2000) | Induced | Other | 0.109 | 0.220 | 0.233 | -0.810 | 1.029 | .816 |
| Barker et al., (2015) | Induced | Other | 0.138 | 0.217 | 0.296 | -0.775 | 1.051 | .768 |
| Newman et al., (2007) | Combined | Other | 0.155 | 0.006 | 2.037 | 0.006 | 0.304 | .042* |
| Wallis & Hetherington (2009) | Induced | Unhealthy | 0.191 | 0.075 | 0.698 | -0.345 | 0.728 | .485 |
| Wardle et al., (2000) | Perceived | Combined | 0.197 | 0.012 | 1.780 | -0.020 | 0.414 | .075 |
| Habhab et al., (2009) | Induced | Other | 0.233 | 0.105 | 0.718 | -0.403 | 0.869 | .473 |
| Vidal et al., (2018) | Perceived | Unhealthy | 0.303 | 0.008 | 3.421 | 0.129 | 0.477 | .001* |
| Lai et al., (2012) | Perceived | Other | 0.363 | 0.022 | 2.470 | 0.075 | 0.650 | .014* |
| Zellner et al., (2006) | Induced | Combined | 0.375 | 0.137 | 1.014 | -0.350 | 1.100 | .310 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Appelhans (2010) | Induced | Other | 0.383 | 0.128 | 1.071 | -0.318 | 1.083 | .284 |
| Dweck et al., (2014) | Induced | Other | 0.426 | 0.017 | 3.302 | 0.017 | 0.173 | .001* |
| Ng & Jeffery (2003) | Perceived | Unhealthy | 0.440 | 0.001 | 16.651 | 0.388 | 0.492 | <.001 * |
| Raspopow et al., (2014) | Induced | Unhealthy | 0.478 | 0.066 | 1.866 | -0.024 | 0.980 | .062 |
| Wallis & Hetherington (2004) | Induced | Unhealthy | 0.596 | 0.054 | 2.569 | 0.141 | 1.052 | .010* |
| Vicennati et al., (2011) | Objective | Combined | 0.619 | 0.035 | 3.308 | 0.252 | 0.986 | .001* |
| O'Connor & O'Connor (2004) | Daily diary | Combined | 0.640 | 0.029 | 3.772 | 0.308 | 0.973 | <.001 * |
| Lemmens et al., (2011) | Induced | Other | 0.653 | 0.028 | 3.900 | 0.325 | 0.981 | <.001 * |
| Conner et al., (1999) | Daily diary | Other | 0.656 | 0.011 | 6.371 | 0.454 | 0.857 | <.001 * |
| Lattimore (2001) | Induced | Unhealthy | 0.852 | 0.648 | 1.059 | -0.725 | 2.429 | .290 |
| Kandiah et al., (2006) | Perceived | Combined | 0.938 | 0.019 | 6.887 | 0.671 | 1.206 | <.001 * |
| Roberts et al., (2014) | Perceived | Combined | 1.140 | 0.151 | 2.930 | 0.377 | 1.902 | .003* |
| Boggiano et al., (2015) | Daily diary | Unhealthy | 1.694 | 0.041 | 8.349 | 1.296 | 2.092 | <.001 * |
| | | **Overall** | 0.102 | 0.001 | 3.847 | 0.050 | 0.154 | <.001 * |

**Appendix Item 5. Example search strategy for meta-analysis on stress and eating behaviours in adolescents.**

| Population Terms | Stress Terms | Eating Behaviour Terms | |
|---|---|---|---|
| 1. exp Adolescent/ or young adult/ or child/<br>2. healthy adolescent*.mp<br>3.adolescen*.mp<br>4. teenager*.mp<br>5. youth.mp<br>6. preadult*.mp<br>7. young adult*.mp<br>8. healthy young adult*mp | 10. exp stress/ [Psychological stress]<br>11. hyperphagi*.mp<br>12. daily hassle*.mp<br>13. daily stress*.mp<br>14. hypophagi*.mp<br>15. cortisol.mp<br>16. saliva adj cortisol.mp<br>17. hair adj cortisol.mp<br>18. stress reactiv*.mp | 20. exp eating [Psychology].mp<br>21. snack*.mp<br>22. snack consumption.mp<br>23. stress induce* eat*.mp<br>24. between meal snack*.mp<br>25. eat* behavio?r.mp<br>26. unhealthy adj diet.mp<br>27. unhealthy adj food*.mp | 28. unhealthy adj eat*.mp<br>29. healthy adj diet*.mp<br>30. healthy adj eat*.mp<br>31. healthy adj food*.mp<br>32. food habit*.mp<br>33. main meal*.mp<br>34. over?eat*.mp<br>35. under?eat*.mp<br>36. diet*.mp |
| **Combined Terms** | | | |
| 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8. | 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18. | 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36. | |
| **9 AND 19 AND 37** | | | |
| **Notes**<br>***** = missing letter **adj** = adjective. **.mp** = title, abstract, subject heading.<br>**exp** = explode subject **/** = map to subject heading. | | | |

**Appendix Item 6. Study characteristics summary table of studies included in meta-analysis of adolescents (*k*=8)**

| Author(s), Year & Sample Size | Gender, Mean age | Stress Category | Eating Behaviour Measure | Eating Behaviour Category |
|---|---|---|---|---|
| Austin et al. (2009) *N*=25 | 15 females 10 males 16.20 years | Perceived | Diet quality [63] | Healthy |
| De Vriendt et al. (2012) *N*=704 | 434 females 270 males 14.81 years | Perceived | Diet quality [63] | Healthy |
| Hong and Peltzer (2017) *N*=65,212 | 31,725 females 33,803 males 15.1 years | Perceived | Healthy & unhealthy diet behaviours | Healthy and unhealthy |
| Jeong and Kim (2007) *N*=350 | All female Mean age not reported | Perceived | Snack consumption[64] | Unhealthy |
| Kim et al. (2013) *N*=333 | 131 females 202 males 17.4 years | Perceived | Food frequency & sugar intake[65] | Unhealthy |
| Michaud et al. (1990) *N*=225 | 147 females 78 males 16.78 years | Perceived[66] | Energy intake[67] | Other |
| Shank et al. (2017)[68] *N*=117 | All female 14.5 years | Perceived | Unhealthy snack foods | Unhealthy |
| Son et al. (2014) *N*=448 | All female Mean age not reported | Perceived | Snack intake & dietary habits[69] | Healthy and Unhealthy |

63 Scales used to measure optimal healthy eating behaviours.

64 Frequency of the consumption of unhealthy snack foods.

65 Consumption of sweet foods only.

66 Perceived stress measured during a control period and a stress period (school examinations).

67 Total energy intake (kcal) on stress and control days.

68 Analyses included anxiety as a moderator.

69 Higher scores on the dietary habit subscales were identified as being healthier than lower scores for dietary habit items.

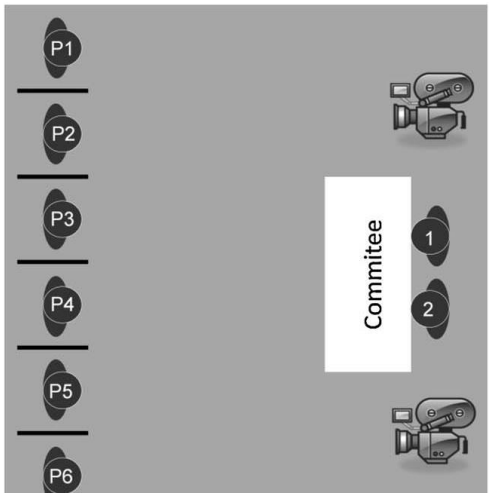
**Appendix Item 7. Individual study findings for stress and food intake overall in studies using adolescents. Findings are arranged by effect size (lowest to highest) and values significant at p <.05 are marked with an asterisk (*).**

| Authors, Year | Stress Measure | Eating Behaviour | Hedges' g | Variance | Z - Value | Lower Limit | Upper Limit | p - Value |
|---|---|---|---|---|---|---|---|---|
| Austin et al., (2009) | Perceived | Healthy | -0.564 | 0.184 | -1.313 | -1.406 | 0.278 | .189 |
| De Vriendt et al., (2012) | Perceived | Healthy | -0.301 | 0.012 | -2.708 | -0.519 | -0.083 | .007* |
| Son et al., (2014) | Perceived | Combined | -0.088 | 0.019 | -0.638 | -0.357 | 0.182 | .524 |
| Hong & Peltzer (2017) | Perceived | Combined | -0.013 | <.001 | -1.645 | -0.028 | 0.002 | .100 |
| Michaud et al., (1990) | Perceived | Other | 0.001 | 0.004 | 0.010 | -0.130 | -0.131 | .992 |
| Kim et al., (2013) | Perceived | Unhealthy | 0.118 | 0.012 | 1.065 | -0.099 | 0.335 | .287 |
| Shank et al., (2017) | Perceived | Unhealthy | 0.317 | 0.036 | 1.681 | -0.053 | 0.686 | .093 |
| Jeong & Kim (2007) | Perceived | Unhealthy | 0.345 | 0.012 | 3.171 | 0.132 | 0.558 | .002* |

**Appendix Item 8. Study protocol for conducting the TSST-G, with instructions for participants and panel members.**

## TSST-G Equipment Set

Materials for the TSST-G should be in place prior to testing. The trier should be carried out in a separate room to the initial questionnaire and the saliva samples. The set up should be similar to that outlined by von Dawans, Kirschbaum and Heinrichs (2011) in the image below.




The panel members should be positioned centrally across from participants, who will be allocated a seat. Where possible, the seating should be separated by partitions to reduce communication and contact (verbal or none verbal) between participants. If partitions are unavailable, the chairs should be adequately spaced out to discourage communication between participants.

A video camera should arranged at the side of the panel members, and should be positioned to include all participants in the camera shot. The panel members should be equipped with the script sheet, a stop watch, list of questions and a list of correct answers for the mental arithmetic task.

If at any point a participant shows signs of distress or discomfort, the panel will ask the participant if they would like to take a minute outside the room. The researcher will also be present during the TSST-G, and so will intervene when required. The participant may then decide whether to continue or withdraw from the TSST-G.

If a participant withdraws from the TSST-G, saliva samples may still be taken following procedure, however the researcher should make a note of the participant ID and saliva coding for later analysis.

## TSST-G Procedure

Emphasise to the participants that they are not permitted to communicate with one another, verbally or none verbally, throughout the testing period. The researcher will ask participants to draw a number at random from a selection (from 1 to a maximum of 6, depending on number of participants in the group).

*1. Introduction, Preparation & Anticipation Phase* (10 minutes).

All participants will receive written instructions about the task, which can also be read verbally to the group. The instructions are as follows:

*"Scenario. Please imagine you have applied for a job and you have been invited for an interview. Unlike a real interview, you have been asked to prepare*

*a talk to convince a panel why you think that you are the best person for the job. You can decide what the job you have applied for is. After receiving these instructions, you will have 5 minutes to prepare your speech.*

*At the end of this time, you will be asked to present your talk to a panel. The panel are experts in none-verbal behaviour (or body language) and will take notes during your talk. You should try to leave a good impression with the panel and adopt the role of the applicant throughout the talk as best as you can. Please note that you will be chosen at random to give your talk and you will be video recorded so that your behaviours can be analysed later.*

*Throughout your talk, the panel may come back to you to ask you some questions. After all participants have given their talk, the panel will ask you to complete a second task. This will be explained to you after you have completed your talk. Please note that you will not be allowed to use any notes during your speech to the panel. Do you have any questions?"*

The researchers' role therefore is to inform the participant to read the instructions carefully and answer any questions they may have. If the participant should ask specific questions regarding the stress task, the researcher should inform them that they will be provided by more information when they have completed their speech preparation period. Once they have read through all the instructions, ask the participants if they are happy to continue and remind them, they can withdraw at any stage should they no longer wish to continue. Participants will be handed lined paper and a pen to prepare their talk, after which they should be informed their 5-minute preparation phase has begun. During the preparation period, the researcher should ensure that the TSST-G is still set up appropriately and the panel have all the required materials for the public speaking task.

*2. Public Speaking Task*

Following the preparation stage, the researcher will lead all participants to a separate room. This room will be set up prior to testing (see previous section for details on set up). Participants will be asked to sit in the seat with their corresponding number.

The researcher will then provide the following instructions:

*"The panel will now randomly choose a number. When your number is chosen, you will stand [at the marked line] in front of the panel, introduce yourself to the panel and tell them why you should get the job. They will instruct you when your interview time is up, and you can return to your seat. When you have all given your talks, you will be given a short task to complete. Please do not communicate in any way with the other participants."*

At this point, the researcher should turn on the video recorder, although does not need to actively record. A panel member will randomly select a participant

number to give their speech. A timer should be set at the start of the participant's speech. The time allowed for each participants speech is 2 minutes. The only feedback (verbal or none verbal) which should be given to the participants is if they stop before the end of the 2-minute period. If a participant finishes within the allotted time, a panel member should use the following script.

*"You have some time left. Please continue!"*

If the participant finishes a second time before the 2-minute period has ended, the panel should remain quiet for 20 seconds before asking the prepared questions (see next page for list of questions). At the end of the 2-minute period, the panel should inform the participant the following:

*"Thank you, your time is now up. Please return to your seat".*

Repeat the process for each participant, with the panel members taking turns to provide the instructions to avoid confusion.

Questions to ask participants in interview stage

If possible, please use each question only once during a testing session. You may want to tick off each question as it is used to avoid repetition.

- Why do you think you are well-qualified for this job?
- Please list your strengths.
- Please list your weaknesses.
- Why do you think you are better qualified then the other applicants?
- Where do you seen yourself 5 years from now?
- What skills would you like to gain from this job?
- How do you deal with pressure or stressful situations?
- Where do you see your position in a team?
- What can you add to a team?

*3. Mental Arithmetic Task*

Once all participants have completed the speech task, the researcher will read out the following instructions:

*"You will now be randomly chosen to complete a calculation task. Please count aloud, backwards in steps of 16 from a given starting number. For example, starting at 4878 the next number would be 4862. You need to count backwards as quickly and as accurately as possible. If you miscalculate, a panel member will point out your mistake and you will start again from the beginning. Again, we ask that you do not communicate with one another. Do you have any questions?"*

The panel should use the list provided to select a different starting number for each participant. When a participant is chosen at random, the instructions should be briefly stated again:

*“Please count backwards in stages of 16 from _____”.*

A timer should be set. The time for this task is 80 seconds (1:20minutes) for each participant. If a participant makes a mistake, they should be interrupted and asked to start again from their initial number. A member of the panel should interrupt as follows:

*“Stop. Please start again from ____".*

The panel members should take it in turns to manage each participant and provide instructions.

Once all participants have completed the mental arithmetic task, the researcher will escort the participants back to their starting room to complete saliva samples and the initial questionnaire.

**Appendix Item 9. Hair sampling information sheet given to participants at study follow up.**

# Investigating the link between stress and eating habits in adolescents

**Researcher: Deborah Hill** **Supervisor: Daryl O'Connor**

## Hair Sampling Information

### Background Information

When we experience stress, our body reacts by releasing a hormone known as cortisol. *Cortisol* is typically measured by taking a sample of saliva which is useful in studies which aim to see how someone responds to a stressful task. However, saliva samples do not contain information about how cortisol levels may have changed over the past week, two weeks or month.

Using hair in psychology is a novel technique which allows for researchers to see how an individual's stress levels have changed over the last few weeks or months.

The next few pages will present some information about the procedure for taking hair samples as part of a research project.

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*Please note that you will be given the opportunity to give two small hair samples as part of this study after reading this information sheet if you wish to.*

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Ethical approval has been received via the School of Psychology Research Ethics Committee on the 19/10/2017 (reference number 17-503).

The supervisors of this research project are Professor Daryl O'Connor and Mark Connor, who can be contacted via d.b.oconnor@leeds.ac.uk and M.T.Conner@leeds.ac.uk respectively.

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## About Hair Sampling

### Why use hair in research?

Using hair to measure stress is a new technique for psychology research. Stress is usually measured by asking the participant to record their stressors in a questionnaire. This is useful to understand what types of stressors are encountered, however self-reporting is not always reliable as people may forget what has happened during their day (i.e., it is subjective). Measuring cortisol avoids this error as it is a biological response. Cortisol can be measured through saliva, however the disadvantage of using saliva is that the cortisol levels are specific to the time the saliva is taken. It cannot show how a person's cortisol levels may have changed over the last week for example. This is why using hair in research can help our understanding of stress, as it can show cortisol levels over the last week, two weeks or even the last month.

The study is interested in cortisol ***only*** i.e., the hair will not be used to investigate drug use or any other hormone.

### What will the participant need to do?

First the participant will complete a short questionnaire about their hair. This includes questions about hair dying/bleaching, what products have been used, any treatments they have had (e.g., straightening, curling) and finally any medicine that the participant is currently taking. Then the participant will give verbal consent, stating that they are happy to give two hair samples.

A small amount of hair from the back of the head (roughly the size of the end of a pencil) is then tied and cut close to the scalp by the experimenter. Participants with longer hair will have the upper layers gripped up out of the way. The participant will give two hair samples, in different locations at the back of the head. This is to make sure that there is enough hair to be analysed.

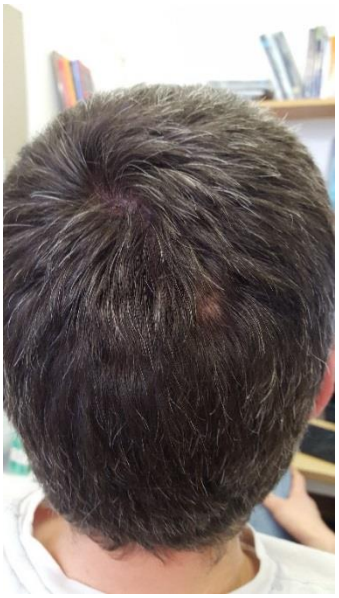
## What does a hair sample look like?

Here is a photograph of two hair samples from one female participant who has given hair in a similar study. The 10p coin gives you an idea of the size of the cutting.

Here is a photograph of two hair samples from a male participant. Again, the 10p coin is included as a scale.

## Is there a noticeable patch where the hair has been taken?

The samples will be taken from back, middle part of the head. This means that for people with long hair, the cutting will be taken underneath the upper layers of hair, so it should be unnoticeable to others. For participants with short hair, there may be a slight spot where the hair has been taken. However, this will be very small, as each of the two samples will be about the size of the end of a pencil.



Right is a photograph of a male participant who has provided two hair samples in a previous study. You may notice that there is a small patch where one of the samples has been taken.