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Stress and eating behaviors in children and adolescents: Systematic review and meta-analysis

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Abstract

It is well established that stress is linked to changes in eating behaviors. Research using adult populations has shown that stress is associated with both increases and decreases in the amount and type of food consumed. However, due to a lack of research reviews, the relationship between stress and eating behaviors in children is unclear. This systematic research review and meta-analysis aimed to identify whether stress is associated with healthy and unhealthy eating behaviors in children aged 8 to 18 years. Studies were included in the review if they measured stress and included a measure of food consumption. All unique studies retrieved (N = 28,070) were assessed for their eligibility at title, abstract and full text levels. A total of 13 studies were included in the final review and data were analysed using Comprehensive Meta-Analysis. Using random-effects modelling, overall stress was not associated with a change in overall eating behaviors. However, additional analyses indicated stress was associated with unhealthy eating behaviors in both younger (*Hedge's g* = 0.283, p < .001) and older (*Hedge's g* = 0.274, p = 0.001) children. In contrast, stress was not associated with healthy eating behaviors in younger children (*Hedge's g* = 0.093, p = 0.156), but was negatively associated with healthy eating behaviors in older children (*Hedge's g* = -0.384, p < .001). The current findings are concerning as they suggest the impact of stress on unhealthy eating may begin as early as 8 or 9 years old. Future research ought to investigate further the role of psychological, behavioral and endocrine factors in the development of stress-related eating in children.

Keywords: Stress, children, adolescents, eating behavior, snacking, unhealthy foods, moderators.

Introduction

The experience of stress has been theorized to influence health outcomes via two different pathways; a direct and an indirect pathway (Contrada & Baum, 2011; O'Connor et al., 2008). Experiencing a stressor directly influences the activation of the hypothalamic-pituitary-adrenal axis which increases circulating glucocorticoids (such as cortisol) and adrenocorticotropic hormones in the body (Ulrich-Lai & Herman, 2009). As such, prolonged experience of stress has been directly associated with detrimental health outcomes, such as increased risk of cardiovascular disease (Kivimäki et al., 2006), poorer mental health (Staufenbiel, Penninx, Spijker, Elzinga, & van Rossum, 2013) and accelerated disease progression (Cohen, Janicki-Deverts, & Miller, 2007).

Indirectly, stress is also thought to influence health outcomes by influencing an individual's engagement with particular behaviors. For example, experiencing a stressor may lead to deviations in normal health behaviors, such as eating habits, which in turn can increase the likelihood of poorer health (Torres & Nowson, 2007; O'Connor & Conner, 2011). Research has indicated that this indirect pathway between stress and health is particularly evident in adult populations. For example, increased experience of stress has been associated with an increase in the consumption of high calorie foods (O'Connor & O'Connor, 2004; Tryon, Carter, DeCant, & Laugero, 2013). Stress has also been linked to an increase in consumption of between-meal snacks and reduced consumption of low calorie high nutrient foods like fruit and vegetables (Mikolajczyk, El Ansari, & Maxwell, 2009; O'Connor et al., 2008). These stress related eating behaviors can have deleterious effects on health by increasing body adiposity (Steptoe & Wardle, 2005), particularly in abdominal areas (Björntorp & Rosmond, 2000) and subsequently heighten the risk of becoming overweight or obese (Berridge, Ho, Richard, & DiFeliceantonio, 2010).

It is through this pathway that stress is thought to contribute (at least partially) to the increased prevalence of childhood obesity (Pervanidou & Chrousos, 2016). Identifying the types of health behaviors children and adolescents engage in is important within this critical age, because these behaviors can translate to habits which continue into adulthood (Mikkilä, Räsänen, Raitakari, Pietinen, & Viikari, 2005). The period spanning from childhood to adolescence is considered to be critical, with many childhood behaviors becoming adult behaviors (Alberga, Sigal, Goldfield, Prud'Homme, & Kenny, 2012). This is particularly true for poorer dietary habits established in childhood, with such behaviors often staying with an individual as they become older (Mikkilä et al., 2005). It therefore remains paramount to understand factors which may influence eating behaviors in children to ensure more positive habits are established in early adolescence, to foster better health for children as they become adults (Todd, Street, Ziviani, Byrne, & Hills, 2015). Although the relationship between stress and eating behaviors in adults is fairly well established (see Greeno & Wing, 1994; O'Connor & Conner, 2011), the influence of stress on eating habits in children and adolescents is less clear.

Moreover, a number of moderators of the stress-eating relationship have been identified in the adult literature (cf., O'Connor & Conner, 2011). Stress has been found to differentially impact healthy compared to unhealthy food intake. For example, Grunberg and Straub (1992) demonstrated that when stressed, women were more likely to select foods high in calories (and fat) and Oliver, Wardle, and Gibson (2000) found changes in consumption of sweet high-fat foods and more energy dense foods. Similarly, O'Connor et al. (2008) showed that daily stressors were associated with increased consumption of high fat/sugar snacks and with a reduction in main meals and vegetable consumption. Taken together, these results suggest that individuals, when stressed, shift their preference to more palatable and energy dense snack foods, which are less healthy and higher in fat. Therefore, an aim of the current meta-analysis was to explore the extent to which type of eating behavior (healthy versus unhealthy) moderated the stress-eating relationship in children.

The effect of age was also explored to compare the effects of stress on eating behaviors between younger (8 to 12 years old) and older (13 to 18 years old) children. These age bands were established based on average age of puberty onset which is typically around the age of 13 for boys and 12 for girls (Vizmanos, Martí-Henneberg, Cliville, Moreno, & Fernandez-Ballart, 2001; Wohlfahrt-Veje et al., 2016). As children progress into adolescence, they are given increased autonomy over their own eating behaviors (Bassett, Chapman, & Beagan, 2008) and as such may find that their eating behaviors are more influenced by stress compared to younger children. Therefore, we explored the effects of age on the stress-eating relationship. Finally, given the effects of stress on eating behaviour are often more frequently observed in female samples (O'Connor & Conner, 2011), we also investigated the moderating effects of sex.

To summarise, the aim of this review was to quantify the relationship between stress and eating behaviors in children and adolescents between the ages of 8 to 18. More specifically, this review aimed to ascertain whether stress was differentially associated with healthy and unhealthy eating behaviors within this age group. Finally this review aimed to explore whether the relationship between stress and eating behaviors (specifically healthy and unhealthy) was similar in younger children (8 to 12 years old) and in adolescents (13 to 18 years old) and in males and females.

Method

Selection Criteria

Articles were retrieved on the 13th June 2016 from the electronic databases using a combination of key terms, advanced Boolean operators and by mapping onto relevant subject headings. Selected databases from Web of Science (Core Collection, BIOSIS Citation Index & Data Citation Index 1990 to present) and Ovid (Global Health 1973 to present, Ovid Medline 1946 to present, Ovid Medline In-Process and Non-Indexed Citations, Allied and Complimentary Medicine 1985 to present, Food Science and Technology Abstracts 1969 to present and PsycInfo 1806 to present) were searched in addition to the Cochrane Library (1993 to present). Key terms were categorized by population, stress measurement and eating behavior (see *Table 1* supplementary materials for an example search strategy using all search terms). Email alerts were established to include recently published articles following the initial search and additional studies were included in the final analysis up until December 1st 2016. Additionally, literature was hand searched using a descendancy approach of citations and reference lists of the studies included at full text level. The search was limited to studies in the English language. This search strategy was registered through PROSPERO on the 16/11/2016, registration number CRD42016051481. Articles were assessed for their eligibility for inclusion in the review based on the following pre-agreed criteria based on the population, stress measurement and eating behavior.

Population

Research papers with a sample of healthy children and/or adolescents (either male or female) ranging from 8 to 18 years old were included. If the specific age range for a study was not available, the mean age of the sample was used to determine inclusion in the screening process. Studies were retained if the mean age of the sample fell within the range defined for this review. Similarly, studies whose samples partially fell within the 8 to 18 year old category (e.g., 17 to 24 year olds) were retained to determine if data were obtainable for the target age band for this review. Studies were excluded from the review if the sample was wholly outside the predefined age category. Additionally, studies were excluded if the sample used medical patients or those that suffered from psychological conditions (e.g., depression or anxiety). Studies which did not include any information regarding screening for the presence of psychological conditions were retained in the review based on the assumption that a healthy population of children or adolescents (i.e., those without existing psychological conditions) was used. Finally, studies were excluded if participants were specifically trained (e.g., elite athletes) and if the sample used only a clinically defined population with disordered eating (e.g., anorexia or bulimia) without the inclusion of a healthy control group.

Stress Measurement

Papers were retained in the screening process if they included any of the following types of stress measurement. Studies were retained if they included a measurement of perceived stress, which could be reported by either a parent, teacher or self-reported by a child. Similarly, studies were retained in the screening process if they induced stress using a stress induction method such as the Trier Social Stress Task (Kirschbaum, Pirke, & Hellhammer, 1993). Finally, studies which adopted an objective measurement of stress (such as blood pressure or cortisol sampling) were also retained in the screening process. Papers were excluded if: 1) the focus was on stress experienced by an individual other than the child, such as maternal, paternal or family stress; 2) The studies reported early life stress of a child (such as physical or emotional abuse in young childhood); or 3) the paper measured a similar aspect, such as emotional distress, rather than stress which was defined as the experience of and the ability to cope with an event or situation. Studies using prospective measurements of stress were retained.

Eating Behavior Outcome

Studies reporting any form of eating or dietary behaviors were retained in the screening process. This included any measure of food intake (e.g., healthy or unhealthy foods, main meals, between-meal snacks, macronutrients) or dietary behaviors (e.g., frequency of unhealthy food consumption). Papers were excluded if: 1) they focused on attitudes towards eating, as opposed to a dietary behaviour; 2) The paper did not include any eating behavior as an outcome of the stress measurement; 3) There was insufficient data on the relationship between stress and eating outcomes; or, 4) the focus was on disordered eating or symptoms of disordered eating. Papers which included dietary restraint (as an individual trait) were included in the screening process.

Data Synthesis

A total of 28,070 papers were screened by two reviewers, where each reviewer independently screened 50% of the articles retrieved at title and abstract levels. Inter-rater reliability was obtained using Cohen's kappa statistic (Cohen, 1960) whereby each reviewer second coded at least 10% of the other's screened articles at title (*N* = 2,800) and abstract (*N* = 40) levels. The kappa value was considered to be good overall for the screening process (κ = 0.74), with moderate agreement at title level (κ = 0.64) and good agreement at abstract level with a kappa value of 0.71 (McHugh, 2012). Both reviewers assessed the eligibility of all papers at full text level, and the inter-rater reliability was considered to be good (κ = 0.87). Data was cross checked for both qualitative and quantitative synthesis. Disagreements in the eligibility of articles at any level were discussed and overcome to determine inclusion within this meta-analysis.

Quality Assessment

A quality assessment scale was developed for use within this meta-analysis and papers were independently evaluated by the first two authors prior to data analysis. This scale enabled the researchers to take the nature and quantification of both the stress and eating variables into consideration. For example, perceived and objective elements of stress needed to be independently assessed. The scale comprised six main criteria; study design, number of stress measure time points, subjective stress measurement, eating behavior frequency, objective eating measurement and validation of eating behavior measure. An overall quality assessment score was calculated for each paper based on the sum of the six criteria.

Studies were assessed on the design adopted, which was quantified as being either cross-sectional (scoring 1 if the sample was adequately matched, or 0 if limited information on the sample was provided) or longitudinal (scoring 2) which also included studies which had used daily diaries. The two frequency categories (one for stress measurement and one for eating behavior) were defined by whether or not stress/eating was measured at either one time point (scoring 0) or at multiple time points (scoring 1). Study quality was also determined through the presence or absence of an objective measurement of stress (such as cortisol sampling). Studies which included an objective measure were scored 1 on this subscale whilst those without any objective measures were score 0. Both the subjective stress measures and eating behavior criteria for study quality were determined based on the use of pre-existing questionnaires/items and whether whole scales or subscales were adopted. Additionally, the assessment for study quality on these criteria included whether studies had reported previous validation and/or reliability of the scales. For subjective stress measures, papers were scored from 0 (measures included limited information on reliability/validity of scales or items included) to 4 (multiple items taken from a previously validated scale). Similarly for the quality assessment of eating behavior measures, studies were scored from 0 (for example a single item question and/or limited information on validity of items used within each paper) to 2 (studies used items from a previously validated scale or used a more robust method to measure food intake such as weighing of foods).

Studies were assessed for their quality based on scales associated with each category, where a maximum score of 12 could be obtained. Studies were identified as being either low (scoring 0 to 4), moderate (5 to 8) or high (scoring 9 to 11) in quality. Inter-rater reliability was calculated based on the reviewers scoring of each element of the study quality assessment scale. Agreement levels were considered to be good, with Cohen's kappa values ranging from $\kappa = 0.81$ to $\kappa = 1.00$ (perfect agreement) across the quality assessment categorization.

Method of Analysis

Data was analyzed using Comprehensive Meta-Analysis (Borenstein, Hedges, Higgins, & Rothstein, 2005) and effect sizes were calculated using Hedge's g values to account for small sample sizes reported in some of the included papers (Orwin, 1983). Analyses were conducted using the random effects model because there was no prior assumption that the effect of stress on eating behaviors would be the same in all papers within the review. Type of eating behavior, age group, sex (% female), stress measurement and study quality were all included as moderating variables. The type of eating outcome used was divided into two categories; healthy or unhealthy food. Similarly the age of the samples used in this review were sub-categorized into younger children (8 to ≤ 12 years old) or older children (13 to ≤ 18 years old). Study outcomes were also split by the type of stress measurement (either perceived, objective or induced stress) utilized. Finally, study quality was used as a moderating variable, whereby studies were identified as being either low or moderate/high in quality (See *Quality Assessment* for further details). These categorical decisions were discussed by two reviewers and an agreement was reached.

Aside from investigating the moderating effect of these variables on the stress and eating behavior relationship, Pearson's correlations were conducted to explore the interdependence between the four moderators. All papers were assessed for potential publication bias using a funnel plot to compare observed and computed effect sizes. Additional analyses were conducted to determine the severity of potential publication bias within the review. Finally, sensitivity analyses were conducted to assess the impact that each study within the review had upon the overall association between stress and eating behaviors across children aged 8 to 18 years old.

Table 1. Summary of main characteristics for all 13 studies, including categorization of age, stress measurement and eating behaviors.

Author(s) and Year	**Sample Size**	**Sex**	**Age Category** [1]	**Design**	**Stress Category**	**Eating Behavior Measurement**	**Eating Behavior Category**
Austin et al. (2009)	25	15 females 10 males	Older	Cross-sectional	Perceived	Diet quality [2]	Healthy
Balantekin & Roemmich (2012)	30	15 females 15 males	Younger	Cross-sectional	Induced	Time spent eating [3]	Unhealthy
Cartwright et al. (2003)	4320	1742 females 2578 males	Younger	Cross-sectional	Perceived	Healthy & unhealthy diet [4]	Healthy Unhealthy
De Vriendt et al. (2012)	704	434 females 270 males	Older	Cross-sectional	Perceived	Diet quality [2]	Healthy
Jenkins et al. (2005)	1026	560 females 465 males 1 Unknown	Younger	Cross-sectional	Perceived	Healthy & unhealthy diet	Healthy Unhealthy
Jeong & Kim (2007)	350	All female	Older	Cross-sectional	Perceived	Food frequency [5]	Unhealthy
Kim et al. (2013)	333	131 females 202 males	Older	Cross-sectional	Perceived	Food frequency & sugar intake [6]	Unhealthy
Michels et al. (2012)	437	219 females 218 males	Younger	Cross-sectional	Perceived	Emotional eating [7]& food frequency **Error! Bookmark not defined.**	Healthy Unhealthy
Michels et al. (2016)	174	96 females 78 males	Younger	Longitudinal	Perceived& Objective	Emotional eating [7]& food frequency **Error!**	Healthy Unhealthy

[1] Category based on reported mean age of the study sample.
[2] Diet quality was defined as an overall index of optimal eating behaviors, where higher scores indicated healthier eating behaviors.
[3] Consumption of an unhealthy snack food determined by a food preference task.
[4] The categories 'fatty foods' and 'snacking behaviors' were classified as unhealthy eating behaviors while 'eating fruit and vegetables' and 'breakfast' were classified as healthy eating behaviors.
[5] Food frequency, specifically for the consumption of 17 unhealthy snack foods such as bread and cookies.
[6] Consumption of sweet foods only.
[7] Emotional eating behavior measured using a subscale of the Dutch Eating Behavior Questionnaire (van Strien, Frijters, Bergers & Defares, 1986).

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Roemmich et al. (2011)	40	20 females 20 males	Younger	Cross-sectional	Induced	Objectively measured food [8]	Unhealthy
Roemmich et al. (2002)	40	17 females 23 males	Younger	Cross-sectional	Induced	Objectively measured food [8]	Unhealthy
Son et al. (2014)	448	All female	Older	Cross-sectional	Perceived	Dietary habits [9] & snack intake[10]	Healthy Unhealthy
Tate et al. (2015)	998	518 females 480 males	Younger	Cross-sectional	Perceived	Food frequency **Error! Bookmark not defined.**	Healthy Unhealthy

[8] Preferred snack foods weighed pre and post stress task.

[9] Higher scores on the dietary habit subscales were identified as being healthier than lower scores for dietary habit items.

[10] This eating behaviour measure was not defined within the paper.

Results

A total of 28,070 unique papers were identified from electronic databases and hand searching of the literature, of which 13 papers were included within this review. A PRISMA flow diagram (Moher, Liberati, Tetzlaff, & Altman, 2009) is presented in *Figure 1* (Supplementary materials) and indicates the number of articles retained at each level of the screening process. The majority of studies initially identified for the review were excluded at title level (*N* = 27,672) predominately because of focusing on an irrelevant topic (*N* = 20,104). At full text level, 74 studies were excluded (from a total of 92) where 19 studies included samples outside the specified age range, 19 articles did not directly investigate stress on eating behaviors and 15 papers focused on psychological or physiological conditions (for example, anxiety or diabetes). The key characteristics of the 13 studies retained in this review are presented in *Table 1.*

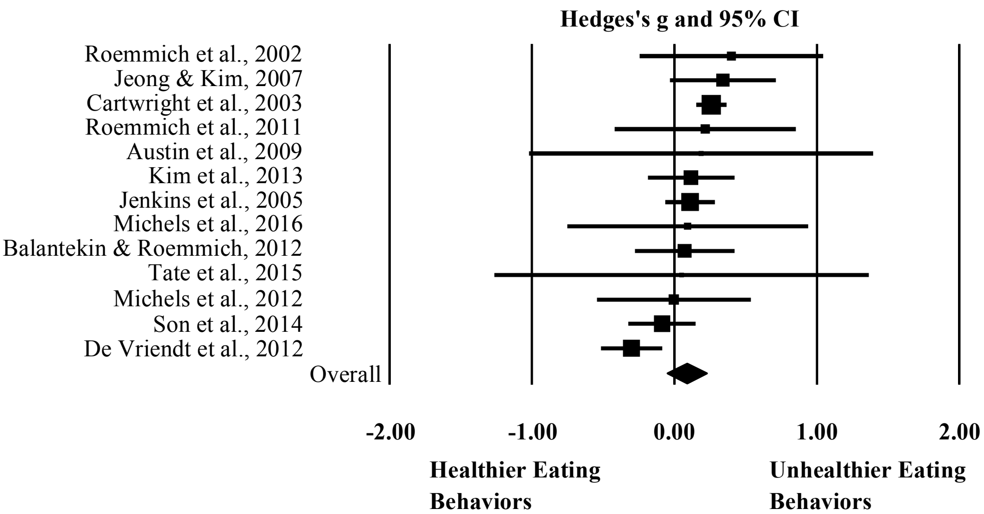
Study Characteristics

The combined number of participants in the review was 8,925 (ranging from 25 to 4,320 participants per study) with an approximately equal number of males and females (4,359 and 4,565 respectively; plus one participant who did not disclose their sex). Eight studies were categorized as testing younger children (8 to ≤ 13 years old) with a pooled sample of 7,065 participants (Balantekin & Roemmich, 2012; Cartwright et al., 2003; Jenkins, Rew, & Sternglanz, 2005; Michels et al., 2012; Michels, Sioen, Ruige, & De Henauw, 2016; Roemmich, Lambiase, Lobarinas, & Balantekin, 2011; Roemmich, Wright, & Epstein, 2002). Five studies used participants with older children (13 to ≤ 18 years old) with a total of 1,860 participants (Austin, Smith, & Patterson, 2009; De Vriendt et al., 2012; Jeong & Kim, 2007; Kim, Yang, Kim, & Lim, 2013; Son, Ro, Hyun, Lee, & Song, 2014). Perceived stress, defined as being participants own experience of stress, was measured in 10 studies. One study also included a measure of objective stress (salivary cortisol) in combination with a measure of perceived stress (Michels et al., 2016). Three studies were identified as using induced stress, where stress was induced using a task but was not measured with any other method. Studies were identified as measuring two categories of eating behavior; healthy (k=8) and unhealthy (k=11) food intake (where studies reported data for both sample sizes were reduced appropriately). Healthy eating behaviors included measures of diet quality, fruit and vegetable consumption and breakfast consumption. Unhealthy eating behaviors were identified as foods which were high calorie and low nutrient content, such as the frequency of unhealthy between-meal snacks (e.g. bread and cookies) and sugar intake (see *Table 1* for more details on measures used in each study).

Meta-Analysis Main Findings

Analyses initially investigated the effect of stress on overall eating behavior (when combining both healthy and unhealthy behaviors) across all 13 studies. This revealed that stress was not significantly associated with overall eating behaviors (*Hedge's g* = 0.083, *95% CI* = -0.055, 0.221, $Z = 1.184$, $p = 0.236$) in children aged 8-18 years old. *Table 2* (in the supplementary materials) reports a summary of the findings and a proportional forest plot (*Figure 1* below) indicating the considerable heterogeneity across the 13 studies, $Q_{(12)}$ = 26.893, $p = .008$, $I^2 = 55.378$. This justified our investigation of potential moderators (see later section).

Figure 1. A proportional high resolution plot of effects sizes (Hedge's g) and 95% CI's for studies retained in the review.

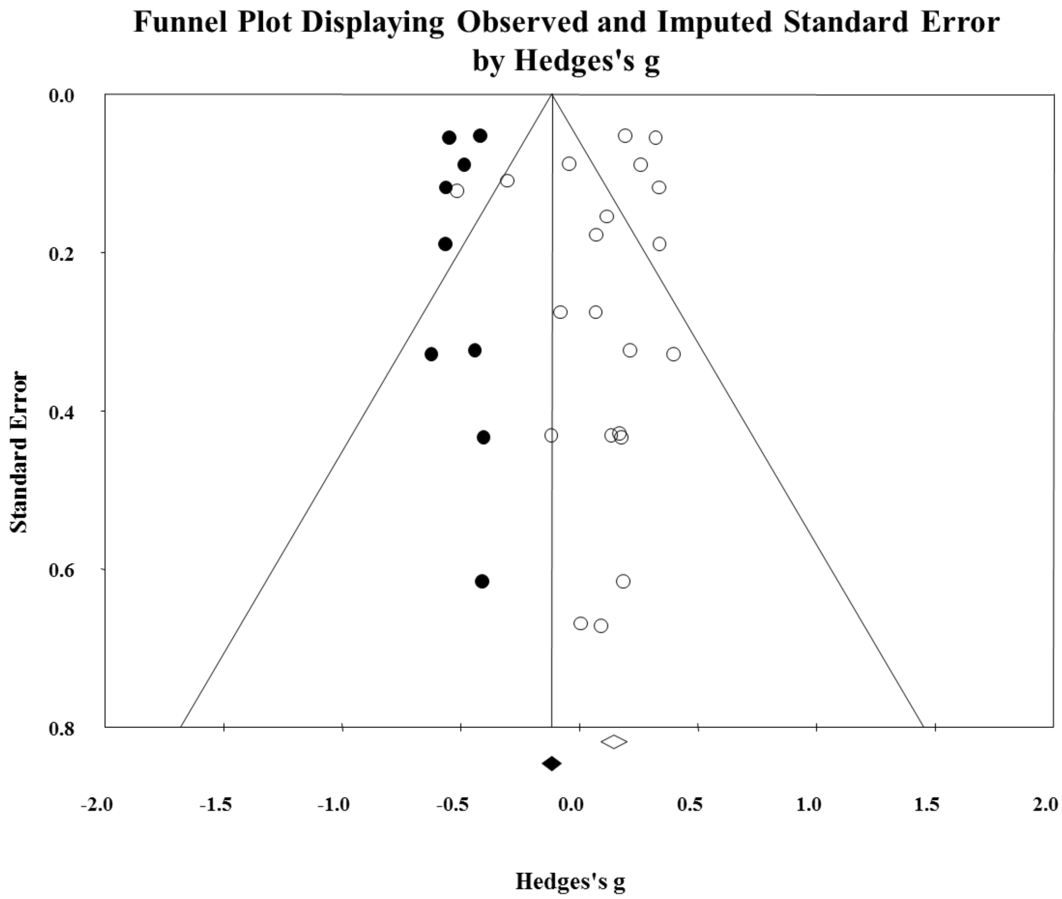


Publication Bias

The presence of publication bias was next investigated across studies assuming independence. Egger's regression coefficient (Egger, Smith, Schneider, & Minder, 1997) did not suggest there was publication bias in the papers included in this review (intercept = -0.575, $df = 19$, $p = 0.383$). However, a funnel plot (Figure 2) and Duval and Tweedie's trim and fill analysis (Duval & Tweedie, 2000) suggested while there were no missing studies from the right of the plot there were potentially nine studies missing from the left side of the plot. Inclusion of the effect sizes imputed from the nine missing studies would have resulted in a small but significant negative effect of stress on eating (*Hedge's g* = -0.116, *95% CI* = -0.157, -0.075).

Sensitivity analysis explored the impact of removing each of the 13 studies in turn from the data set on the overall relationship between stress and eating behaviors. The analysis indicated that, when removing one study at a time, the removal of one study (De Vriendt et al., 2012) did impact on the overall effect size observed and resulted in a small but significant positive effect of stress on eating among the remaining 12 studies (*Hedge's g* = 0.177, *95% CI* = 0.102, 0.252, $p < .001$).

Figure 2. Funnel plot of observed (white circles) and imputed (black circles) standard error values based on Hedge's g effect size with 95% confidence intervals for all study outcomes assuming independence between measurements.



Moderators of the stress and eating relationship in children

The considerable heterogeneity observed and mixed findings from the bias and sensitivity analyses justified an exploration of potential moderator variables (Table 2). We therefore examined the moderators of healthy versus unhealthy eating, age group, type of stress measurement (perceived and objectively measured stress), study quality (low study quality studies scorning 0 to 4 overall and moderate/high quality studies scoring 5 to 11 overall) and sex. First, we explored the effects of healthy and unhealthy eating behaviors. Analyses indicated that there was a significant moderating effect of type of eating, $Q_{(1)} = 9.071$, $p < .01$, in this age group (8 to 18 years old). Further investigation indicated that while stress was not reliably associated with healthy eating behaviors (*Hedge's g* = -0.104, *95% CI* = -0.343, 0.135, Z = -0.854, *p* = 0.393), it was reliably associated with unhealthy eating behaviors (*Hedge's g* = 0.281, *95% CI* = 0.206, 0.356, *Z* = 7.306, *p* < .001). These findings suggest that increased stress was associated with increased consumption of unhealthy food, although the size of this effect was small (Cohen, 1992).

Table 2. Summary of heterogeneity across all 13 studies for the subgroups of eating behavior, age, stress measurement and study quality.

Subgroup[11]	**Variables**	**Number of study outcomes**	**Effect size (95% CI)** ***Mixed Effects Model***	I^2 **%[12]**	**Q and P value (Within Studies)**	**Q & P value for the difference between the groups**
Eating Behavior Category	Healthy	9	-0.104 (-0.343, 0.135)	79.660%	39.332 (<.001)	9.071 (0.003)*
	Unhealthy	12	0.281 (0.206, 0.356)	0.000%	4.558 (0.951)	
Age	Younger	8	0.207 (0.123, 0.291)	0.000%	3.756 (0.807)	2.723 (0.099)
	Older	5	-0.008 (-0.248, 0.233)	62.899%*	10.781 (0.029)	
Stress Measurement[13]	Perceived	16	0.079 (-0.069, 0.227)	77.823%**	67.637 (<.001)	0.257 (0.612)
	Induced	3	0.160 (-0.117, 0.436)	0.000%	0.807 (0.668)	
Study Quality	Low	5	0.150 (-0.003, 0.303)	52.489%	8.419 (0.077)	1.451 (0.228)
	Moderate & High	8	0.002 (-0.186, 0.189)	27.984%	9.720 (0.205)	

*Note: * Significant at p<.05 level, ** significant at p<.001 level.*

Second, the moderating effect of age on the stress-eating relationship was investigated. The analysis indicated a marginally significant effect of age, $Q_{(1)} = 2.723$, $p = 0.099$. Further analyses revealed that the association between stress and overall eating

[11] Design was not included in the heterogeneity analysis due to only one study adopting a longitudinal approach.

[12] The I^2 value reflects the percentage of variance due to heterogeneity (opposed to chance) across the studies included within each subgroup (Higgins & Thompson, 2002).

[13] The 'combined' and 'objective' stress measurement categories were not included in this analysis because there was only one study within each category so analysis could not have been conducted.

behaviors was significant and positive in younger children (*Hedge's g* = 0.207, *95% CI* = 0.123, 0.291, Z = 4.813, p <.001) but not significant in older children (*Hedge's g* = -0.008, *95% CI* = -0.248, 0.233, Z = -0.064, p = 0.949).

Given the moderating effects of both healthy versus unhealthy eating and age group we also explored their simultaneous moderating effects. In younger children, the results indicated a significant difference between healthy and unhealthy eating behaviors, $Q_{(1)}$ = 5.825, p = 0.016. In particular, it was found that in younger children, stress was significantly positively associated with unhealthy eating behaviors (*Hedge's g* = 0.283, *95% CI* = 0.198, 0.367, Z = 6.544, p < .001), but not associated with healthy eating behaviors (*Hedge's g* = 0.093*, 95% CI* = -0.035, 0.222*,* Z = 1.419, p = 0.156). In older children, analyses indicated a significant difference between healthy and unhealthy eating behaviors, $Q_{(1)}$ = 25.465, p <.001. Here it was observed that in older children, stress was significantly positively associated with unhealthy eating behaviors (*Hedge's g* = 0.274, *95% CI* = 0.109, 0.439, Z = 3.250, p = .001) and was significantly negatively associated with healthy eating behaviors (*Hedge's g* = -0.384, *95% CI* = -0.579, -0.189, Z = -3.860, p < .001).

Thirdly, sex (% female) was investigated to determine whether the percentage of females present within each study moderated the association between stress and eating behaviors. A meta-regression using the Unrestricted Maximum Likelihood method on the continuous variable (%female) indicated no significant difference in the effect of stress on eating behaviours at different levels of %female (B = 0.003, SE = 0.003, p = 0.333).

Fourth, the moderating effect of the type of stress measurement (perceived or objective) was not found to significantly influence the stress-eating behaviors relationship, $Q_{(1)}$ = 0.257, p = 0.612.

Fifth and finally, study quality was assessed as a moderating variable on the association between stress and eating behaviors. The majority of the papers included in this review were assessed as being either low (N = 5) or moderate (N = 7) in quality. As only one paper was identified as being high in quality, it was combined with those of moderate quality to create two groupings (low or moderate/high). The results indicated that study quality was not found to be a significant moderator of the association between stress and eating behaviors, $Q_{(1)}$ = 1.451, p = 0.228.

Independence of Moderating Variables

Pearson's correlation analyses were conducted to explore whether the moderating variables of eating behaviour, age, sex (% female), stress measurement, and study quality were independent. The analysis showed that while there was a significant association between type of stress measurement and study quality ($r = .449$, $p = .041$; i.e., studies using an objective measurement of stress tended to be judged higher quality), no other significant associations were identified between the moderating variables. This supports the independence of the examined moderators.

Discussion

This systematic review and meta-analysis found that although there was no overall relationship between stress and eating in 8-18 year olds this overall effect was significantly moderated simultaneously by age and type of eating behaviour (healthy and unhealthy) but not the type of stress measure used or study quality. Specifically, analyses revealed that stress was significantly positively related to unhealthy eating in both younger and older children, i.e. higher levels of stress were associated with greater consumption of unhealthy foods to a similar degree (small effect size) in both groups. In contrast, the review indicated that while stress was not related to healthy eating in younger children, it was negatively associated with healthy eating in older children, i.e. higher levels of stress were associated with lower healthy food intake in older children. The percentage of females present in each study sample was found not to moderate the relationship between stress and eating behaviors. Similarly, the relationship between stress and eating in children was not affected by the type of stress measure used, i.e. similar effects were observed for perceived and objective stress measures. Finally, the relationship was not affected by judged quality of the studies examined, although the lack of high quality studies in this area was notable. More generally, the limited number of available studies and the heterogeneity in some effects sizes, even after controlling for moderators (Table 3), points to the urgent need for further high quality studies that preferably include both younger and older children and examine both healthy and unhealthy eating.

The positive relationship between stress and unhealthy food consumption supports a large number of published studies in adults (e.g., Wallis & Hetherington, 2009; O'Connor et al., 2008; Oliver, Wardle, & Gibson, 2000; Wardle et al., 2000). It is well established that stress does not necessarily have a general impact on overall eating, but instead its effect is specific to particular types of foods (with increases in the consumption of some foods and decreases in the consumption of others). The effects of stress on eating are often on more palatable or easily consumed foods (e.g., fast foods) or foods with particular sensory or health characteristics (e.g., high-fat foods; Gibson, 2006; O'Connor & Conner, 2011). For example, early work by Oliver, Wardle and Gibson (2000) found stress-related changes in consumption of sweet high-fat foods and more energy dense foods. Steptoe, Lipsey, and Wardle (1998) demonstrated that 'fast food' was eaten more frequently when respondents reported experiencing greater levels of stress. However, within this context, the current findings are alarming as they suggest the impact of stress on increasing unhealthy eating may begin as early as 8 or 9 years old. This is particularly concerning as habits around eating behaviors are established at a young age, and as such, detrimental eating behaviors (i.e. eating unhealthy foods in response to stress) could stay with children as they progress into adulthood (Mikkilä et al., 2005), which may consequently increase the risk of obesity in later life (Ebbeling, Pawlak, & Ludwig, 2002). Therefore, understanding the indirect influence of stress on eating behaviors could be important in developing effective methods for attempting to reduce increasing levels of childhood obesity (Olds et al., 2011; Rokholm, Baker, & Sørensen, 2010; Wabitsch, Moss, & Kromeyer-Hauschild, 2014).

These findings are also important as they highlight the need to understand the precise mechanisms that may explain stress-induced eating of unhealthy foods in children. In adults it has been shown that stress-induced or emotional eating is an automatic response to negative emotions (e.g. stress) that leads to overconsumption (Jacquier et al., 2012) irrespective of feelings of hunger (van Strien et al., 1986). Evidence suggests also that stress promotes glucocorticoid-induced and insulin-delineated palatable food intake that leads to the formation of strong associations between "feeling stressed" and "feeling better" following consumption of "comfort foods" (Dallman, 2010). As such, individuals who are stress-induced eaters learn to cope with stress by unhealthy snacking, which alleviates the negative emotions associated with stressful situations. Moreover, it is argued that overtime, these reinforced associations become automatic habits with little conscious recognition (Dallman, 2010; O'Connor et al., 2015). However, it remains unknown if similar processes are at play in children or what factors may increase the likelihood of becoming a stress-induced eater. Therefore, future research ought to investigate further the role of psychological, behavioral and endocrine factors in the development of stress-related eating in children.

We also observed that there was no reliable association between stress and healthy eating in younger children, but that in older children, stress was significantly associated with lower healthy food consumption. Consideration of family dynamics, such as parental restrictions on the availability of foods within the household may be a contributory factor for the differing effects of stress on healthy eating behaviors between the younger and older children (Birch, Fisher & Grimm-Thomas, 1996; Fisher, Mitchell, Smiciklas-Wright & Birch, 2002). Within the studies with younger children (8 to 12 years olds), it is likely that parental eating behaviors and practices will have influenced child eating behavior. In addition, parents may try to ensure that only healthy food options are made available to younger children to help them meet recommendations about fruit and vegetable intake. It is also possible that the younger children are more compliant to the parental food choices made for them compared to older children and as such these factors may help explain the absence of a relationship between stress and healthy food intake in younger children. Differences in stress-induced unhealthy and healthy eating may also be explained by cost. For example, unhealthy fast foods are often relatively less expensive compared to healthier alternatives and as such cost may act as a barrier to healthy snacking for younger children, particularly in times of stress. Moreover, Birch and Fisher (1998) acknowledge that parents provide both the genetic and environmental components for their children to model parental behavior, thus providing a difficult backdrop for understanding and determining what eating behaviors could be learned through modelling or reinforcement, and alternatively, what behaviors could be initiated through genes. The access, availability and variety of foods which are readily available to younger children within the home may provide useful insights into how stress-related eating behaviors may or may not manifest within younger children.

This review also highlighted that there is currently limited research exploring the relationship between stress and eating behaviors in children and adolescents. This is particularly true for longitudinal studies which have the potential to investigate how stress could influence children's health over time and whether stress has a detrimental impact on their developing health and weight status as they move into adulthood. We noted also that few studies attempted to account for the role of puberty in understanding stress-related changes in eating. This is surprising given that previous research have shown that puberty is associated with changes to normal eating behaviors in adolescents (Alberga et al., 2012), and particularly amongst younger adolescents aged 11 to 13 (van Jaarsveld, Fidler, Simon, & Wardle, 2007). In addition, there seems to be a general lack of studies that have employed objective measures of stress (e.g., using blood pressure, cortisol sampling or galvanic skin response) in children and adolescents. The method of measuring stress varied greatly across the included studies here, with some using single-item questions to indicate perceived stress, and others adopting the use of multiple items from previously validated scales. Objective measurements of stress could provide a more reliable insight into the experience of stress in children compared to the current alternative of self-report questionnaires (cf., Newman et al., 2007). Nevertheless we should note that type of stress measures was not a significant moderator of the observed relationships between stress and eating.

Finally, we recognise that the current review is based upon associations and does not imply a cause and effect relationship between stress and eating behaviors due to the over reliance on cross-sectional study designs utilised in this area. There is however evidence to support the direction of the effect, to indicate stress influences eating and not vice versa. For example, Michels et al. (2012) showed that stress was found to be associated with both emotional eating behaviors and unhealthy eating practices. Nevertheless, future research could usefully confirm the current findings in a single, longitudinal investigation that addresses the previously identified shortcomings.

Conclusion

In conclusion, this systematic research review and meta-analysis found that the effects of stress on eating behavior were moderated by age and type of eating behavior (healthy and unhealthy foods). Specifically, stress was found to be positively related to unhealthy eating in children aged 8 to 18 years old, such that higher levels of stress were associated with greater consumption of unhealthy foods. In addition, stress was found not to be related to healthy eating in younger children, however, in older children it was associated with lower healthy food intake. The current findings are concerning as they suggest the impact of stress on unhealthy eating may begin as early as 8 or 9 years old. Confirming these effects in high quality studies should be an urgent focus of attention. Future research also ought to investigate further the role of psychological, behavioral and endocrine factors in the development of stress-related eating in children in this age range.

Author Contributions

DH, RM, DO and MC identified a gap within the literature and conceived the purpose for this review. DH and RM carried out the searching, elimination, agreement and data extraction for the review, with advice from DO and MC. BSM supported DH and RM in the analytical stages within comprehensive meta-analysis, as did DO and MC. DH, RM, DO and MC wrote this manuscript. All authors checked the final version of this review and are happy to be accountable for this piece.

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Supplementary Materials

Table 1. Key terms based on population, stress and eating behavior criteria displayed as an example search strategy.

Population	Stress	Eating	
1. exp Adolescent/ or young adult/ or child/	15. exp stress/ [Psychological stress]	32. exp eating [Psychology].mp	49. healthy adj eat*.mp
		33. snack*.mp	50. body mass index.mp
2. healthy adolescent*.mp	16. hyperphagi*.mp	34. diet*.mp	51. food habit*.mp
3. healthy young adult*	17. daily hassle*.mp	35. food habit/ or meals/ or breakfast/ or lunch/ or snacks/	52. adiposity.mp
4. teenager*.mp	18. daily stress*.mp		53. eat* behave?r
5. adolescen*.mp	19. hypophagi*.mp	36. eat* pathology.mp	54. fat*
6. child*.mp	20. cortisol.mp	37. eat*.mp	55. main meal*
7. young adult*.mp	21. saliva adj cortisol.mp	38. stress adj eat*.mp	56. fruit*.mp
8. youth.mp	22. worry*.mp	39. diet* restrain*.mp	57. overeat*
9. preadult.mp	23. distress*.mp	40. eat* behavi?r	58. vegetable*.mp
10. juvenile.mp	24. stress reactiv*.mp	41. eat* attitude.mp	59. undereat*
11. school child*	25. coping.mp	42. unhealthy adj diet.mp	60. fast adj food*.mp
12. minor	26. perceive* stress.mp	43. sugar*.mp	61. food consum*.mp
13. teen.mp	27. life event*	44. unhealthy adj food*.mp	62. junk adj food*.mp
	28. life stress*.mp	45. unhealthy adj eat*.mp	63. calorie*.mp
	29. trier social stress.mp	46. healthy adj diet.mp	64. food intake
	30. initiated stress*.mp	47. emotion* eat*.mp	65. kilocalorie*.mp
		48. healthy adj food*.mp	66. BMI.mp
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.	15 or 16 or 17 or 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.	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 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66.	
14 AND 31 AND 67			
Notes: * = missing letter **adj** = adjective. **.mp** = title, abstract, subject heading. **exp** = explode subject / = map to subject heading.			

Figure 1. A PRISMA flow diagram displaying the number of studies retrieved within each stage of retrieval and screening.

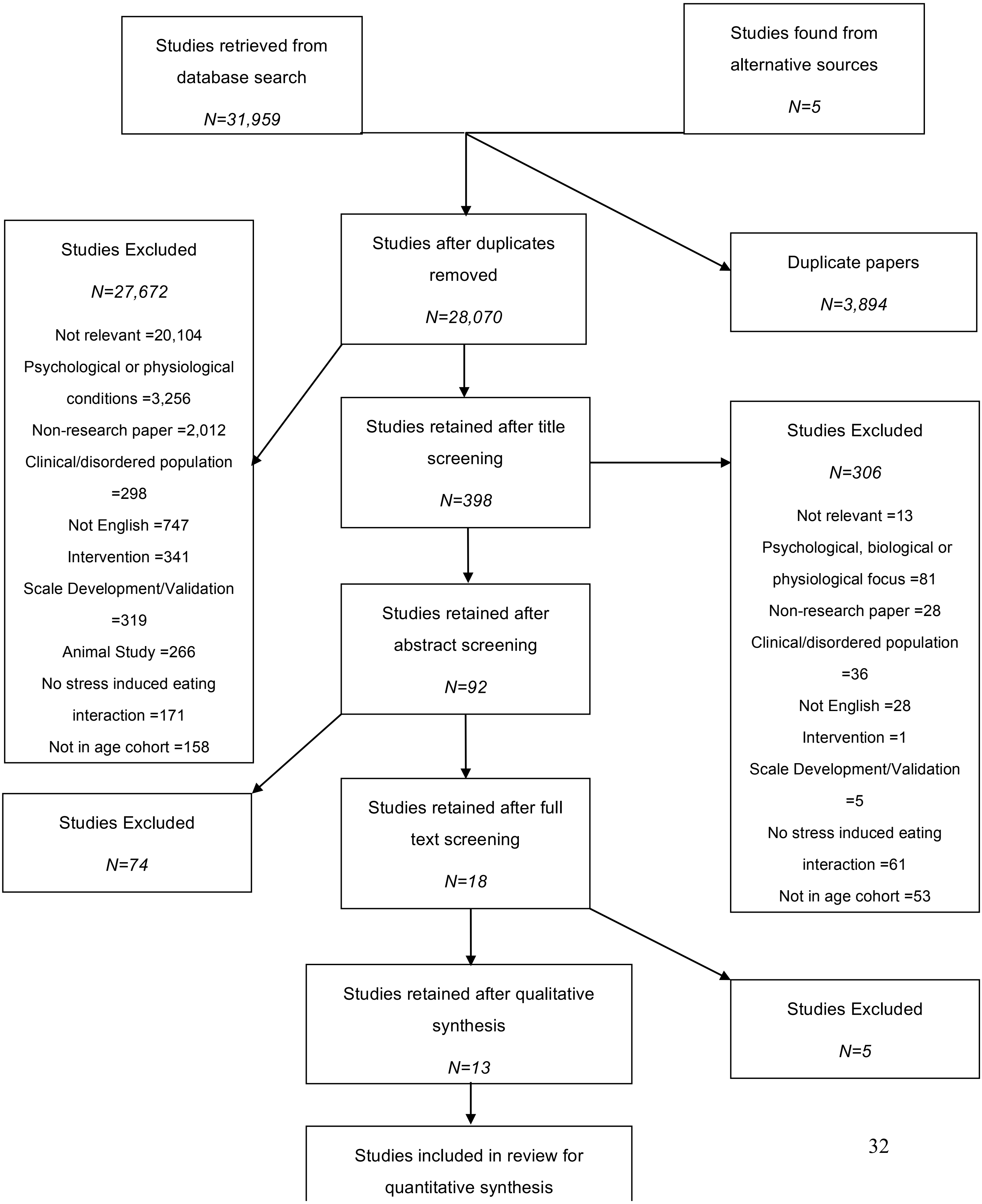

Table 2. Individual study findings, arranged by Hedge's g value (highest to lowest) of combined outcomes (stress and/or eating). Values significant at the *p* <.05 level have been marked with an asterisk (*).

Authors, Year	**Stress Measurement**	**Eating Beahvior**	**Hedge's g**	**Variance**	**Z - Value**	**Lower Limit**	**Upper Limit**	**P - Value**
Roemmich et al. (2002)	Induced	Unhealthy	0.400	0.108	1.217	-0.245	1.045	0.224
Jeong & Kim (2007)	Perceived	Unhealthy	0.340	0.036	1.792	-0.032	0.712	0.073
Cartwright et al. (2003)	Perceived	Combined	0.260	0.003	4.818	0.154	0.365	0.000*
Roemmich et al. (2011)	Induced	Unhealthy	0.217	0.105	0.668	-0.419	0.852	0.504
Austin et al. (2009)	Perceived	Healthy	0.187	0.380	0.303	-1.021	1.395	0.762
Kim et al. (2013)	Perceived	Unhealthy	0.118	0.024	0.762	-0.186	0.422	0.446
Jenkins et al. (2015)	Perceived	Combined	0.111	0.008	1.249	-0.063	0.285	0.212
Michels et al. (2016)	Combined	Combined	0.093	0.186	0.216	-0.753	0.939	0.829
Balantekin & Roemmich (2012)	Induced	Unhealthy	0.072	0.032	0.405	-0.277	0.421	0.686
Tate et al. (2015)	Perceived	Combined	0.051	0.450	0.075	-1.264	1.365	0.940
Michels et al. (2012)	Perceived	Combined	-0.005	0.076	-0.016	-0.545	0.536	0.987
Son et al. (2014)	Perceived	Combined	-0.087	0.015	-0.722	-0.323	0.149	0.470
De Vriendt et al. (2012)	Perceived	Healthy	-0.301	0.012	-2.748	-0.516	-0.086	0.006*
		Overall	0.083	0.005	1.184	-0.055	0.221	0.236