Associations of maternal stress with children's weight-related behaviours: a systematic literature review

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O'Connor, S.G., Maher, J.P., Belcher, B.R., Leventhal, A.M., Margolin, G., Shonkoff, E.T., Dunton, G.F. (2017). Associations of maternal stress with children's weight-related behaviors: A systematic literature review. *Obesity Reviews*. 18(5): 514-525.

Abstract:

Low adherence to guidelines for weight-related behaviours (e.g. dietary intake and physical activity) among US children underscores the need to better understand how parental factors may influence children's obesity risk. In addition to most often acting as primary caregiver to their children, women are also known to experience greater levels of stress than men. This study systematically reviewed associations between maternal stress and children's weight-related behaviours. Our search returned 14 eligible articles, representing 25 unique associations of maternal stress with a distinct child weight-related behaviour (i.e. healthy diet [n = 3], unhealthy diet [n = 6], physical activity [n = 7] and sedentary behaviour [n = 9]). Overall, findings for the relationship between maternal stress and children's weight-related behaviours were mixed, with no evidence for an association with children's healthy or unhealthy dietary intake, but fairly consistent evidence for the association of maternal stress with children's lower physical activity and higher sedentary behaviour. Recommendations for future research include prioritizing prospective designs, identifying moderators, and use of high-resolution, real-time data collection techniques to elucidate potential mechanisms.

Keywords: Childhood obesity | maternal mental health | weight-related behaviour

Article:

Abbreviations:

BMI body mass index
F&V fruit and vegetable
MVPA moderate-to-vigorous physical activity
SSB sugar sweetened beverages

Introduction

Childhood obesity continues to be a pressing public health issue [1], and behavioural health factors play important risk or protective roles. Only one-third of US children ages 2 to 19 meet the minimum daily recommendation for fruit and vegetable (F&V) intake [2], while approximately 40% of total caloric intake for US children ages 2 to 18 is in the form of added sugars and solid fats [3]. Statistics for physical activity and sedentary behaviour paint a similarly grim picture; despite the recommendation of the American Academy of Paediatrics that children ages 2 and older limit daily media use to 2 h, the average US child and adolescent ages 2 to 18 watches 3 h of television of day [4]. Further, even toddlers are engaging in high amounts of sedentary screen behaviour, including the 48% of US toddlers ages 12 to 23 months who watch more than 2 h of screen time per day [5]. Along with elevated engagement in sedentary activities, few youth meet national guidelines for physical activity; a recent analysis of the US 2012 National Health and Nutrition Examination Survey National Youth Fitness Survey found that 40% of children ages 6 to 11 and 72% of adolescents ages 12 to 15 did not meet physical activity guidelines [6].

Given the significant control and influence that parents exert on their children's lives, examination of the role that parents, specifically mothers, may play in children's weight-related behaviours [7, 8] merits continued examination. According to family systems theory, the behaviours of one individual cannot be fully explained in isolation from the larger family unit [9]. The relationship between mothers and their children is of particular relevance because mothers are most often the primary caregiver [10]. One way in which mothers may influence their children's weight-related behaviours and obesity risk is through their experience of psychological stress. Psychological stress can be defined as a perceived imbalance between demands on an individual and the individual's ability or resources to meet these demands [11]. Stress may arise from external events or from an individual's perception of their situation as stressful [11]. Previous studies have suggested that psychological stress in mothers may play a role in parenting style [12] and mother–child interactions [13] and may also lead to elevated cortisol levels (a stress hormone) in their children [14]. The important role of maternal stress is even more relevant in light of estimates showing that women experience greater levels of chronic stress and daily stressors than men [15, 16]. Further, elevated stress and the experience of stressful life events are independent risk factors for the development of depression [15], which is also more prevalent in women and which may further compound the negative effects of maternal stress on their children's health and well-being [17].

Maternal stress has been shown to influence various aspects of parenting practices and mother–child interactions [18], and it is hypothesized that maternal mental health may influence children's weight-related behaviours through three primary pathways. First, maternal stress may

affect parenting behaviours or mother–child interactions (e.g. through parenting or feeding style), which may in turn alter her child's behaviour. For example, mothers experiencing high levels of stress may spend less time with their children [19] or may be less responsive and involved in interacting with their children than less stressed mothers [20]. Second, maternal stress may alter mothers' own physical activity, sedentary behaviour, and dietary intake, which in turn may alter her child's behaviour via altered maternal modelling [21]. Finally, elevated maternal stress may directly influence her child's behaviour via alterations in her child's own stress response [21], including a heightened biological [14] or psychological stress response in her child.

It is clear that maternal stress plays a role in the overall health and well-being of her child, and a recent meta-analysis [22] concluded that children of mothers experiencing high levels of psychological stress are also at greater risk of obesity. The authors note several potential mechanisms through which maternal stress may affect children's body mass index (BMI), such as elevated stress in the child, and emphasize the need to better understand the behavioural pathways through which maternal stress may influence children's obesity risk [22]. To our knowledge, no systematic review to date has investigated the role of maternal stress on the weight-related behaviours of their children. A recent review investigated a similar question, concerning the associations between maternal psychopathology (e.g. body dissatisfaction, anxiety, self-esteem and depression) and young children's obesity risk and obesity 'lifestyle risk factors' (i.e. weight-related behaviours) [23]. This study found a consistent positive association between one maternal mental health dimension – depressive symptoms – with obesity and obesity lifestyle risk factors in their children, but mixed findings for associations of other maternal psychopathology (i.e. body dissatisfaction) with children's weight-related behaviours [23]. Because maternal stress represents a common psychological experience that is both related to depressive symptoms [24] and an independent risk factor for obesity outcomes in children [22], the investigation of the unique contribution of maternal stress on children's weight-related behaviours represents a unique contribution to the literature on maternal mental health and children's obesity risk.

Thus, the goal of this review was to (a) identify the instruments and methods most commonly used to measure maternal stress as well as child healthy and unhealthy dietary intake, physical activity and sedentary behaviour; (b) examine the associations between maternal stress and children's weight-related behaviours across studies in the literature and (c) identify whether maternal stress is differentially associated with children's obesity-related behaviours (i.e. healthy and unhealthy dietary intake, physical activity and sedentary behaviour). We selected these four distinct weight-related behaviours as they represent unique risk (i.e. unhealthy dietary intake and sedentary behaviour) and protective (i.e. healthy dietary intake, physical activity) factors that have been highlighted as playing a role in children's obesity risk [25-27].

Methods

Inclusion/exclusion criteria

Studies that met the following criteria were included in the review: (a) available in English language; (b) included children between the ages of 0 and 18; (c) contained a self-report measure of maternal perceived stress or experience of stressors; (d) contained a measure of child dietary

intake, child physical activity or child sedentary behaviour and (e) in studies containing mothers and/or fathers, at least 70% of the sample were mothers. Search terms included a combination of two elements: (a) maternal stress and (b) child weight-related behaviour. The following keywords were used to identify relevant articles: ('maternal' OR 'mother' OR 'parental') AND ('stress*' OR 'stressors') AND ('youth' OR 'child') AND ('weight-related' OR 'obesogenic' OR 'diet*' OR 'food' OR 'intake' OR 'nutrition' OR 'eat*' OR 'activity' OR 'physical' OR 'sport*' OR 'sedentary' OR 'television') NOT ('rat' OR 'prenatal').

Search process

A review of the literature was performed using three databases (i.e. Web of Science, PubMed and PsycINFO) restricting the time frame of the search from the time of database inception until 15 April 2016. Three individuals conducted the original literature search, according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. E. T. S. and S. G. O. independently searched and screened for articles examining dietary outcomes, and J. P. M. and S. G. O. screened articles examining physical activity and sedentary behaviour outcomes. Figure 1 displays the Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram for the literature search. After the removal of duplicates due to using multiple databases, the search produced 3,158 unique records. On the basis of the title review, 2,100 records were removed, and the abstracts of the remaining 1,058 records were reviewed, from which 65 articles were downloaded and the full-text versions were reviewed for eligibility. Two independent readers reviewed each article and determined whether it met the inclusion criteria. Ultimately, 14 articles were included in the qualitative review. Primary reasons for exclusion included study measured only maternal stress or child weight-related behaviour(s), or measured both stress and weight-related behaviour within the same individual (e.g. in either mother or child), or study measured child obesity outcomes (e.g. BMI) but not weight-related behaviours.

Study quality coding

After identifying all eligible articles (n = 14), articles were coded for study characteristics. Study characteristics and key findings are summarized in Table 1. Study quality was assessed by two independent coders using a modified study quality rating tool [28], which assessed risk of bias in (a) the selection of exposed and non-exposed cohorts (i.e. from the same underlying population), (b) the quality of exposure assessment (i.e. using a validated measure), (c) confidence that the outcome was not present at the start of the study or that baseline levels of the outcome were controlled for in analyses, (d) the quality of outcome assessment (i.e. using a validated measure) and (e) adequate follow-up (for longitudinal) or adequate recruitment rate (for cross-sectional). Studies were also coded for whether or not analyses controlled for a number of potential confounders, including child factors (e.g. race and sex), maternal factors (e.g. marital status, health, BMI and education) and household factors (e.g. household income). Coders met to compare codes, and any discrepancies were resolved and agreed upon. The choice to conduct a systematic narrative analysis of results, as opposed to a quantitative meta-analysis, was based on the great diversity of operational definitions used to describe the concepts of maternal stress and child weight-related behaviours across studies.

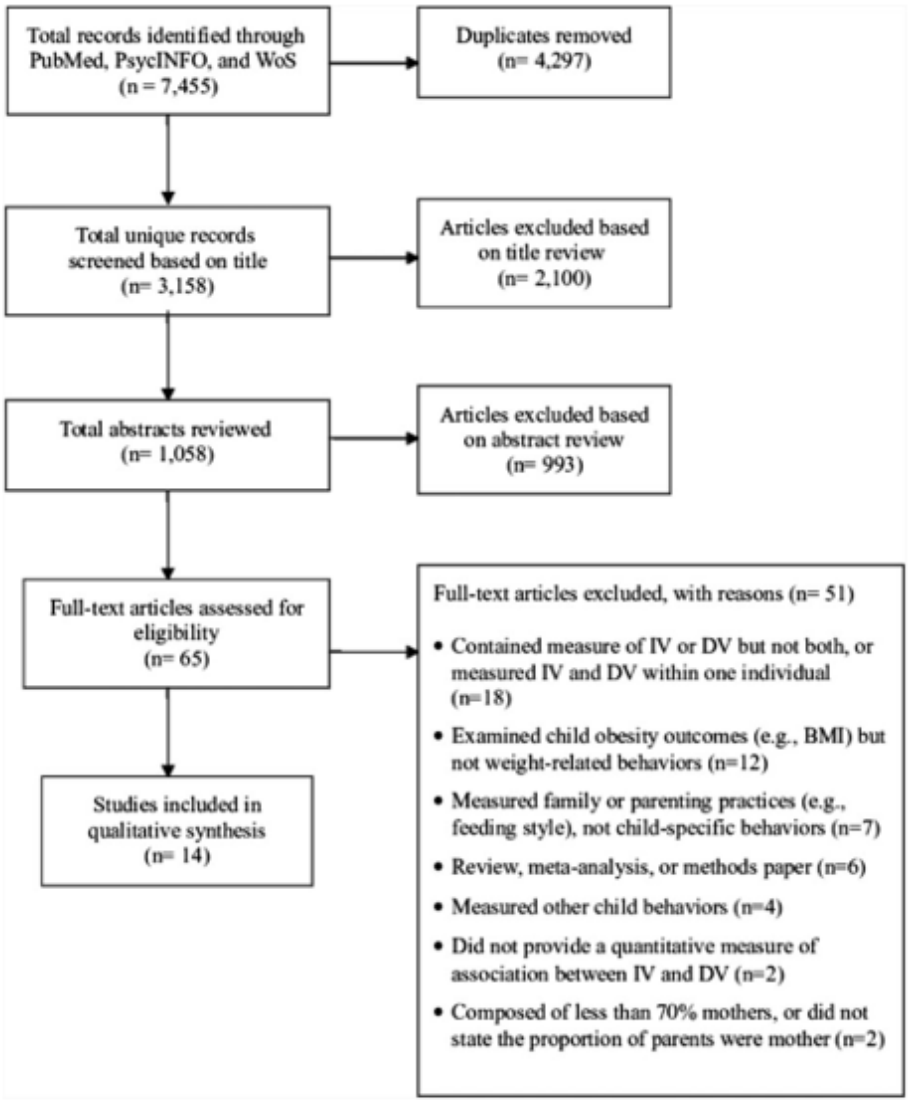

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram, summarizing the search process to identify and screen articles examining the associations between maternal stress with children's weight-related behaviours published through April 2016.

Table 1 Associations of maternal stress with child weight-related behaviours

Authors	Study design	Child age	Race/ ethnicity	Socioeconomic status	Sample size (*N*)	% Mother	Maternal stress measurement	Child outcome measurement	Association with child healthy dietary intake	Association with child unhealthy dietary intake
Studies examining the association of maternal stress with children's healthy and unhealthy dietary intake										
Parks *et al.* (29)	Cross-sectional	3–17 years	Parent: 58% Caucasian; Child: 56% Caucasian	Low income	2,119	72	Measure of perceived stress and number of stressors	Healthy and unhealthy (fruits and vegetables, fast food; parent reported)	0	+/0
McPhie *et al.* (30)	Longitudinal	T1- M: 2.8, SD: 0.7; T2- M: 3.91, SD: 0.73	Unspecified: 74% Australian or New Zealand	Annual household income: 70% > $85,000	117	100	Short form of the Parenting Stress Index	Healthy and unhealthy (children's eating and physical activity questionnaire; mother reported)	–/0	0
Nanjappa *et al.* (32)	Cross-sectional	3–4 years	Mother: 57% Caucasian	Low income	698	100	Family assessment device and measure of family functioning	Unhealthy (sugary foods; Food Frequency Questionnaire from National Diet and Nutrition Survey; mother reported)	N/A	+
Suglia *et al.* (33)	Longitudinal	T1–12 mo, T2–36 mo, T3–60 mo	Child: 51% African–American	Low income	129	100	Measure of maternal stressors	Unhealthy (juice/sugar sweetened beverages; mother reported)	N/A	+
Hurley *et al.* (34)	Cross-sectional	0–12 months	Mother: 50% White	Low income	689	100	Perceived Stress Scale	Unhealthy (age-inappropriate foods and early cereal to bottle; 24-h dietary recall; mother reported)	N/A	0/+
Reiner *et al.* (31)	Cross-sectional	M: 14 years	Not provided; German	N/A	214	100	Trierer Inventory for chronic stress	Healthy and unhealthy (core foods, non-core foods, Food Frequency Questionnaire; child reported)	–/0	0/+
									Association with child physical activity	Association with child sedentary behaviour
Studies examining the association of maternal stress with children's physical activity and sedentary behaviour										
Gray *et al.* (35)	Cross-sectional	M: 12.8, SD: 1.8	Child: 52% Caucasian	Median household income: $20,000–$39,999	95	82	Global Severity Index	Physical activity (relative to peers; parent reported)	–	N/A
Parks *et al.* (29)	Cross-sectional	3–17 years	Parent: 58% Caucasian; Child: 56% Caucasian	Low income	2,119	72	Measure of perceived stress and number of stressors	Physical activity (days/week; parent reported)	0/–	N/A
McConley *et al.* (36)	Cross-sectional	M: 11.1, SD: 0.57	Child: 43% Hispanic	Median household income: $30,000–34,999	4,601	89	Brief Symptom Inventory	Physical activity (School Physical Activity and Nutrition Questionnaire; parent reported); sedentary behaviour (minutes/ day; parent reported)	–	+

(*Continues*)

Table 1 (Continued)

Authors	Study design	Child age	Race/ ethnicity	Socioeconomic status	Sample size (*N*)	% Mother	Maternal stress measurement	Child outcome measurement	Association with child physical activity	Association with child sedentary behavior
Lundahl *et al.* (37)	Cross-sectional	8–11 years	Child: 52.4% Caucasian	Low income	122	88	Measure of perceived financial strain	Physical activity (Fels Physical Activity Questionnaire for children; child reported); sedentary behaviour (Modifiable Activity Questionnaire; child reported)	+	+
Walton *et al.* (38)	Cross-sectional	2–5 years	Parent: 55% Hispanic	Annual household income: 64% < $45,000	110	93	Parenting Stress Index	Physical activity (minutes/day; parent reported); sedentary behaviour (TV viewing/day; parent reported)	–	0
Loprinzi (39)	Cross-sectional	6–17 years	Child: 88.5% Hispanic	N/A	101,672	79	Measure of family functioning	Physical activity (days/week; parent reported); sedentary behaviour (screen time/day; parent reported)	–	+
Reiner *et al.* (31)	Cross-sectional	M: 14 years	Not provided; German	N/A	214	100	Trierer Inventory for chronic stress	Physical activity (days/week, minutes/day; child reported); sedentary behaviour (minutes/day; child reported)	–	+
Thompson and Christakis (43)	Cross-sectional	4–35 months	Mother: 63% Caucasian	Median household income: $45,001–$60,000	1,793	100	Mental Health Inventory-5	Sedentary behaviour (minutes/day; mother reported)	N/A	+
Suglia *et al.* (33)	Longitudinal	T1–12 mo, T2–36 mo, T3–60 mo	Child: 51% African–American	Low income	129	100	Measure of maternal stress	Sedentary behaviour (TV viewing/ day; mother reported)	N/A	0/+
Li, Jurkowski and Davidson (41)	Cross-sectional	M: 3 years	Mothers: 72% Caucasian	Low income	1,589	100	Perceived Stress Scale	Sedentary behaviour (TV viewing/ day; mother reported)	N/A	+
Pempek and McDaniel (42)	Cross-sectional	12–48 months	Mothers: 85.5% Caucasian	Mean household income: $64,039	358	100	Relational well-being score, representing relationship conflict	Sedentary behaviour (tablet use/ day; mother reported)	N/A	0/+

'+' indicates a positive association; '–' indicates a negative (inverse) association; and '0' indicates a null association between a specific maternal mental health variable and child weight-related behaviour type; 'N/A' indicates that the given association was not examined within a study. R, range; T1, time one (baseline) measurement; M, mean; SD, standard deviation; T2, time two (follow-up); T3, time three (follow-up).

Results

Study characteristics

In total, our search returned 14 unique articles investigating the associations of maternal stress with children's weight-related behaviours, representing 25 unique associations. Of these, three measures of association described the association between maternal stress and children's healthy dietary intake [29-31], six for maternal stress and children's unhealthy dietary intake [29-34], seven for maternal stress and children's physical activity [29, 31, 35-39], and nine for the association between maternal stress and children's sedentary behaviour [31, 33, 36-42].

Study quality ratings and covariates

On the basis of the study criteria described in the Study quality coding, average study quality rating [28] was 0.81 (range: 0–1, with '1' representing the best possible), and study ratings were similar across dietary only (0.83) and activity only (0.81) studies. The majority of studies adjusted for at least some covariates. Across studies examining dietary outcomes, the most commonly adjusted for covariates included children's sex (67%), household income (67%), race of either the mother or the child (67%) and mother's marital status (50%). Across studies examining physical activity or sedentary behaviour outcomes, far fewer studies controlled for covariates overall, and the covariates most commonly adjusted for include maternal education (63%), child gender (55%) and race of either the mother or the child (36%).

Demographic characteristics of included samples

Approximately half of included studies (n = 6, 43%) focused either specifically or exclusively on low-income populations within the USA [29, 33, 34, 37, 41, 43]. The majority of other studies sampled a representative US population. Three (21%) studies were conducted outside of the USA, in Australia [30], Germany [31] and the UK [32]. Although the majority of studies contained predominantly Caucasian participants, there were some studies with a majority of Hispanic [39, 44] or African–American [33] participants.

Maternal stress measures

Measures of maternal stress varied widely across studies. Several studies used the concept of family or parenting stress, including the McMaster Family Assessment Device – General Functioning Scale [32], the short form of the Parenting Stress Index [30, 38] and a general family functioning index [39]. Two studies used the Perceived Stress Scale, a general measure of perceived stress [34, 41]. Other studies used various scales, including the Brief Symptom Inventory to assess symptomatic distress [35], the Mental Health Inventory-5 [40] and a 'Personal well-being' and 'Relational well-being' measure constructed to represent role overload and stress due to relationships and conflict [42]. Several studies measured parental report of stressors experienced in specific domains. These included one study that used a Stressor Index (0–7 scale), measuring four domains of stress: physical health, mental health, financial strain and family structure, in conjunction with a single-item past-year Perceived Stress Scale [29]; one study using a measure of perceived financial strain [37]; one using the Trierer Inventory for

Chronic Stress to assess sources of past-three-month stress [31]; and one study that used a Cumulative Social Risk Score, summing maternal reports of six domain-specific stressors [33]. Overall, the variety of scales employed to measure maternal stress across studies illustrates the wide range of definitions and criteria used to operationalize stress.

Child weight-related behaviour measures

Child healthy and unhealthy dietary intake

Child dietary intake was measured through a variety of instruments, most commonly through Food Frequency Questionnaires [31, 32] or the Children's Eating and Physical Activity Questionnaire [30]. In general, mothers recalled information on children's usual dietary intake over a specified period of time. Other studies used targeted questionnaires to assess children's intake of specific food items, including F&V or fast food [29], or sugar sweetened beverages (SSB) [33]. One study in infants used interviewer-assessed 24-h dietary recalls [34]. The types of foods that constituted 'healthy' and 'unhealthy' varied and were defined within each study. In general, studies defined 'healthy' dietary intake as including intake of F&V or 'core' nutritious foods, and age-appropriate intake (e.g. breast milk) for infants. 'Unhealthy' dietary intake was commonly defined as intake of fast food, SSB, or foods high in added sugars (i.e. 'non-core' foods), or in infants, age-inappropriate intake (i.e. introduction of solid foods earlier than recommended).

Child physical activity and sedentary behaviour

Overall, the majority of studies assessing physical activity asked mothers to recall children's habitual activity levels. One study asked mothers to rate their child's physical activity as compared with peers [35], while others asked mothers to provide the number of minutes per day [31, 38] or per week [29, 39] that their child engages in physical activity. A small number of studies used validated questionnaires to assess children's physical activity, including the School Physical Activity and Nutrition [36], the Fels Physical Activity Questionnaire [37], both of which were child reported. The majority of studies assessing the influence of maternal stress on children's sedentary behaviour used a single mother-reported item of children's screen time, assessing the number of hours per day the child spends watching TV [33, 38, 39, 41] or using tablets [42]. Other studies asked mothers to report on the number of minutes their child spends engaged in sedentary behaviour overall [31, 40], while one study used the Modifiable Activity Questionnaire to assess sedentary behaviour through child self-report [37].

Associations between maternal stress and child weight-related behaviours

There were 25 unique associations of the relationship between maternal stress and a specific child weight-related behaviour outcome, as summarized in Table 1.

Healthy dietary intake

There is little evidence to support an association between maternal stress and children's healthy dietary intake, with the three studies measuring maternal stress and child healthy dietary intake finding mixed [30, 31] and null [29] associations. Studies with mixed findings found differing

effects either by maternal stress type or by child healthy food definition. In a longitudinal study of preschool-aged children, there was a negative association between maternal parenting stress at baseline (child mean age = 2.8 years, SD = 0.68) and mother-reported children's intake of vegetables, but no association with children's intake of fruit 1 year later (child mean age = 3.9 years, SD = 0.73) [30]. Reiner *et al*. [31] used the Trierer Inventory of Chronic Stress to examine the association of maternal stress overall, as well as stress in the specific domains of work overload, social overload and social tension, with children's intake of core foods – a sum of intake of six healthy foods assessed in the frequency questionnaire. Maternal overall stress was significantly associated with decreased intake frequency of core foods ($\beta = -0.135$, $p < 0.05$); however, maternal stress in each of the three-specific sub-domains of stress was not associated with children's core food consumption [31]. In a large (n = 2,119) cross-sectional study of children ages 3 to 17, there was no association between either maternal perceived stress or number of stressors experienced over the past year and children's current intake of F&V [29].

Unhealthy dietary intake

Of the six studies (four cross-sectional and two longitudinal) examining the association between maternal stress and child unhealthy dietary intake, two studies [32, 33] found a positive association, three studies [29, 31, 34] found mixed associations and one [30] found a null association. Of the two studies finding a positive association between maternal stress and child unhealthy intake, one longitudinal [33] and one cross-sectional [32], both found maternal stress to be associated with greater mother-reported child intake of foods high in added sugars, including juice, SSBs and sugary foods. Three cross-sectional studies [29, 31, 34] found mixed positive and null associations between maternal stress and child unhealthy intake, across a variety of child ages. In a study of over 2,000 children ages 3 to 17, Parks *et al*. [29] examined the association of both maternal perceived stress and number of stressors experienced, finding that greater perceived stress was associated with increased odds of children eating fast food at least two times per week in both unadjusted and adjusted analyses (OR = 1.06, 95% CI = 1.02, 1.10, $p < .001$), but that the number of stressors experienced, although significantly associated with fast food intake in unadjusted analyses, became non-significant (OR = 1.00, 95% CI = 0.93, 1.08) in adjusted analyses. This suggests potential divergent effects of perceived stress ratings and objective stressor experience on children's unhealthy intake. Similarly, the study by Reiner *et al*. [31] found that while maternal overall perceived stress was marginally associated with increased consumption of non-core foods (a sum of four unhealthy foods) in their children ($\beta = 0.131$, $p < 0.10$), increased ‘social overload’ stress in mothers was significantly associated with increased non-core food consumption in their children ($\beta = 0.30$, $p < 0.05$) [31]. Hurley *et al*. [34] also found conflicting results depending on the type of unhealthy dietary intake. Although maternal perceived stress was also positively associated with concurrently reported early addition of cereal to 4- to 6-month-old infants' bottles (before the recommended age), maternal stress was not associated with 7- to 12-month-old children's unhealthy dietary intake, defined as consumption of age-inappropriate foods (e.g. snacks and desserts) and measured by maternal-reported 24-h dietary recall. One study by McPhie *et al*. [30] found null results between maternal parenting stress measured at baseline and children's unhealthy (i.e. snacks, sweets and pastries) dietary intake 1 year later. Overall, there appears to be no clear pattern of findings for the association between maternal stress and children's unhealthy dietary intake across study design, child age range or type of unhealthy foods measured.

Physical activity

There appears to be a consistent negative association between maternal stress and children's physical activity; among the seven cross-sectional studies investigating this association, five [31, 35, 36, 38, 39] found a negative association, one [29] indicated mixed results and one [37] found a positive association between maternal stress and child physical activity. The most consistent finding of a negative association between maternal stress and child physical activity spanned a variety of measures of maternal stress (e.g. perceived stress, family stress and chronic stress inventory) as well as a variety of conceptualizations of child physical activity (e.g. School Physical Activity and Nutrition Questionnaire, physical activity minutes per day and physical activity of child as compared to peers). Overall, studies finding a negative association relied on maternal report of children's usual physical activity levels, with only one study using a child-report measure [31], and no studies using an objective measure of physical activity (e.g. accelerometry). The mixed findings by Parks *et al*. [29] indicated that neither perceived stress nor number of stressors was associated with parent-reported days per week of child moderate-to-vigorous physical activity (MVPA); however, a particular stressor (i.e. financial) was negatively associated with days per week of child MVPA. Conversely, Lundahl *et al*. [37] documented a positive association between financial strain and child-reported physical activity, as reported through the Fels Physical Activity Questionnaire, suggesting that higher levels of financial strain were associated with greater volume of physical activity in children. The conflicting results for the association between mother-reported financial stress and children's physical activity between these studies might be viewed in light of sample size, as the study by Parks *et al*. [29] finding a negative association included over 2,000 children, while Lundahl *et al*. [37] found a positive association in just over 100 children.

Sedentary behaviour

Studies exploring the association between maternal stress and children's sedentary behaviour either conceptualized sedentary behaviour as mother-reported sedentary screen time [33, 38, 39, 41, 42] or as mother-reported [36, 40] or child-reported [31, 37] sedentary minutes. Of the nine studies (one longitudinal and eight cross-sectional) investigating this association, six [31, 36, 37, 39-41] indicated a positive association, two [33, 42] indicated mixed findings and one [38] indicated a null association. Of the six studies indicating a positive association between maternal stress and sedentary behaviour, two [37, 39] found that higher levels of maternal stress were associated with higher levels of child-reported and parent-reported screen time per day among children, respectively. Furthermore, Thompson and Christakis [40] and Reiner *et al*. [31] concluded that higher levels of maternal stress were associated with higher levels of child-reported and parent-reported total sedentary time per day among children, respectively. In the only longitudinal study assessing associations between maternal stress and sedentary behaviour, Suglia *et al*. [33] found that reporting two or more maternal stressors at child age 12 and 36 months, compared with no maternal stressors, was significantly associated with watching television for more than 2 h a day (72% vs. 55%) among boys at 5 years; however, this association was not found among girls. The only study to conclude a null association between maternal stress and sedentary time, Walton *et al*. [38] found that the odds of watching two or more hours of TV per day did not differ depending on level of mother-reported parenting stress for either weekdays or weekend days; however, confidence intervals were large, indicating

possible variability in the association among participants (weekday OR = 0.95 [CI 0.33–2.31]; weekend day OR = 1.93 [CI 0.66–5.66]). Among these studies, there appears to be a trend by age, where the studies with mixed or null findings had the youngest child age, ranging from 1 to 5 years of age [33, 38, 42]; this may indicate a stronger effect of maternal stress on the sedentary behaviour of older children. Overall, the results from these cross-sectional studies indicate a positive association between maternal stress and child sedentary behaviour.

Discussion

Summary

Overall, findings for the relationship between maternal stress and children's weight-related behaviours were mixed, with no evidence for an association with children's dietary intake, but fairly consistent evidence for the association of maternal stress with lower physical activity and higher sedentary behaviour in children. The associations of maternal stress and children's healthy diet are equivocal; of the three studies exploring the relationship between maternal stress and children's healthy (i.e. F&V) intake, one found null, and two found mixed associations, suggesting that, if the two are related, important moderators may be overlooked and are potential avenues for future studies. The findings for maternal stress and children's unhealthy dietary intake were also mixed, and studies finding a positive association between maternal stress and child unhealthy intake generally operationalized unhealthy intake as foods and drinks high in added sugars, such as juice and candies; studies finding mixed or null results generally operationalized unhealthy foods as including fast food or age-inappropriate foods (for infants). This suggests that the effects of maternal mental health on children's unhealthy dietary intake may differ by food type.

Maternal stress and children's physical activity were largely found to be associated, with the majority of studies across a variety of ages supporting the notion that maternal perceived stress is inversely related to children's daily minutes of physical activity. One study noted a positive association between maternal (financial) stress and children's physical activity, where increased financial strain was associated with more physical activity in children; this is unexpected, and the authors postulate that parents with heightened financial difficulties may work late and place their children in afterschool programs were physical activity is promoted or may encourage their children to play outside independently more than parents with less financial strain [37]. Similarly, across the vast majority of studies included, maternal stress was positively associated with children's sedentary behaviour, most often conceptualized as time spent watching television per day.

Although stress may represent one generalizable phenomenon, there are many sub-classifications of stress, including general perceived stress, perceived stress limited to a specific domain (e.g. financial, health or social) or the experience of specific stressful life events (e.g. death and divorce). It is possible that a mother's experience of each of these different types of stress may differentially relate to her child's weight-related behaviours. Although different types of stress may have similar characteristics, there may be distinct pathways through which each stress type operates. For example, one study measured both overall maternal chronic stress and stress in three-specific domains (e.g. work overload, social overload and social tension) and found overall

maternal stress to be associated with children's decreased healthy ‘core’ foods, but only social tension to be associated with children's increased intake of unhealthy ‘non-core’ foods [31]. Similarly, another study found that only maternal financial stress, not perceived stress or number of stressors experienced, was negatively associated with their children's lower physical activity levels [29]. These discrepant findings suggest that there may be unique processes linking specific domains of maternal stress with children's weight-related behaviours.

Interestingly, of the two studies that measured the associations of parenting stress with children's weight-related behaviours [30, 38], results for an association with obesogenic behaviours were largely null. For example, one study found no association of maternal parenting stress with intake of unhealthy foods [30], while the second study found no association between parenting stress and children's TV viewing [38]. One potential interpretation may be that mothers are stressed partly because of their parenting duties, such as limiting junk food intake or time spent watching television, which could deplete cognitive and emotional resources.

Strengths of the literature

The studies reviewed were highly representative of low income or at-risk populations and included a variety of racial and ethnic groups. Additionally, there were a range of study designs and child ages represented, from infancy through 17 years of age, and studies addressed both dietary intake and physical activity outcomes.

Limitations of the literature and future directions

A major limitation of the included studies is the wide variety of child activity outcome measurements. For example, among studies measuring the effect of maternal stress on children's unhealthy dietary intake, the definitions of ‘unhealthy’ dietary intake included a variety of food types and classifications of quantity or frequency of consumption, from whether a child typically consumes fast food two or more times per week [29] to whether a child drinks three or more servings of SSBs per day [33]. Similarly, for studies measuring physical activity outcomes, definitions and measurements of physical activity ranged greatly, from maternal report of the number of days in the previous week in which her child was physically active for at least 20 min [39] to the FELS PAQ score, on the basis of child report of various questions relating to physical activity over the past year [37], to a mother's rating on a single item of how physically active her child is as compared with other children [35]. The disparate methods of defining and quantifying child weight-related behaviours complicate the standardization and comparison of findings across studies. Future studies should consider using more standardized methods of collection and quantifying activity outcomes, such as the use of accelerometers to capture physical activity and standardized algorithms to classify time spent in MVPA.

An additional limitation of the included studies is the dearth of longitudinal designs. For example, our search found no longitudinal studies examining the associations between maternal stress and child physical activity. The cross-sectional design of most studies poses two concerns. First, there is a potential for bidirectional effects, as certain health behaviours could lead to an increased risk of stress (e.g. low intake of F&V, sedentary lifestyle and diet high in fat and sugar). One study found that consuming a ‘Western’ diet, high in fat and sugar was associated

with elevated risk of anxiety and depression in large sample of women [45]. Thus, it may not be that mothers experiencing high levels of stress have increased palatability for unhealthy foods and fewer cognitive and emotional resources to prepare healthy foods for their children, but conversely that mothers of children with the highest intake of unhealthy foods also consume these foods themselves and are thus at elevated risk of experiencing high levels of psychological stress. Second, health behaviours in mothers are correlated with health behaviours of their children [7], yet maternal health behaviour was not controlled for in any included study. Thus, the mechanisms through which mothers influence their children's weight-related behaviours may be varied and complex and cannot be fully addressed through cross-sectional designs. As such, longitudinal studies can provide better insight as to the stability of the association of maternal stress on children's weight-related behaviours, as well as reveal any critical time windows in the developmental process. Additionally, experimental studies, such as interventions designed to reduce maternal stress and measure changes in children's weight-related behaviours, are important for a better understanding of causality.

Although a few studies of older children (6 years of age and up) used child-reported physical activity and sedentary behaviour information [31, 37] or dietary intake information [31], the majority of studies used maternal report of children's weight-related behaviours. While this may be necessary for very young children, reliance on maternal report may also introduce potential bias. Mothers may simply not be aware of all of their child's activity or food consumption, such as the types of snacks her child eats during school time. Additionally, previous studies have demonstrated that mothers experiencing mental health issues (e.g. depression) may misperceive or misreport on their children's behaviours, resulting in biased reports [46]; this may also be the case in parents with elevated stress levels, who may report in inaccurate reporting of child behaviours.

Another major limitation of the field is a lack of real-time self-report data capture such as Ecological Momentary Assessment (EMA) to assess maternal stress and/or child weight-related behaviours as they occur naturally within the context of everyday life. The majority of studies ask participants to recall ‘usual’ or habitual behaviour over a period of time in the recent past (i.e. the past week or month). For example, nearly all of the included studies examining children's sedentary behaviour used a single item (i.e. parent-reported number of TV viewing minutes per day); this is problematic, as this estimation of usual levels may evoke recall bias, and more importantly because sedentary behaviour may include more than simply time spent in sedentary screen activities. One notable exception to the use of recall to assess ‘usual’ levels of weight-related behaviours includes the use of 24-h recall to ask mothers to report on their child's complete previous-day dietary intake [34]. Although even the 24-h recall method does not capture events in real time as they occur, it might pose an advantage over studies relying more heavily on recall. Other methods, such as EMA, can provide a notable advantage over commonly used retrospective methods, as it allows for more ecologically valid data capture that is less prone to biases triggered by recall or laboratory settings. For example, a study design in which mothers and children report on their own social context, affective and stress states and weight-related behaviours through EMA can allow for more precise examination of the roles that maternal stress may play in children's weight-related behaviours on an acute and chronic basis [47].

In addition to utilizing EMA methods, future studies should strive to incorporate more objective monitor-based measures of children's physical activity and sedentary behaviour, such as accelerometers, pedometers or ActivPAL thigh-worn monitors (PAL Technologies Ltd, Glasgow, UK), which allow for more precise classification of the sitting, standing and walking events. Similarly, use of higher resolution methods, such as multiple-pass 24-h dietary recall paired with the calculation of a more comprehensive measure of dietary quality, such as the Health Eating Index, a scoring method based on the US Dietary Guidelines that can be used to determine an individual's overall dietary quality [48], can provide a more nuanced description of an individual's weight-related behaviours. The combination of EMA-reported contextual information along with objective measures of children's activity could provide more useful opportunities for understanding the effects of maternal stress on child weight-related behaviour. For example, in an event-contingent EMA prompting schedule, a certain threshold of sedentary behaviour as measured by accelerometer (e.g. 30 min of sedentary activity), could prompt an EMA survey designed to gain more information about the context and antecedents of this activity.

In addition to the need for more comprehensive and fine-grained data, several studies point to the need to examine maternal and child factors that may moderate the association between maternal stress and children's weight-related outcomes. For example, the study by Suglia *et al*. [33] found maternal experience of >2 cumulative social risk factors (e.g. housing insecurity and paternal incarceration), to be longitudinally associated with elevated soda and juice consumption in both boys and girls, but with watching >2 h per day of television in boys only. This suggests that maternal stress may differentially affect children based on sex, potentially reflecting gender-specific differences in the social acceptability of strategies that a mother may use to cope with stressors (e.g. mothers may use television as a tool to occupy boys in times of stress but use different strategies for girls) [33]. Although generally used only as covariates in the included studies, other child factors (e.g. race and ethnicity) and other parental factors, such as socioeconomic status, marital status or household structure, may also play an important moderating role; future studies should consider formally analyzing these demographic characteristics where appropriate.

Conclusion

Overall, the present review found mixed evidence for an association between maternal stress and children's weight-related behaviours; higher maternal stress tended to be consistently linked with lower child physical activity and higher sedentary behaviour but not consistently associated with dietary intake of healthy or unhealthy foods. Future research should examine the connection between maternal stress and children's weight-related behaviours with careful consideration of potential moderators, and prioritizing longitudinal study design along with high-resolution, real-time data collection techniques. Given the current state of the evidence for an association between maternal stress and children's weight-related behaviours (e.g. physical activity and sedentary behaviour), clinicians may consider behavioural interventions, such as mindfulness-based stress reduction, to diminish the effects of stress in mothers on children's weight-related behaviours as an additional strategy to address childhood obesity prevention and intervention.

Acknowledgements

This study was funded by the University of Southern California Graduate School Provost Fellowship (attributed to the first author), the National Institutes of Health Cancer Control and Epidemiology Research Training Grant (T32CA009492) and the National Heart, Lung, and Blood Institute (R01HL119255, attributed to the last author).

Conflict of interest statement

The authors declare no conflict of interest.

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