Psychoneuroendocrinology 153 (2023) 106105

Contents lists available at ScienceDirect

Psychoneuroendocrinology

journal homepage: www.elsevier.com/locate/psyneuen

Daily stress and eating behaviors in adolescents and young adults: Investigating the role of cortisol reactivity and eating styles

Deborah Hill [a], Mark Conner [a], Matt Bristow [b], Daryl B. O'Connor [a,*]

[a] School of Psychology, University of Leeds, Leeds LS2 9JT, UK
[b] Department of Psychology, Anglia Ruskin University, Cambridge CB1 1PT, UK

ARTICLE INFO

Keywords:
Stress
Cortisol reactivity
Eating behavior
Eating style

ABSTRACT

Stress-related eating has been well documented in previous literature. However, there is limited research investigating the role of cortisol reactivity in daily stress-eating associations in samples of adolescents and young adults. 123 participants completed a baseline questionnaire and the Trier Social Stress Test in groups. Four saliva samples were taken at − 10, + 00, + 10 and + 40 min during the stress-induction task. Following this, participants completed an online daily diary each evening for 14 consecutive days to record daily stress and between-meal snack consumption. Multilevel modelling indicated that daily stress was positively associated with daily snack intake, particularly for ego-threatening and work/academic stressors. Emotional and external eating styles were found to moderate the stress-snacking relationship. Cortisol reactivity also moderated stress-eating associations, such that as cortisol reactivity levels increased from lower to higher levels, the impact of stress on eating decreased. The current findings highlight the importance of cortisol reactivity status and eating styles in understanding the complex relationship between daily stress and eating behavior in adolescents and young adults. Future research should continue investigating stress-eating associations in these groups and explore the role of other aspects of hypothalamic-pituitary-adrenal axis functioning.

1. Introduction

Understanding stress-health relations presents an ongoing challenge due to the complex nature of stress and the behavioral, endocrine, and neural systems it influences (Finch et al., 2019; O'Connor, Thayer and Vedhara, 2021). Stress can negatively influence health via two different, but not distinct, pathways. Firstly, stress can directly influence health through changes to autonomic and neuroendocrine processes (Aschbacher et al., 2013; McEwen, 2004; O'Connor et al., 2021). Secondly, stress can act indirectly through the disruption of health behaviors such as eating, which may consequently lead to negative health outcomes (Cartwright et al., 2003; Greeno and Wing, 1994; Tomiyama, 2019).

Recent reviews have identified a reliable effect of stress on eating behaviors across samples of children aged 8–17 years old and adults (Hill et al., 2018; Hill et al., 2022). Specifically, research indicates that higher levels of stress are associated with increased intake of unhealthy foods, whilst simultaneously decreasing intake of healthy foods (Araiza and Lobel, 2018; Lyzwinski et al., 2018; O'Connor and Conner, 2011). This association has been demonstrated in studies which have adopted a daily diary approach in adolescents. In a sample of adolescents aged 14–17 years old, Hsu and Raposa (2021) showed that higher levels of perceived stress and more negative life events were associated with greater cravings for, and trouble stopping the consumption of, tasty foods. Similarly, in a sample of adolescents with overweight and obesity aged 14–18 years, Ajibewa et al. (2021) found that daily stressors were positively associated with greater calorie intake, highlighting the impact of acute, daily stressors on eating behaviors in young people. This association between daily stress and eating behaviors in samples of young adults only has received relatively little research attention, but nevertheless, increased daily stress has been found to be associated with greater consumption of between meal snacks (Conner et al., 1999; Newman et al., 2007), particularly unhealthy snack foods (Boggiano et al., 2015; Moss, Conner and O'Connor, 2021).

Although the precise mechanisms underpinning the stress-eating relationship remain unclear (Dallman et al., 2003; Hill et al., 2022; Moss et al., 2021), evidence suggests that biological (e.g., cortisol reactivity to stress) and psychological (e.g., eating styles) factors in part explain individual differences in vulnerability to stress-related eating. Previous research in samples of adults has found that cortisol reactivity is differentially associated with ad-libitum food intake following an

* Correspondence to: School of Psychology, University of Leeds, UK.
E-mail address: d.b.oconnor@leeds.ac.uk (D.B. O'Connor).

https://doi.org/10.1016/j.psyneuen.2023.106105
Received 8 November 2022; Received in revised form 29 March 2023; Accepted 29 March 2023
Available online 31 March 2023

acute stressor. Epel et al. (2001) found that women with heightened cortisol reactivity to stress consumed more snacks following a stress-induction task compared to women with lower cortisol reactivity to stress. Similarly, Newman et al. (2007) reported that, in a sample of adult women, individuals who were high reactors (i.e., had higher cortisol levels in response to an acute laboratory stressor) consumed a greater number of snacks in naturalistic settings when stressed compared to those with a low cortisol response to stress. More recently, Moss et al. (2021) found similar results in a small sample of children aged 9–10 years old. However, it remains unknown whether similar effects are observable in adolescents and young adults – a key aim of the current study.

Differences in eating styles may also contribute to our understanding of individual variability in stress-eating associations according to literature based on adult samples (Greeno and Wing, 1994; O'Connor and Conner, 2011). Higher levels of emotional (Tomiyama et al., 2011; Wallis and Hetherington, 2004), external (Conner et al., 1999; O'Connor et al., 2008) and restrained (Levine and Marcus, 1997; Newman et al., 2007; Roberts et al., 2007; Zellner et al., 2006) eating behaviors have been linked with increased snack consumption in response to stress. Of these three, emotional eating has been suggested to be the pre-eminent eating style in moderating stress-induced eating behaviors (O'Connor et al., 2008), however, relatively few studies have investigated the influence of eating styles on daily eating behaviors. Therefore, the current study also considered the moderating effects of emotional, external and restrained eating styles on daily stress-eating associations.

The type of stressor can also differentially influence eating behaviors (Epel et al., 2018). For example, earlier work by Wallis and Hetherington (2004) and Lattimore and Caswell (2004), highlighted the importance of considering different types of stressors (e.g., cognitively demanding stressors, active and passive coping tasks) in conjunction with eating style variables. In a daily diary study, O'Connor et al. (2008) found that work related, ego-threatening and interpersonal stressors were all associated with increased snack intake, while stressors which were physical in nature were associated with decreased snack intake. Moreover, stressors that have a social evaluation component (such as a laboratory stress induction paradigm or where there is a threat to your self-esteem) have been found to elicit much stronger stress responses and may be more likely to result in changes to normal eating behaviors (Dickerson and Kemeny, 2004). However, at present, few studies have considered such situational factors around the experience of daily stress which may provide greater insights into the stress-eating relationship (Hill et al., 2022). Therefore, the current study aimed to develop this avenue of research and also investigate the effects of different types of daily stressors on eating behaviors.

Furthermore, it is worth noting that a great deal of past research into the effects of stress on eating behavior has been overly reliant on laboratory-based, cross-sectional methodologies and many studies have utilised single indices or 'snap-shot' measurements of stress (Hill et al., 2022; O'Connor and Conner, 2011). The assessment of eating behavior has also been beset with similar measurement shortcomings and difficulties. Such approaches have ignored the growing body of evidence showing that fluctuations in within-person daily stressors are important in understanding stress-outcome processes and that major stressors can have a cascading effect on daily undesirable events (Segerstrom and O'Connor, 2012). Therefore, the current study utilised online daily diary methods in order to offset these previous concerns and to explore day-to-day fluctuations in stressors and eating behaviors together with the moderating effects of cortisol reactivity status and eating style variables.

Finally, we wanted to explore whether individual differences in cortisol reactivity interacted with eating styles to predict daily stress-eating relations. Newman et al. (2007) reported evidence of interactive effects of eating styles and cortisol reactivity status such that the effects of restraint, emotional eating and disinhibited eating styles on snack intake were stronger in high compared to low cortisol reactors. The present study aimed to formally test whether eating styles interacted with cortisol reactivity to influence daily stress-eating relationships. Despite the plethora of research investigating the stress-eating relationship, evidence predominantly utilizes samples of adults (Adam and Epel, 2007; Araiza and Lobel, 2018; Hill et al., 2022; Lyzwinski et al., 2018) and any focus on adolescents and young adults is limited (for a meta-analysis see Hill et al., 2018). Given that eating habits established during adolescence may persist into adult life (Mikkilä et al., 2005), further research on stress-eating associations in adolescents and young adults is necessary to determine the extent to which eating behaviors are influenced by stress on a daily level in this group. Therefore, the aim of the present study was to address this gap in the literature by investigating stress-eating associations in both adolescents and young adults.

2. Method and materials

2.1. Participants

Adolescents aged ≥ 16 years were recruited from local sixth form/colleges and received a £ 5 Love2Shop voucher for their participation. Young adults were recruited via the University of Leeds School of Psychology participant pool scheme and were reimbursed with course credits. A minimum age of 16 years old was used to help ensure participants' independent choices around their food intake were captured; a behavior which occurs more as adolescents progress to sixth forms / colleges and spend more time away from the environment provided by a primary caregiver. Informed consent was received via a consent form and the study was conducted in line with the Code of Ethics of the World Medical Association. Participants were excluded where a self-reported diagnosis of a previous or existing anxiety or anxiety-related disorder (including post-traumatic stress disorder) was disclosed. Similarly, participants were excluded where a self-reported diagnosis of previous or existing disordered eating was disclosed.

One hundred and thirty-six participants completed the initial questionnaire and stress-induction task. Of these, four participants were excluded due to violations in the group Trier Social Stress Test (TSST-g; see below) protocol, four were excluded due to completing no daily diaries on time (i.e., diaries were backfilled), four were excluded due to disclosure of disordered eating during the study period and one participant was excluded due to insufficient saliva across sampling points. Consequently, complete data is reported for 123 participants (59 adolescents; 64 young adults) with 1196 individual diary entries. The current study and sample size were directly informed by the design and findings of Newman et al. (2007). This earlier study recruited 50 adults and employed a comparable daily diary design to explore the role of cortisol reactivity in the context of daily hassles and eating behavior. Therefore, in the current study, in order to account for drop out and potentially greater levels of attrition in the younger aged sample, we aimed to recruit at least 80 adolescents and young adults. The sample was predominately female (N = 102, 83%; 21, 17% males) with a mean age of 17.93 years (range 16–22 years). Most participants identified as being White British (N = 85; 69%). BMI was calculated for 81 participants via self-reported height and weight measures (as a result of a technical problem). The mean BMI for the sample was 22.57 kg/m^2 (range 14.76–37.25 kg/m^2). Thirteen participants reported being on a diet or having specialist dietary requirements (11%) and 16 participants reported being smokers (13%).

2.2. Design and procedure

The study was conducted in sixth form/colleges and at the University of Leeds (2017–2018). Sessions were conducted between 1 pm and 3 pm to maintain consistency in diurnal cortisol patterns (Kirschbaum and Hellhammer, 1989; Kudielka, Broderick, and Kirschbaum, 2003) and participants were asked to avoid eating at least one hour prior to the session to minimise the effect of food consumption on cortisol levels (Kudielka et al., 2003). The study de-brief was provided to participants after the study had finished recruitment to avoid prospective participants learning the nature of the stress task prior to completing the study.

2.2.1. Group Trier Social Stress Task

The stress-induction task was a modified version of the Trier Social Stress Test (Kirschbaum, Pirke, and Hellhammer, 1993) as outlined by Von Dawans, Kirschbaum, and Heinrichs (2011) to facilitate group testing. Participants were tested in groups of up to 6. The group Trier Social Stress Test (TSST-g) follows a similar procedure to the TSST to elicit both a subjective and neuroendocrine response through the combination of cognitive and socio-evaluative tasks in a novel, unpredictable situation (Seddon et al., 2020). Participants were given 5 min to prepare a speech to convince a panel of two 'experts in body language' (i.e., research students) why they are the best candidate for a hypothetical job. Participants were informed that they would be video recorded so that their non-verbal behaviors could be analysed. Participants were randomly allocated a number and took turns in completing the speech task for a duration of 2 min. After all participants in the group had completed their speech, the second task was presented; a serial subtraction task. For this task, participants were asked to count backwards, quickly and accurately, from a given starting number in steps of 16. To avoid any learning effects, the starting number was different for each participant. Participants were randomly chosen in a different order to the speech task to take turns completing the serial subtraction task. If an incorrect response was made, the participant was interrupted by a panel member and asked to start again. The serial subtraction task lasted 80 s per participant. Verbal consent was received from participants to complete both tasks in the TSST-g and participants were reminded of their right to withdraw at regular intervals. The TSST-g was completed in a separate room to minimise anticipatory stress prior to the first sampling point (Wetherell et al., 2015).

2.2.2. Salivary cortisol sampling and analysis

Saliva samples were obtained using salivette swabs and tubes (Salimetrics, US) at four time points; the first saliva sample was taken 10 min prior to the TSST-g (t_{-10}) with three subsequent samples after the completion of the stress task (t_{+00}, t_{+10} and t_{+40}). Samples were frozen at − 20 °C at the end of each testing session to preserve stability (Chiappin et al., 2007; Gröschl et al., 2001).

Missing data was calculated at each of the four measurement points, where missing data ranged from 1.16% at t_{-10} and t_{+00} to 4.1% at t_{+10}. Little's Missing Completely at Random test (MCAR; Little, 1988) was not significant, indicating that the data was missing completely at random, $X^2(16) = 24.579$, $p = .078$ (Schlomer et al., 2010). Therefore, missing values were imputed with the sample mean value for each time point.

Cortisol levels were determined using a competitive enzyme-linked immunosorbent assay kit (ELISA). The mean inter-assay coefficient variation between the duplicate repeats was 3.921% (range 0–28.554%). The coefficient variation was high for 8 samples, however the difference between duplicates was within an accepted range (0.03 ug/dL). 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, a violation to protocol during collection or technical problems during assay (Smith et al., 2018). Twelve samples were identified as outliers (2.44%): two samples at t_{-10}, three samples each at t_{+00} and t_{+10}, and four samples at t_{+40}. These outlying values were 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 were likely the result of violations to the sampling procedure or were anomalies in the data set (Starr et al., 2019). Three samples were identified as having extreme low cortisol concentrations: one sample at t_{+00} and two at t_{+40}. Due to the limited number of low outlying values in the data set (<1%), these extreme values were replaced with the mean value for the sampling timepoint.

Area Under the Curve with respect to ground (AUCg) was calculated using the formula by Pruessner et al. (2003) and following procedures outlined in previous research (Gartland et al., 2014; O'Connor et al., 2013). AUCg reflects total cortisol response throughout the TSST-g. The time between t_{-10} and t_{+00} 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 min to 35 min. These differences in sampling points were accounted for in AUCg calculations.

2.2.3. Baseline questionnaire

After completion of the TSST-g, participants were asked to complete a questionnaire detailing demographic information and eating styles using the Dutch Eating Behavior Questionnaire (DEBQ; Van Strien et al., 1986). The DEBQ includes 33 items to measure restrained, emotional and external eating behaviors and internal reliability was found to be high across the three eating styles (restrained $\alpha = .91$; emotional $\alpha = .93$; external $\alpha = .88$). Missing data ranged from 0% to 17.9% across eating style items where the highest level of missing values was due to an item being omitted from the questionnaire (emotional eating item "*Do you have a desire to eat when you are bored/restless?*") which was subsequently added during the recruitment phase of the study. Little's MCAR (Little, 1988) was not significant, indicating that the data was missing completely at random in the initial questionnaire, $\chi^2(444) = 474.499$, $p = .153$ (Schlomer et al., 2010). Therefore, missing data was treated at item level using the series mean of participant responses across subscale items. Due to the potential effect of nicotine on cortisol levels, the questionnaire also recorded smoking status of participants (Badrick, Kirschbaum and Kumari, 2007; Direk et al., 2011).

2.2.4. Daily diaries

An interval-contingent method was used whereby online daily diaries were completed each evening for 14 consecutive days starting the evening after the test day (i.e., the TSST-g and baseline questionnaire). Participants were presented with instructions on how to complete the daily diaries. Firstly, the experimenter explained at the end of the testing session what the daily diaries were, how they would access them (i.e., participants were given a link in a text or email reminder which was sent daily at 9 pm during the study period) and how to complete the diary entries. This included showing the participants an example diary and checking their understanding with the opportunity to ask questions about the daily diary phase of the study. Subsequent information was presented on the daily diaries themselves, explaining what information they should include in the diary, how to enter information and submit their record.

2.2.4.1. Daily stressors. Participants were provided with the description of a daily hassle outlined by O'Connor et al. (2008, p. S20) and asked to record up to six stressors they had experienced each day using free-response text boxes; a methodology based on similar studies conducted using samples of adults. Based on previous research the average number of stressors reported per day was 0.97, with a range of 0–5 stressors (Newman et al., 2007; O'Connor et al., 2008). Given the small variability in the number of stressors reported on average, and in keeping with methodology previously outlined, the number of daily stressors was capped at 6 in the present study.

Stressors were coded into 5 categories as used by O'Connor et al. (2008); ego-threatening (where there is potential for failure), interpersonal (communications with others or stressors caused by others), work/academic (relating to school, university, employment or volunteering), physical (i.e., stressors which are physical in nature) or other stressors (for stressors which did not fit into the previous four categories). With the exception for 'other', stressors could be coded into more than one category (e.g., failing an exam can be both ego-threatening and work/

academic). The number of stressors were summed to create a total stress score (i.e., number of stressors per day) and were summed for each type of stress. Inter-rater agreement was obtained on at least 10% of stressors reported in the daily diaries (N = 1950; second coded N = 208) by an independent researcher. The level of agreement was good overall (κ = .73). Disagreements in the coding of stressors were discussed between the researchers and an agreement reached.

2.2.4.2. Between-meal snacks. Aside from stressors, participants recorded up to eight between-meal snacks per day using free-response text, noting the brand (where applicable) and quantity of snacks consumed. Using daily diaries to record between-meal snack intake and fruit and vegetable consumption is a well-established method in the health literature due to its unique ability to capture longitudinal data and has been shown to be an ecologically valid method in several directly related studies (e.g., O'Connor et al., 2015; 2008; Conner et al., 1999). Between-meal snacks were capped at 8 as previous literature has demonstrated that, on average, people record 1.84 (range 0–6; Newman et al., 2007) to 3.79 between-meal snacks per day (O'Connor et al., 2008). This included high calorie drinks (such as fruit juice, fizzy drinks and alcohol). Between-meal snacks were summed to give a total number of snacks consumed per day. The daily diary used two items to report portions of fruit and vegetables, with an overall measure created by summing the two variables.

2.3. Analytical method

Prior to the main analyses, a Multivariate Analysis of Variance was conducted to determine whether smoking status and use of medications were associated with AUCg. Neither smoking status nor medications were associated with AUCg (smoking F(1, 119) = 0.022, p = .881; medications F(1, 119) = 0.050, p = .824). Therefore, these variables were not controlled for in the analyses.

A manipulation check was conducted to determine whether the TSST-g was successful in increasing circulating cortisol. Paired samples t-tests indicated a significant increase from t_{-10} to t_{+00}, t(122) = −5.33, p < .001, and from t_{-10} to t_{+10}, t(122) = −5.40, p < .001. Finally, t_{-10} was similar to t_{+40}, t(122) = 0.20, p = .840, indicating that cortisol returned to similar baseline levels by the fourth sampling point.

Descriptive statistics are reported for level 1 (within-person) and level 2 (between-person) data separately. Analyses were conducted using HLM7 (Raudenbush et al., 2011) to create hierarchical multilevel models. Two-level structures were used to match within-person data (i.e., daily stress and eating behaviors) to between-person data (i.e., demographics, cortisol reactivity and eating style) as outlined in O'Connor et al. (2008). Two-way interactions were used to investigate the moderating effect of AUCg on the stress-eating relationship. Three-way interactions were used to determine the moderating effect of eating style in the two-way model (i.e., AUCg and stress-eating). Moderating effects were decomposed using simple slopes following the procedures outlined by Preacher and colleagues (Preacher and Kelley, 2011) and measures were mean centred to produce comparable plots. Finally, in order to examine the effects of daily stress as a between-person variable, the average number of daily stressors per day across completed diary entries was computed. This between person-level variable was then included in HLM models at level 2 along with the within-person variable of daily stress at level 1 and the main analyses rerun.

3. Results

3.1. Descriptive statistics

Descriptive statistics are presented in Table 1. Participants reported experiencing on average 1.63 stressors a day, with work/academic stressors reported most frequently followed by physical stressors.

Table 1
Descriptive statistics for level 1 (within-subjects) and level 2 (between-subjects) variables.

Level and variables	Mean	SD
Level 1 Variables		
Snacks / day	2.02	1.43
Stressors / day	1.63	1.26
Portions of Fruit and Vegetables / day	2.84	2.22
Ego Threat Stressors / day	0.15	0.40
Interpersonal Stressors / day	0.30	0.55
Work / Academic Stressors / day	0.71	0.80
Physical Stressors / day	0.52	0.83
Other Stressors / day	0.28	0.54
Level 2 Variables		
Age	17.93	1.38
BMI	22.57	4.03
AUCg	440.37	237.39
Emotional Eating	35.28	11.68
Restrained Eating	25.24	8.68
External Eating	33.76	7.33

Note: BMI was calculated for 81 participants based on self-reported height and weight.

Participants reported eating 2.02 between-meal snacks plus 2.84 portions of fruit and vegetables a day. Mean values were calculated across emotional (*mean* = 35.28), external (*mean* = 33.76) and restrained (*mean* = 25.24) eating styles. Mean age, BMI and AUCg are also reported in Table 1.

3.2. Preliminary correlations between study variables

Pearson's correlations were conducted to investigate associations between level 2 variables (Table 2). Age was positively associated with restrained (r = .264, p = .003) and external eating (r = .216, p = .016), and negatively associated with gender (r_p = −.214, p = .018), with females on average older than males. Similarly, gender was positively associated with BMI (r_p =.300, p = .006) and AUCg (r_p =.241, p = .007), with males having greater BMI and increased cortisol reactivity compared to females. BMI was also positively correlated with emotional eating (r = .263, p = .018), with participants who had a higher BMI reporting greater emotional eating. AUCg was negatively correlated with emotional (r = −.206, p = .023) and restrained eating styles (r = −.203, p = .025), with individuals higher in emotional and restrained eating style scores exhibiting lower cortisol reactivity to the TSST-g (AUCg). Finally, a strong positive correlation was found between emotional and external eating (r = .641, p < .001), with individuals higher in emotional eating also being higher in external eating.

3.3. Effects of daily stress and cortisol reactivity on snack intake

HLM was used to investigate associations between the level 1 variables of daily reported stress and between-meal snack consumption (Table 3, upper panel). Analyses indicated that daily reported stress was significantly positively associated with daily snacks (β = 0.176, p < .001). No effects were found for daily reported stress on portions of fruit and vegetables eaten.

HLM analyses were also used to assess the effects of daily reported stress (i.e., total number of stressors; level 1) and cortisol reactivity (level 2) on snacking and fruit and vegetable intake (Table 3, lower panel). This indicated no main effect for cortisol reactivity on total snack intake (AUCg: β = 0.0005, p = .162) or portions of fruit and vegetables eaten (AUCg: β = −0.0002, p = .741). In the same analysis a cross-level interaction for AUCg on the daily reported stress-total snack intake relationship was observed (β = −0.0005, p = .004). The cross-level interaction for AUCg on the daily reported stress-fruit and vegetable intake relationship was not significant (Table 3, lower panel). The moderating effect of AUCg on the daily reported stress-total snack intake

Table 2
Correlation matrix between level 2 study variables.

Variables	Age	Gender	BMI	AUCg	Emotional	Restrained	External
Age	-						
Gender	-.214 *	-					
BMI	.034	.300 * *	-				
AUCg	.024	.241 * *	.053	-			
Emotional	.138	-.097	.263 *	-.206 *	-		
Restrained	.264 * *	-.269 * *	.105	-.203 *	.049	-	
External	.216 *	.017	.135	-.054	.641 * *	-.135	-

Note: *p < .05, * *p < .001; Emotional = emotional eating, Restrained = restrained eating, External = external eating.

Table 3
Effects of daily stress on between-meal snack intake and portions of fruit and vegetables (upper panel) and moderating effects of AUCg on daily stress and snack intake and portions of fruit and vegetables (lower panel).

Model and Variables	β	Coefficient	SE	p
Total snacks				
Intercept	β_{00}	2.032	0.094	< .001
L1 slope: Daily stress - total snacks	β_{10}	0.176	0.041	< .001
Fruit & vegetable intake				
Intercept	β_{00}	2.703	0.155	< .001
L1 slope: Daily stress - fruit & vegetable intake	β_{10}	0.030	0.046	.509
Model and Variables	β	**Coefficient**	**SE**	**p**
Snacks				
Intercept	β_{00}	2.031	0.093	< .001
L1 Slope: Stress and snacks	β_{10}	0.178	0.040	< .001
AUCg – snacks	β_{01}	0.0005	0.0004	.162
AUCg x stress -snacks	β_{11}	-0.0005	0.0002	.004
Fruit and vegetables				
Intercept	β_{00}	2.703	0.154	< .001
L1 Slope: Stress and fruit and vegetables	β_{10}	0.030	0.045	.487
AUCg –fruit and vegetables	β_{01}	-0.0002	0.0007	.741
AUCg x stress – fruit and vegetables	β_{11}	-0.0003	0.0002	.091

Note: AUCg = area under the curve with respect to ground

relationship was decomposed using simple slopes analyses (see Fig. 1, upper panel). The results showed that as AUCg increased from low (*coefficient* = 0.281, $p < .001$), to the mean (*coefficient* = 0.175, $p < .001$), to high (*coefficient* = 0.068, $p = .210$) levels of cortisol reactivity, the impact of stress on eating decreased, becoming non-significant at the highest level of AUCg. This indicates that the impact of stress on snacking was only significant in individuals with low or mean levels of AUCg, at higher levels it was attenuated and became non-significant.

When person-level mean daily reported stress was included in the main analyses, both mean stress (the between-subjects measure) and daily stress (the within-subjects measure) predicted daily snack intake. These effects remained when controlling for AUCg. Mean stress did not moderate the effects of daily reported stress on snacking. Neither mean nor daily stress nor their interaction predicted daily fruit and vegetable intake. In sum, the main results remained unchanged when person-level daily stress was included in the models.

3.4. *Type of stress on snack intake*

Table 4 explored the effects of different types of stress on total snack intake. This was not tested for fruit and vegetable intake given the non-significant effect reported in Table 3. Analyses indicated that ego-threatening stressors ($\beta = 0.226$, $p = .020$) and work/academic stress ($\beta = 0.186$, $p < .001$) both had significant effects on total snacks, and the effects were of a similar magnitude to that observed for daily reported stress. No associations were found between interpersonal, physical or other stressors and total snack intake (Table 5).

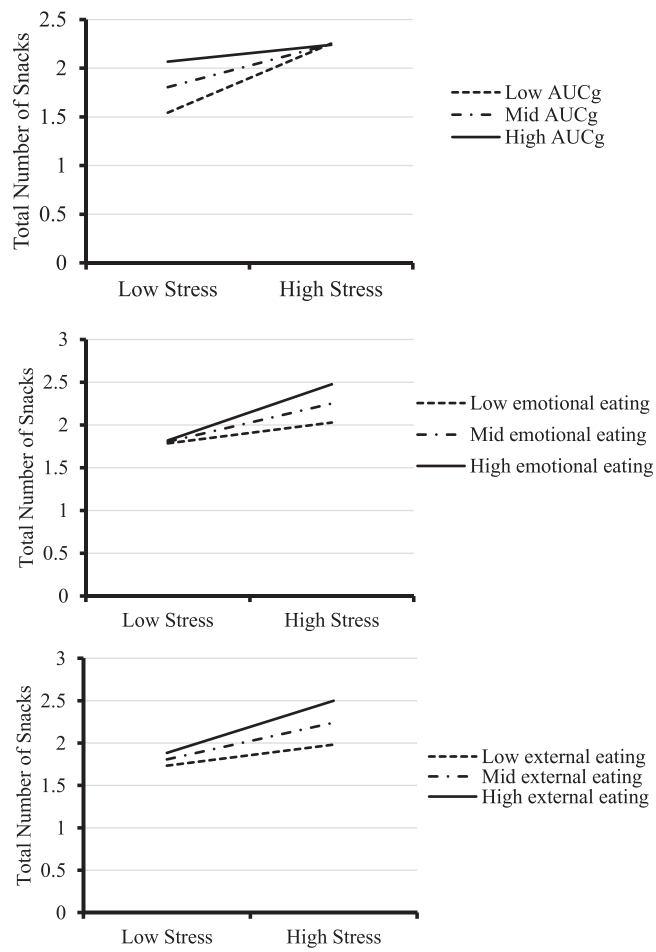

Fig. 1. Moderating effects of cortisol reactivity (upper panel), emotional eating (middle panel) and external eating (lower panel) on the daily stress and total snacks relationship.

Table 4
Summary of level 1 results for type of stress on total snack intake.

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

Table 5
Summary of results for the moderating effect of eating styles on stress and total snack intake.

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

3.5. Effects of eating styles on total snack intake

Hierarchical linear models were used to investigate if eating styles (emotional, restrained and external) individually moderated the effects of daily reported stress on total snack consumption. We did not investigate models with more than one eating style given the high correlations between some of these measures (Table 2). The three models indicated no main effects for emotional ($\beta = 0.011$, $p = .146$), restrained ($\beta = -0.018$, $p = .057$) or external eating styles ($\beta = 0.023$, $p = .064$) on total snack intake. Cross-level models (Table 5) indicated that emotional ($\beta = 0.007$, $p = .017$) and external eating styles ($\beta = 0.010$, $p = .033$) but not restrained moderated the daily reported stress-total snack relationship.

The interactions between emotional eating and stress, and between external eating and stress on total snacks were decomposed using simple slopes analysis (see Fig. 1, middle panel). The simple slopes for the relationship between daily reported stress and total snacks indicated that as levels of emotional eating increased from low (*coefficient* = 0.096, $p = .052$), to the mean (*coefficient* = 0.178, $p < .001$), to high (*coefficient* = 0.260, $p < .001$) levels of emotional eating, the impact of stress on eating also increased. These results indicated that stress was a stronger predictor of total snack consumption for those high in emotional eating compared to those low in emotional eating. For external eating style, the simple slopes for the relationship between daily reported stress and total snacks indicated that as external eating increased from low (*coefficient* = 0.099, $p = .062$), to the mean (*coefficient* = 0.171, $p < .001$), to high (*coefficient* = 0.244, $p < .001$) levels of external eating, the impact of stress on eating also increased (see Fig. 1, lower panel). Stress was significantly positively related to eating at mean and high levels of external eating, but not at low levels of external eating. Similar to above, these results indicated that stress only influences snack intake in those with moderate or high levels of external eating.

3.6. Moderating effects of cortisol reactivity and eating style on the daily stress and total snack intake relationship

A final set of analyses explored effects of cortisol reactivity plus eating style as moderators of the daily reported stress-total snack relationship. This was done separately for emotional and external eating (and not for restrained eating which was not a significant moderator; Table 5) given the high correlation between these two eating styles (Table 2). The focus was on whether the cortisol reactivity x stress and eating style x stress moderation effect operated simultaneously or one moderator dominated. In addition, we explored whether these moderation effects were influenced by a three-way interaction between cortisol reactivity x eating style x stress on total snacks.

In relation to emotional eating, these analyses indicated that the AUCg x stress interaction remained significant ($\beta = -0.0004$, $p = .016$) while the emotional eating x stress interaction became non-significant (Supplemental Table 1, model 1). There was no evidence of a three-way interaction for cortisol reactivity x emotional eating x stress (Supplemental Table 1, model 2). This pattern was similar for external eating. The AUCg x stress interaction remained significant ($\beta = -0.0004$, $p = .008$) and the external eating x stress was not significant in this model (Supplemental Table 2, model 1). There was no evidence of a three-way interaction for cortisol reactivity x external eating x stress (Supplemental Table 2, model 2). Taken together, these results indicate that stress was significantly positively related to snack intake at mean and high levels of external and emotional eating, but not at low levels of external or emotional eating. Although cortisol reactivity and eating styles moderated the stress-eating relationship independently, there were no interaction effects seen when AUCg and eating styles were added into the same model.

4. Discussion

The present study aimed to utilise online daily diary methods in combination with a physiological measure of stress reactivity to better understand the relationship between daily reported stress and eating behaviors in adolescents and young adults. Daily reported stress was positively associated with between-meal snack intake, where a greater number of snacks were consumed on days of higher stress compared to days of lower stress. This finding corroborates previous findings that food intake increases as a function of stress, a finding which is seen across both adults (Hill et al., 2022) and youth aged 8–18 years old (Hill et al., 2018). Furthermore, these findings provide support for theories that posit that food is used as a coping mechanism when experiencing stress (Dallman et al., 2003; Torres and Nowson, 2007; Ulrich-Lai et al., 2010).

More interestingly, the present study found that cortisol reactivity (AUCg) negatively moderated the impact of total daily reported 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, but not at high levels of AUCg. These findings suggest that, in high reactors, merely the experience of any stressor (and not the number of stressors) influences eating behaviors, as high reactors ate a similar number of snacks on both low and high stress days. In contrast, mean and low reactors demonstrated a stress-induced eating response (i.e., snack intake significantly increased from low to high stress). These results are broadly in line with previous research in samples of adults aged 18 and over, which indicate that 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 behaviors. They may also indicate that the influence of cortisol reactivity may be more complex in adolescents and young adults compared to adults. Nevertheless, these findings support previous research studies which have utilised samples of adults (Appelhans et al., 2010; Epel et al., 2001; Newman et al., 2007), children aged 9–10 (Moss et al., 2021, 2022) and adolescents aged 14–18 (Ajibewa et al., 2021; Hsu and Raposa, 2021), finding that fluctuations in cortisol levels play a role in understanding stress-related changes to eating habits. Future research ought to replicate the effects found in the current study with larger samples of adolescents and young adults and using different indices of hypothalamic-pituitary-adrenal axis functioning (e.g., Moss et al., 2022).

The current study also found that ego-threatening stressors were positively associated with total snack consumption. This is in line with previous research in samples of adults (O'Connor et al., 2008; Wallis and Hetherington, 2009) which has suggested that ego-threatening stressors can have the greatest impact on eating behaviors due to individuals attempting to alter negative appraisals of the self through a change in focus towards an external stimulus such as food (Wallis and Hetherington, 2009). Similarly, work/academic stressors also predicted total snack intake. Consistent with past research (O'Connor et al., 2008), these findings indicate that differences in the type of stress experienced can result in changes in eating behaviors. Taken together, these findings suggest that the type of stress may be also a key contributory factor to understanding differences in maladaptive, stress-related eating behaviors in adolescents and young adults.

External and emotional eating styles were found to significantly moderate the stress-eating relationship, where stress was found to influence snack intake in individuals with either moderate or high levels of external and/or emotional eating. 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 and Kurtz, 2010). However, the moderating effect of emotional eating has been more consistently reported across the literature. Previous studies have reported a moderating effect of emotional eating style on stress and food intake across both children aged 5–12 years old (Michels et al., 2012) and adults (Oliver et al., 2000; Wallis and Hetherington, 2004; Wilson et al., 2015). Advancing on previous research by Newman et al. (2007), the current study investigated the combined effects of stress reactivity and eating styles on stress-eating associations within a younger sample. Whilst cortisol reactivity and eating styles were found to independently moderate stress-eating associations, there were no interaction effects between the two when entered in the same model. Furthermore, the analyses highlighted that cortisol reactivity may be a more dominate moderator of stress-eating compared to eating styles.

Taken together, the findings from the present study indicate that stress-eating relations are present in adolescents and young adults aged 16–22, corroborating existing literature. Adolescence presents a unique period for the establishment of health behaviors, particularly dietary habits (Albani et al., 2018; Todd et al., 2015), as adolescents are given increased autonomy over their eating behaviors due to decreased dependence on the family home environment (Bassett et al., 2008). Previous research has highlighted the importance of understanding health behaviors in emerging adulthood (Ames et al., 2018; Boyce and 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.

Such stress-induced changes to eating habits may result in poorer health behaviors being established during adolescence which may 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 50–100 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 and Oltmanns, 2014; Sinha and Jastreboff, 2013). Understanding patterns and moderators of stress-related eating behaviors in emerging adulthood can inform future interventions to help to reduce stress-induced eating (cf., O'Connor et al., 2015; Tapper, 2022).

4.1. Limitations of the study

We recognise there are a number of limitations with the current study. First, there was an imbalance of males and females within the sample. Previous research has suggested that the effect of stress on eating habits influences males and females differently. For example, some studies have found that females are more likely to change their normal eating behaviors when experiencing stress compared to males (Mikolajczyk et al., 2009; Sims et al., 2008; Stone and Brownell, 1994; Weinstein et al., 1997) although this difference has not been consistently found (Barrington et al., 2014; Conner et al., 1999; El Ansari and Berg-Beckhoff, 2015; Reichenberger et al., 2018). The sample age may also present limitations in the application of the study findings. Whilst preliminary analyses indicated no moderating effect of age group on the relationship between daily reported stress and eating behaviors, future research should endeavour to include a broader age range of adolescents opposed to adolescents aged 16 and over. It is therefore valuable for future research to determine at what age stress-induced eating habits are formed and understand moderators of stress-related eating behaviors in emerging adulthood.

Aside from demographic factors, the method of measuring stress may present constraints. Situational factors regarding the stress experience, such as perceived intensity of a stressor, may provide additional insights into stress-eating associations beyond the mere occurrence of a stressor and the broad categorisation of the type of stressor. The context, severity and nature of a stressor are all important considerations in stress research - disentangling the experience of daily stress would produce valuable insights into the stress-eating relationship often reported in studies and warrants further investigation.

A further consideration for the present study is the absence of more objective measures of eating behavior. Whilst online daily diaries provide a more naturalistic approach to measuring eating behaviors compared to laboratory-based methods (such as ad libitum food intake), the subjective nature of recall based self-reported food intake introduces biases. Alternative methods such as ecological momentary assessments (Shiffman et al., 2008) can improve ecological validity by recording eating behaviors temporally close together as they naturally occur, and in so doing, limiting retrospective recall biases which are inherent with a single point of daily recall (Mason et al., 2020). Nevertheless, the current approach allowed us to reduce participant burden over a 14 day window and it is noteworthy that the main findings in relation to daily stressors and snack intake were in the predicted direction.

5. Conclusions

The current findings highlight the importance of two distinct factors, cortisol reactivity status and eating styles, in understanding the complex relationship between daily stress and eating behavior in adolescents and young adults. They also underline the need to explore the impact of different types of stressors on daily eating behavior. Future research should endeavour to continue investigating stress-eating associations in adolescents and young adults and explore the role of other aspects of hypothalamic-pituitary-adrenal axis functioning.

Funding

This research was in part funded by Anglia Ruskin University via Matt Bristow for the assay of cortisol samples.

CRediT authorship contribution statement

Deborah Hill: Project administration, Methodology, Investigation, Validation, Data curation, Formal analyses, Writing – original draft, Writing – review & editing. **Mark Conner:** Conceptualization, Methodology, Formal analyses, Writing – review & editing, Supervision. **Matthew Bristow:** Resources, Methodology, Data curation, Validation, Supervision. **Daryl B. O'Connor:** Conceptualization, Methodology, Formal analyses, Writing – review & editing, Supervision.

Conflict of interest

None of the authors have any conflict of interest to declare.

Data Availability

The data from this study can be made available upon reasonable request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.psyneuen.2023.106105.

References

Adam, T.C., Epel, E.S., 2007. Stress, eating and the reward system. Physiol. Behav. 91 (4), 449–458. https://doi.org/10.1016/j.physbeh.2007.04.011.

Ajibewa, T.A., Robinson, L.E., Toledo-Corral, C., Miller, A.L., Sonneville, K.R., Hasson, R. E., 2021. Acute daily stress, daily food consumption, and the moderating effect of disordered eating among adolescents with overweight/obesity. Child. Obes. 17 (6), 391–399. https://doi.org/10.1089/chi.2021.0017.

Albani, V., Butler, L.T., Traill, W.B., Kennedy, O.B., 2018. Understanding fruit and vegetable consumption in children and adolescents. The contributions of affect, self-concept and habit strength. Appetite 120, 398–408. https://doi.org/10.1016/j.appet.2017.09.018.

Ames, M.E., Leadbeater, B.J., MacDonald, S.W., 2018. Health behavior changes in adolescence and young adulthood: implications for cardiometabolic risk. Health Psychol. 37 (2), 103113 https://doi.org/10.1037/hea0000560.

Appelhans, B.M., Pagoto, S.L., Peters, E.N., Spring, B.J., 2010. HPA axis response to stress predicts short-term snack intake in obese women. Appetite 54 (1), 217–220. https://doi.org/10.1016/j.appet.2009.11.005.

Araiza, A.M., Lobel, M., 2018. Stress and eating: definitions, findings, explanations, and implications. Soc. Personal. Psychol. Compass 12 (4), e12378. https://doi.org/10.1111/spc3.12378.

Aschbacher, K., O'Donovan, A., Wolkowitz, O.M., Dhabhar, F.S., Su, Y., Epel, E., 2013. Good stress, bad stress and oxidative stress: insights from anticipatory cortisol reactivity. Psychoneuroendocrinology 38 (9), 1698–1708. https://doi.org/10.1016/j.psyneuen.2013.02.004.

Badrick, E., Kirschbaum, C., Kumari, M., 2007. The relationship between smoking status and cortisol secretion. J. Clin. Endocrinol. Metab. 92 (3), 819–824. https://doi.org/10.1210/jc.2006-2155.

Barrington, W.E., Beresford, S.A., McGregor, B.A., White, E., 2014. Perceived stress and eating behaviors by sex, obesity status, and stress vulnerability: findings from the vitamins and lifestyle (VITAL) study. J. Acad. Nutr. Diet. 114 (11), 1791–1799. https://doi.org/10.1016/j.jand.2014.03.015.

Bassett, R., Chapman, G.E., Beagan, B.L., 2008. Autonomy and control: The co-construction of adolescent food choice. Appetite 50 (2), 325–332. https://doi.org/10.1016/j.appet.2007.08.009.

Boggiano, M.M., Wenger, L.E., Turan, B., Tatum, M.M., Sylvester, M.D., Morgan, P.R., Burgess, E.E., 2015. Real-time sampling of reasons for hedonic food consumption: further validation of the Palatable Eating Motives Scale. Front. Psychol. 6, 744. https://doi.org/10.3389/fpsyg.2015.00744.

Boyce, J.A., Kuijer, R.G., 2015. Perceived stress and freshman weight change: the moderating role of baseline body mass index. Physiol. Behav. 139, 491–496. https://doi.org/10.1016/j.physbeh.2014.12.011.

Cartwright, M., Wardle, J., Steggles, N., Simon, A.E., Croker, H., Jarvis, M.J., 2003. Stress and dietary practices in adolescents. Health Psychol. 22 (4), 362–369. https://doi.org/10.1037/0278-6133.22.4.362.

Chiappin, S., Antonelli, G., Gatti, R., Elio, F., 2007. Saliva specimen: a new laboratory tool for diagnostic and basic investigation. Clin. Chim. Acta 383 (1–2), 30–40. https://doi.org/10.1016/j.cca.2007.04.011.

Conner, M., Fitter, M., Fletcher, W., 1999. Stress and snacking: a diary study of daily hassles and between-meal snacking. Psychol. Health 14 (1), 51–63. https://doi.org/10.1080/08870449908407313.

Dallman, M.F., Pecoraro, N., Akana, S.F., La Fleur, S.E., Gomez, F., Houshyar, H., Manalo, S., 2003. Chronic stress and obesity: a new view of "comfort food". Proc. Natl. Acad. Sci. 100 (20), 11696–11701. https://doi.org/10.1073/pnas.1934666100.

Dickerson, S.S., Kemeny, M.E., 2004. Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. Psychol. Bull. 130 (3), 355–391. https://doi.org/10.1037/0033-2909.130.3.355.

Direk, N., Newson, R.S., Hofman, A., Kirschbaum, C., Tiemeier, H., 2011. Short and long-term effects of smoking on cortisol in older adults. Int. J. Psychophysiol. 80 (2), 157–160. https://doi.org/10.1016/j.ijpsycho.2011.02.007.

Ebbeling, C.B., Pawlak, D.B., Ludwig, D.S., 2002. Childhood obesity: public-health crisis, common sense cure. Lancet 360 (9331), 473–482. https://doi.org/10.1016/S0140-6736(02)09678-2.

El Ansari, W., Berg-Beckhoff, G., 2015. Nutritional correlates of perceived stress among University Students in Egypt. Int. J. Environ. Res. Public Health 12 (11), 14164–14176. https://doi.org/10.3390/ijerph121114164.

Epel, E., Lapidus, R., McEwen, B., Brownell, K., 2001. Stress may add bite to appetite in women: a laboratory study of stress-induced cortisol and eating behavior. Psychoneuroendocrinology 26 (1), 37–49. https://doi.org/10.1016/S0306-4530(00)00035-4.

Epel, E.S., Crosswell, A.D., Mayer, S.E., Prather, A.A., Slavich, G.M., Puterman, E., Mendes, W.B., 2018. More than a feeling: a unified view of stress measurement for population science. Front. Neuroendocrinol. 49, 146–169. https://doi.org/10.1016/j.yfrne.2018.03.001.

Finch, L.E., Tiongco-Hofschneider, L., Tomiyama, A.J., 2019. Stress-induced eating dampens physiological and behavioral stress responses. Nutr. Prev. Treat. Abdom. Obes. 175–187. https://doi.org/10.1016/B978-0-12-407869-7.00018-0.

Gartland, N., O'Connor, D.B., Lawton, R., Bristow, M., 2014. Exploring day-to-day dynamics of daily stressor appraisals, physical symptoms and the cortisol awakening response. Psychoneuroendocrinology 50, 130–138. https://doi.org/10.1016/j.psyneuen.2014.08.006.

Greeno, C.G., Wing, R.R., 1994. Stress-induced eating. Psychol. Bull. 115 (3), 444–464. https://doi.org/10.1037/0033-2909.115.3.444.

Gröschl, M., Wagner, R., Rauh, M., Dörr, H.G., 2001. Stability of salivary steroids: the influences of storage, food and dental care. Steroids 66 (10), 737–741. https://doi.org/10.1016/S0039-128X(01)00111-8.

Hill, D., Conner, M., Clancy, F., Moss, R., Wilding, S., Bristow, M., O'Connor, D.B., 2022. Stress and eating behaviours in healthy adults: a systematic review and meta-analysis. Health Psychol. Rev. 16 (2), 280–304. https://doi.org/10.1080/17437199.2021.1923406.

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. https://doi.org/10.1016/j.appet.2017.11.109.

Hsu, T., Raposa, E.B., 2021. Effects of stress on eating behaviours in adolescents: a daily diary investigation. Psychol. Health 36 (2), 236–251. https://doi.org/10.1080/08870446.2020.1766041.

Hu, T., Jacobs Jr, D.R., Larson, N.I., Cutler, G.J., Laska, M.N., Neumark-Sztainer, D., 2016. Higher diet quality in adolescence and dietary improvements are related to less weight gain during the transition from adolescence to adulthood. e183 J. Pediatr. 178, 188–193. https://doi.org/10.1016/j.jpeds.2016.08.026.

Jauch-Chara, K., Oltmanns, K.M., 2014. Obesity–a neuropsychological disease? Systematic review and neuropsychological model. Prog. Neurobiol. 114, 84–101. https://doi.org/10.1016/j.pneurobio.2013.12.001.

Kirschbaum, C., Hellhammer, D.H., 1989. Salivary cortisol in psychobiological research: an overview. Neuropsychobiology 22 (3), 150–169. https://doi.org/10.1159/000118611.

Kirschbaum, C., Pirke, K.-M., Hellhammer, D.H., 1993. The 'Trier Social Stress Test'–a tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology 28 (1–2), 76–81. https://doi.org/10.1159/000119004.

Koehn, S., Gillison, F., Standage, M., Bailey, J., 2016. Life transitions and relevance of healthy living in late adolescence. J. Health Psychol. 21 (6), 1085–1095. https://doi.org/10.1177/1359105314546340.

Kudielka, B.M., Broderick, J.E., Kirschbaum, C., 2003. Compliance with saliva sampling protocols: electronic monitoring reveals invalid cortisol daytime profiles in noncompliant subjects. Psychosom. Med. 65 (2), 313–319. https://doi.org/10.1097/01.PSY.0000058374.50240.BF.

Lattimore, P., Caswell, N., 2004. Differential effects of active and passive stress on food intake in restrained and unrestrained eaters. Appetite 42, 167–173.

Levine, M.D., Marcus, M.D., 1997. Eating behavior following stress in women with and without bulimic symptoms. Ann. Behav. Med. 19 (2), 132–138. https://doi.org/10.1007/BF02883330.

Little, R.J., 1988. Missing-data adjustments in large surveys. J. Bus. Econ. Stat. 6 (3), 287–296.

Lyzwinski, L.N., Caffery, L., Bambling, M., Edirippulige, S., 2018. The relationship between stress and maladaptive weight-related behaviors in college students: a review of the literature. Am. J. Health Educ. 49 (3), 166–178. https://doi.org/10.1080/19325037.2018.1449683.

Mason, T.B., Do, B., Wang, S., Dunton, G.F., 2020. Ecological momentary assessment of eating and dietary intake behaviors in children and adolescents: a systematic review of the literature. Appetite 144, 104465. https://doi.org/10.1016/j.appet.2019.104465.

McEwen, B.S., 2004. Protection and damage from acute and chronic stress: allostasis and allostatic overload and relevance to the pathophysiology of psychiatric disorders. Ann. N. Y. Acad. Sci. 1032 (1), 1–7. https://doi.org/10.1196/annals.1314.001.

Michels, N., Sioen, I., Braet, C., Eiben, G., Hebestreit, A., Huybrechts, I., De Henauw, S., 2012. Stress, emotional eating behaviour and dietary patterns in children. Appetite 59 (3), 762–769. https://doi.org/10.1016/j.appet.2012.08.010.

Mikkilä, V., Räsänen, L., Raitakari, O., Pietinen, P., Viikari, J., 2005. Consistent dietary patterns identified from childhood to adulthood: the cardiovascular risk in Young Finns Study. Br. J. Nutr. 93 (06), 923–931. https://doi.org/10.1079/BJN20051418.

Mikolajczyk, R.T., El Ansari, W., Maxwell, A.E., 2009. Food consumption frequency and perceived stress and depressive symptoms among students in three European countries. Nutr. J. 8 (31), 1–8. https://doi.org/10.1186/1475-2891-8-31.

Moss, R.H., Conner, M., O'Connor, D.B., 2021. Exploring the effects of daily hassles on eating behaviour in children: the role of cortisol reactivity. Psychoneuroendocrinology, 104692. https://doi.org/10.1016/j.psyneuen.2020.104692.

Moss, R.H., Conner, M., O'Connor, D.B., 2022. Exploring the effects of daily hassles and uplifts on eating behaviour in young adults: the role of daily cortisol levels. Psychoneuroendocrinology, 105231. https://doi.org/10.1016/j.psyneuen.2021.105231.

Mozaffarian, D., Hao, T., Rimm, E.B., Willett, W.C., Hu, F.B., 2011. Changes in diet and lifestyle and long-term weight gain in women and men. N. Engl. J. Med. 364 (25), 2392–2404. https://doi.org/10.1056/NEJMoa1014296.

Newman, E., O'Connor, D.B., Conner, M., 2007. Daily hassles and eating behaviour: the role of cortisol reactivity status. Psychoneuroendocrinology 32 (2), 125–132. https://doi.org/10.1016/j.psyneuen.2006.11.006.

O'Connor, D.B., Conner, M., 2011. Effects of stress on eating behavior. In: Contrada, R.J., Baum, A. (Eds.), The handbook of stress science: Biology, psychology, and health. Springer Publishing Company, New York, NY, pp. 275–286.

O'Connor, D.B., Thayer, J.T., Vedhara, K., 2021. Stress and health: a review of psychobiological processes. Annu. Rev. Psychol. 72, 663–688. https://doi.org/10.1146/annurev-psych-062520-122331.

O'Connor, D.B., Walker, S., Hendrickx, H., Talbot, D., Schaefer, A., 2013. Stress-related thinking predicts the cortisol awakening response and somatic symptoms in healthy adults. Psychoneuroendocrinology 38 (3), 438–446. https://doi.org/10.1016/j.psyneuen.2012.07.004.

O'Connor, D.B., Armitage, C.J., Ferguson, E., 2015. Randomized test of an implementation intention-based tool to reduce stress-induced eating. Ann. Behav. Med. 49 (3), 331–343. https://doi.org/10.1007/s12160-014-9668-x.

O'Connor, D.B., Jones, F., Conner, M., McMillan, B., Ferguson, E., 2008. Effects of daily hassles and eating style on eating behavior. Health Psychol. 27 (1), S20–S31. https://doi.org/10.1037/0278-6133.27.1.S20.

Oliver, G., Wardle, J., Gibson, E.L., 2000. Stress and food choice: a laboratory study. Psychosom. Med. 62 (6), 853–865.

Preacher, K.J., Kelley, K., 2011. Effect size measures for mediation models: quantitative strategies for communicating indirect effects. Psychol. Methods 16 (2), 93–115. https://doi.org/10.1037/a0022658.

Pruessner, J.C., Kirschbaum, C., Meinlschmid, G., Hellhammer, D.H., 2003. Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. Psychoneuroendocrinology 28 (7), 916–931. https://doi.org/10.1016/S0306-4530(02)00108-7.

Raudenbush, S., Bryk, A., Cheong, Y., Congdon, R., Du Toit, M., 2011. HLM 7 [Computer software]. Scientific Software International, Lincolnwood, IL.

Reichenberger, J., Kuppens, P., Liedlgruber, M., Wilhelm, F.H., Tiefengrabner, M., Ginzinger, S., Blechert, J., 2018. No haste, more taste: An EMA study of the effects of stress, negative and positive emotions on eating behavior. Biol. Psychol. 131, 54–62. https://doi.org/10.1016/j.biopsycho.2016.09.002.

Roberts, B.W., Kuncel, N.R., Shiner, R., Caspi, A., Goldberg, L.R., 2007. The power of personality: the comparative validity of personality traits, socioeconomic status, and cognitive ability for predicting important life outcomes. Perspect. Psychol. Sci. 2 (4), 313–345. https://doi.org/10.1111/j.1745-6916.2007.00047.x.

Royal, J.D., Kurtz, J.L., 2010. I ate what?! The effect of stress and dispositional eating style on food intake and behavioral awareness. Personal. Individ. Differ. 49 (6), 565–569. https://doi.org/10.1016/j.paid.2010.04.022.

Schlomer, G.L., Bauman, S., Card, N.A., 2010. Best practices for missing data management in counseling psychology. J. Couns. Psychol. 57 (1), 1. https://doi.org/10.1037/a0018082.

Schlotz, W., 2011. Ambulatory psychoneuroendocrinology: assessing salivary cortisol and other hormones in daily life. In: Mehl, M.R., Conner, T.S. (Eds.), Handbook of Research Methods for Studying Daily Life. Guilford Press, New York, pp. 193–209.

Seddon, J.A., Rodriguez, V.J., Provencher, Y., Raftery-Helmer, J., Hersh, J., Labelle, P.R., Thomassin, K., 2020. Meta-analysis of the effectiveness of the Trier Social Stress Test in eliciting physiological stress responses in children and adolescents. Psychoneuroendocrinology 116, 104582. https://doi.org/10.1016/j.psyneuen.2020.104582.

Segerstrom, S.C., O'Connor, D.B., 2012. Stress, health and illness: Four challenges for the future. Psychol. Health 27 (2), 128–140. https://doi.org/10.1080/08870446.2012.659516.

Shiffman, S., Stone, A.A., Hufford, M.R., 2008. Ecological momentary assessment. Annu. Rev. Clin. Psychol. 4, 1–32. https://doi.org/10.1146/annurev.clinpsy.3.022806.091415.

Sims, R., Gordon, S., Garcia, W., Clark, E., Monye, D., Callender, C., Campbell, A., 2008. Perceived stress and eating behaviors in a community-based sample of African Americans. Eat. Behav. 9 (2), 137–142. https://doi.org/10.1016/j.eatbeh.2007.06.006.

Sinha, R., Jastreboff, A.M., 2013. Stress as a common risk factor for obesity and addiction. Biol. Psychiatry 73 (9), 827–835. https://doi.org/10.1016/j.biopsych.2013.01.032.

Smith, M.A., Riccalton, V.C., Kelly-Hughes, D.H., Craw, O.A., Allen, S.F., O'Connor, D.B., Wetherell, M.A., 2018. The relationship between Type D personality and physical health complaints is mediated by perceived stress and anxiety but not diurnal cortisol secretion. Stress 21 (3), 229–236. https://doi.org/10.1080/10253890.2018.1435637.

Starr, L.R., Dienes, K., Li, Y.I., Shaw, Z.A., 2019. Chronic stress exposure, diurnal cortisol slope, and implications for mood and fatigue: moderation by multilocus HPA-Axis genetic variation. Psychoneuroendocrinology 100, 156–163. https://doi.org/10.1016/j.psyneuen.2018.10.003.

Stone, A.A., Brownell, K.D., 1994. The stress-eating paradox: multiple daily measurements in adult males and females. Psychol. Health 9 (6), 425–436. https://doi.org/10.1080/08870449408407469.

Tapper, K., 2022. Mindful eating: what we know so far. Nutr. Bull. 47, 168–185. https://doi.org/10.1111/nbu.12559.

Todd, A.S., Street, S.J., Ziviani, J., Byrne, N.M., Hills, A.P., 2015. Overweight and obese adolescent girls: the importance of promoting sensible eating and activity behaviors from the start of the adolescent period. Int. J. Environ. Res. Public Health 12 (2), 2306–2329. https://doi.org/10.3390/ijerph120202306.

Tomiyama, A.J., 2019. Stress and obesity. Annu. Rev. Psychol. 70, 703–718. https://doi.org/10.1146/annurev-psych-010418-102936.

Tomiyama, A.J., Dallman, M.F., Epel, E.S., 2011. Comfort food is comforting to those most stressed: evidence of the chronic stress response network in high stress women. Psychoneuroendocrinology 36 (10), 1513–1519. https://doi.org/10.1016/j.psyneuen.2011.04.005.

Torres, S.J., Nowson, C.A., 2007. Relationship between stress, eating behavior, and obesity. Nutrition 23 (11), 887–894. https://doi.org/10.1016/j.nut.2007.08.008.

Ulrich-Lai, Y.M., Christiansen, A.M., Ostrander, M.M., Jones, A.A., Jones, K.R., Choi, D. C., Davis, J.F., 2010. Pleasurable behaviors reduce stress via brain reward pathways. Proc. Natl. Acad. Sci. 107 (47), 20529–20534. https://doi.org/10.1073/pnas.1007740107.

Van Strien, T., Frijters, J.E., Bergers, G., Defares, P.B., 1986. The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. Int. J. Eat. Disord. 5 (2), 295–315. https://doi.org/10.1002/1098-108X(198602)5:2<295::AID-EAT2260050209>3.0.CO;2-T.

Von Dawans, B., Kirschbaum, C., Heinrichs, M., 2011. The Trier Social Stress Test for Groups (TSST-G): a new research tool for controlled simultaneous social stress exposure in a group format. Psychoneuroendocrinology 36 (4), 514–522. https://doi.org/10.1016/j.psyneuen.2010.08.004.

Wallis, D.J., Hetherington, M.M., 2004. Stress and eating: the effects of ego-threat and cognitive demand on food intake in restrained and emotional eaters. Appetite 43 (1), 39–46. https://doi.org/10.1016/j.appet.2004.02.001.

Wallis, D.J., Hetherington, M.M., 2009. Emotions and eating. Self-reported and experimentally induced changes in food intake under stress. Appetite 52 (2), 355–362. https://doi.org/10.1016/j.appet.2008.11.007.

Watts, A.W., Loth, K.A., Peterson, C., Boutelle, K.N., Neumark-Sztainer, D., 2016. Characteristics of a favorable weight status change from adolescence to young adulthood. J. Adolesc. Health 58 (4), 403–409. https://doi.org/10.1016/j.jadohealth.2015.09.009.

Weinstein, S.E., Shide, D.J., Rolls, B.J., 1997. Changes in food intake in response to stress in men and women: psychological factors. Appetite 28 (1), 7–18. https://doi.org/10.1006/appe.1996.0056.

Wetherell, M.A., Lovell, B., Smith, M.A., 2015. The effects of an anticipated challenge on diurnal cortisol secretion. Stress 18 (1), 42–48. https://doi.org/10.3109/10253890.2014.993967.

Wilson, S.M., Darling, K.E., Fahrenkamp, A.J., D'Auria, A.L., Sato, A.F., 2015. Predictors of emotional eating during adolescents' transition to college: does body mass index moderate the association between stress and emotional eating? J. Am. Coll. Health 63 (3), 163–170. https://doi.org/10.1080/07448481.2014.1003374.

Zellner, D.A., Loaiza, S., Gonzalez, Z., Pita, J., Morales, J., Pecora, D., Wolf, A., 2006. Food selection changes under stress. Physiol. Behav. 87 (4), 789–793. https://doi.org/10.1016/j.physbeh.2006.01.014.