Appetite 135 (2019) 100–107

Contents lists available at ScienceDirect

Appetite

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

Sleep duration and quality are associated with eating behavior in low-income toddlers

Alison L. Miller[a,b,*], Sara E. Miller[a], Monique K. LeBourgeois[c], Julie Sturza[b], Katherine L. Rosenblum[b,d], Julie C. Lumeng[b,e,f]

[a] Department of Health Behavior and Health Education, University of Michigan School of Public Health, United States
[b] Center for Human Growth and Development, University of Michigan, United States
[c] Department of Integrative Physiology, University of Colorado Boulder, United States
[d] Department of Psychiatry, University of Michigan Medical School, United States
[e] Department of Pediatrics, University of Michigan Medical School, United States
[f] Department of Nutritional Sciences, University of Michigan School of Public Health, United States

ARTICLE INFO

Keywords:
Sleep
Eating in the absence of hunger
Eating behavior
Toddlers
Low-income

ABSTRACT

Objective: The present study examined whether different sleep health parameters (duration, timing, and quality) are associated with obesity-related eating behaviors including emotional overeating, food responsiveness, enjoyment of food, satiety responsiveness, and eating in the absence of hunger (EAH), during toddlerhood.
Design: Among 134 low-income 33-month-old children, parents reported on child sleep parameters, including sleep quality (Children's Sleep Wake Scale; CSWS) and usual bedtimes and wake times on weekdays and weekends (weeknight sleep duration, weekday-to-weekend bedtime delay). Child eating behaviors were assessed using both observed and parent-report measures. Child Emotional Overeating, Food Responsiveness, Enjoyment of Food, and Satiety Responsiveness were measured by parent report using the Child Eating Behavior Questionnaire-Toddler. Observed child EAH was evaluated by measuring kilocalories of palatable foods consumed following a meal. Multivariable linear regression was used to examine the associations between sleep parameters and eating behaviors.
Results: Poorer child sleep quality was associated with greater Emotional Overeating (standardized $\beta = -0.20$ (SE 0.09), $p < .05$) and greater Food Responsiveness ($\beta = -0.18$ (SE 0.09), $p < .05$). Shorter child nighttime sleep duration was associated with greater EAH kcal consumed (standardized $\beta = -0.22$ (SE 0.09), $p < .05$). Child bedtime delay was not associated with any of the eating behaviors, and no child sleep variables were associated with either Enjoyment of Food or Satiety Responsiveness.
Conclusions: Shorter nocturnal sleep duration and poorer sleep quality during toddlerhood were associated with some, but not all, of the obesity-related eating behaviors. Poor sleep health may promote childhood obesity risk through different eating behavior pathways. As children growing up in poverty may experience greater sleep decrements, sleep duration and sleep quality may be important targets for intervention among low-income families with young children.

1. Introduction

Poor sleep health (short duration, irregular or late timing, and disrupted quality) in early childhood is associated with concurrent obesity and overweight, as well as excessive weight gain across time in children and adolescents (Cappuccio et al., 2008; Fatima, Doi, & Mamun, 2016; Hart, Cairns, & Jelalian, 2011). Eating behavior has been proposed as a key mechanism through which the association between poor sleep and obesity becomes established (Burt, Dube, Thibault, & Gruber, 2014), and it has been hypothesized that sleep and eating behaviors are associated through both biological and behavioral mechanisms (Miller, Lumeng, & LeBourgeois, 2015). For example, insufficient sleep may drive unhealthy eating behavioral patterns or habits (e.g., eating in the absence of hunger, eating in response to emotional stress) (Lundahl &

Abbreviations: EAH, eating in the absence of hunger; CSWS, Child Sleep Wake Scale; CEBQ-T, Children's Eating Behavior Questionnaire for Toddlers; EOE, emotional overeating; EF, enjoyment of food; FR, food responsiveness; SR, satiety responsiveness; BMI, body mass index

* Corresponding author. School of Public Health, University of Michigan, 1415 Washington Heights, room 3718. Ann Arbor, MI, 48109-0209, United States.
E-mail address: alimill@umich.edu (A.L. Miller).

https://doi.org/10.1016/j.appet.2019.01.006
Received 18 July 2018; Received in revised form 3 January 2019; Accepted 7 January 2019
Available online 08 January 2019
0195-6663/

Nelson, 2015) and/or promote obesogenic food choices (e.g., craving for sweets, carbohydrates) (Chaput, 2014; Mullins et al., 2017). Toddlerhood is a sensitive period when both sleep routines and independent eating habits become established, as this is a period of significant growth in autonomy in each of these domains (Peltz, Rogge, Sturge-Apple, O'Connor, & Pigeon, 2016; Schwartz, Scholtens, Lalanne, Weenen, & Nicklaus, 2011). For example, toddlers show increased food preferences and a desire for autonomy in feeding (Schwartz et al., 2011) and develop dietary patterns that may shape later outcomes (Andersen et al., 2015). With regard to sleep, toddlers begin dropping their daytime naps and exhibiting nighttime sleep consolidation (Bathory & Tomopoulos, 2017; Mindell et al., 2016); however, against this background of normal developmental change, sleep difficulties such as bedtime resistance and/or nighttime fears emerge, are prevalent, and impact family functioning and routines (Mindell & Owens, 2015; Peltz et al., 2016). Yet, to date few studies have examined associations of sleep parameters with eating behaviors that are hypothesized to promote obesity risk during this period of development, especially among children living in poverty. This was the goal of the current study.

The manner in which a child eats can drive both food selection as well as the amount of food eaten, which can combine to promote obesity risk over time (French, Epstein, Jeffery, Blundell, & Wardle, 2012; Mooreville et al., 2015). Eating behaviors associated with obesity and adiposity include emotional overeating (Braet & Van Strien, 1997), food responsiveness (Webber, Cooke, Hill, & Wardle, 2010), enjoyment of food (Webber et al., 2010), and low satiety responsiveness (Webber, Hill, Saxton, Van Jaarsveld, & Wardle, 2009). Emotional overeating reflects greater food intake during negative emotional states, which over time may promote obesity risk if adopted as a strategy to cope with stress (Wardle, Guthrie, Sanderson, & Rapoport, 2001). Greater responsiveness to external food cues, or food responsiveness, is an eating behavior that may serve to increase attention to and intake of foods that are highly-palatable (i.e., high in sugar, fat, sugar, or salt) and thereby promote excessive weight gain over time (Herman & Polivy, 2008). Enjoyment of food is an eating behavior that reflects a generally positive approach to food and pleasure in eating (Webber et al., 2010), and is also associated with overweight in young children (Domoff, Miller, Kaciroti, & Lumeng, 2015). Finally, satiety responsiveness is considered an index of the child's capacity to stop eating when full, and is typically associated with lower risk for obesity (Mooreville et al., 2015; Webber et al., 2009).

Eating in the absence of hunger (EAH) is another eating behavior that has been associated with higher adiposity and BMI among children (Asta et al., 2016; J. O.; Fisher & Birch, 1999). EAH is considered to reflect the propensity to consume foods, particularly highly palatable foods, when sated (Lansigan, Emond, & Gilbert-Diamond, 2015). EAH can be measured objectively in young children (Asta et al., 2016) and likely indexes multiple dimensions of eating behavior (e.g., satiety responsiveness; enjoyment of food) that contribute to increases in caloric consumption (Lansigan et al., 2015). EAH has underlying genetic components (Birch, Fisher, & Davison, 2003; Faith, Carnell, & Kral, 2013), yet is also hypothesized to be influenced by parenting and early-life experiences, and possibly triggered by external cues (Hill, Prokosch, DelPriore, Griskevicius, & Kramer, 2016; Lansigan et al., 2015). Although many of the aforementioned eating behaviors have been assessed in young children in relation to weight, they have rarely been examined in association with sleep during early childhood. As these behaviors can drive dietary intake and function as early markers of risk for excessive eating and later obesity (Mooreville et al., 2015), it is important to consider how poor sleep health associates with such eating behaviors early in development.

Of the limited research examining associations between sleep and eating in children, most studies have focused on dietary intake. Many studies have found associations with shorter nocturnal sleep duration and increased intake (A. Fisher et al., 2014; Mullins et al., 2017; Petrov et al., 2017), though others found no association (Hager et al., 2016; Thellman, Dmitrieva, Miller, Harsh, & Lebourgeois, 2017; Thivel et al., 2015). Among children younger than 5 years, shorter nocturnal sleep at 16 months was associated with greater parent-reported intake at 21 months in a large prospective study (A. Fisher et al., 2014) and in a smaller cross-sectional study of low-income 2-4 year-olds with obesity (Petrov et al., 2017). Sleep duration was not associated with dietary intake in a separate cross-sectional study of 20-month olds (Hager et al., 2016). Although most studies that have examined sleep and diet in young children are correlational, one experimental study (Mullins et al., 2017) of healthy 32- to 47-month-olds found that acute sleep restriction (~3 h) in comparison to sleep optimization increased parent-reported kilocalories by about 20%, acting specifically via increases in sugar and carbohydrate intake. In addition to duration, researchers have examined the timing of sleep with regard to variability in sleep schedules (typically weekday-to-weekend shifts), which reflects more inconsistent sleep timing and has been proposed to drive unhealthy eating patterns and risk for obesity and other poor health outcomes via increased opportunity to eat and/or hormonal dysregulation (Gooley, 2016; He et al., 2015; Kjeldsen et al., 2013; Miller, Lumeng, et al., 2015). Among toddlers, later sleep schedules on weekends compared to weekdays (bedtime delay) was associated with greater parent-reported fat consumption in a sample of low-income 2-4 year-olds with obesity (Petrov et al., 2017). In older children, later weekend bedtimes were associated with more snacking (Thivel et al., 2015), and shifted weekend-to-weekday timing was associated with multiple adiposity indicators, although eating behavior was not measured (Lee et al., 2018). Researchers have also considered sleep timing with regard to when in the 24-h day sleep occurs. Among older children, later sleep timing (across weekends and weekdays) was associated with greater consumption of energy-rich foods (Thellman et al., 2017), with no associations between sleep duration and diet. Taken together, there is emerging evidence that multiple sleep parameters, including shorter sleep duration and shifted schedules or later sleep timing, are associated with dietary intakes that are related to later obesity risk, suggesting different aspects of disrupted sleep health are associated with unhealthy dietary intake in children. Yet, particularly in young children, we do not know how these different aspects of sleep health may associate with the eating behaviors that may drive dietary intake.

Understanding how sleep may shape the manner in which a child consumes food may therefore yield additional insight into early-emerging eating-related behavioral pathways through which poor sleep may promote later obesity risk. That is, short sleep duration, variable or shifted sleep timing, and poor sleep quality may promote excessive dietary intake in part through eating behaviors that lead to overeating in response to hedonic reasons, as opposed to homeostatic hunger (Chaput & St-Onge, 2014; Lowe & Butryn, 2007). For example, insufficient sleep may reduce child capacity to cope with stress, resulting in emotional overeating (Lundahl & Nelson, 2015), or may heighten child attention to tempting external food cues, i.e., greater food responsiveness (McDonald, Wardle, Llewellyn, & Fisher, 2015). Of the few studies examining associations between sleep and such eating behaviors in children, results have been mixed, and most studies have focused on older children. Regarding duration, shorter nocturnal sleep duration in school aged-children was associated with greater parent-reported food responsiveness (McDonald et al., 2015) and external eating (Burt et al., 2014). The one study examining sleep and observed EAH in youth found no association between sleep duration and EAH, but the sample was exclusively overweight female adolescents (Kelly et al., 2016). Regarding other sleep parameters and eating behavior, poorer sleep quality (Burt et al., 2014) and later sleep onset latency (Nguyen-Rodriguez, McClain, & Spruijt-Metz, 2010) were associated with greater emotional eating among school-aged children. Thus, to our knowledge no study has considered multiple sleep parameters in relation to the eating behaviors of interest in the toddler age range, or among low-income populations. The current study sought to fill this gap in understanding associations between sleep parameters and eating behaviors in young children.

Finally, few of the aforementioned studies have focused on young, low-income children. This is a significant oversight, as risk for obesity is often established early in the lifespan and once present it tends to persist (Nader et al., 2006). Furthermore, children growing up in poverty are at disproportionate risk for obesity (Pan, May, Wethington, Dalenius, & Grummer-Strawn, 2013), and they may experience sleep disturbances (i.e. noise, crowded spaces, lack of temperature control) that contribute to this greater risk for poor sleep (El-Sheikh et al., 2013). In order to inform early interventions, it is critical to examine associations involved in the pathway for these children very early in the lifespan. In this study, we address these limitations by examining multiple sleep parameters in relation to child eating behaviors, specifically parent-reported child emotional overeating, food responsiveness, enjoyment of food and satiety responsiveness, and observed child EAH, in a sample of low-income toddlers. We hypothesize that shorter nocturnal sleep duration, shifted sleep timing (weekday-to-weekend bedtime delay), and poorer sleep quality would associate with more food "approach" eating behaviors (higher emotional overeating, food responsiveness, and enjoyment of food; lower satiety responsiveness; and higher EAH).

2. Method

2.1. Participants and recruitment

Mother-child dyads were recruited between 2010 and 2014 from Women, Infant, and Child (WIC) clinics and Early Head Start programs throughout south-central Michigan. Children were either 21 months (n = 186) or 27 months old (n = 58) at recruitment, and were followed up at 33-months of age, the assessment that is the focus of the current study. Our data collection protocol was designed such that families participated in multiple home visits to complete tasks on separate days. Questionnaires were completed in person during the first protocol visit. The EAH procedure was thus completed on a separate day, but no more than 1 month after the first protocol element was started. The sample of children was 52.2% male, and 56.0% non-Hispanic white. Dyads were included in the study if the biological mother was the legal guardian of the child; was at least 18 years old; and had obtained an education level less than a 4-year college degree. Additional inclusion criteria were that participants were English speaking; that someone in the family was eligible for Head Start, WIC, or Medicaid; and that children were born at ≥36 weeks gestational age and had no food allergies, perinatal or neonatal complications, serious medical conditions, or developmental delays. The study was approved by the University of Michigan Institutional Review Board (IRB) and written informed consent was obtained from mothers.

For the current study, children who participated in the EAH protocol (n = 112) and/or had CEBQ-T and sleep data at 33 months of age (n = 134) were included in analyses. Participants with EAH data did not differ from those missing EAH data with regard to with regard to maternal education or child race/ethnicity, or income to needs ratio (all p's > 0.20). Participants with CEBQ-T data did not differ from those missing CEBQ-T data with regard to maternal education or child race/ethnicity. Participants with CEBQ-T data vs. those missing CEBQ-T data had a higher income-to-needs ratio (1.03 vs. 0.74, p = .003).

2.2. Measures

2.2.1. Sleep

2.2.1.1. Nocturnal sleep duration and timing. Parents responded to the following questions used in prior work (Miller et al., 2014): "What is your child's usual bedtime on weekday nights?", "What is your child's usual wake time on weekday mornings?", "What is your child's usual bedtime on weekend nights?", and "What is your child's usual wake time on weekend mornings?". From these, a variable indicating total weeknight sleep duration (in hours) was created by calculating the difference between parent-reported bedtimes and wake times. Higher values indicated longer weeknight sleep duration.

To assess bedtime delay, a variable was calculated to indicate the delay in bedtime on weekends compared to weekdays. Positive values indicated a larger shift in weekday to weekend sleep schedules (hours of delay on weekends compared to weekdays), suggesting a weekend delay in the timing of bedtime.

2.2.1.2. Sleep quality. Parents reported on child sleep quality using the Children's Sleep Wake Scale (CSWS), a questionnaire with good-to-excellent validity and reliability for research studies of toddlers and preschoolers (LeBourgeois & Harsh, 2016). Parents respond to 25 items on a 6-point Likert-type scale (ranging from "1 = never" to "6 = always") that reflect the child's success across 5 behavioral dimensions of sleep quality: Going to Bed, Falling Asleep, Maintaining Sleep, Reinitiating Sleep, and Returning to Wakefulness in the morning. The mean of the 5 subscales was calculated (with appropriate items reversed) to create an overall sleep quality score (Cronbach's $\alpha = 0.82$). Higher scores indicate better sleep quality.

2.2.2. Eating behaviors

Child eating behaviors were assessed using both parent report and observational measures, each of which have been used in prior work with young children (Asta et al., 2016; Birch & Fisher, 1995; Domoff et al., 2015).

2.2.2.1. Child eating behavior questionnaire for toddlers (CEBQ-T). The CEBQ-T is a toddler-age version (Herle, Fildes, van Jaarsveld, Rijsdijk, & Llewellyn, 2016) of the widely-used 35-item parent-report CEBQ (Carnell & Wardle, 2007; Wardle et al., 2001) that was interviewer-administered to mothers. We used four subscales from the CEBQ-T: Emotional Overeating (EOE), reflecting the child's tendency to overeat when upset (4 items; $\alpha = 0.83$), Food Responsiveness (FR), reflecting the child's tendency to eat food in response to external stimuli rather than hunger (5 items; $\alpha = 0.84$), Enjoyment of Food (EF), reflecting the child's general desire to eat food (4 items; $\alpha = 0.83$), and Satiety Responsiveness (SR), reflecting the child's capacity to stop eating in response to internal satiety cues (5 items; $\alpha = 0.65$). Mothers rated the child's eating behaviors using a 5-point Likert scale ranging from "1 = never" to "5 = always", with higher scores indicating more of the behavior. The CEBQ has been validated against observational measures of eating behavior (Carnell & Wardle, 2007) and used with young, low-income children (Domoff et al., 2015).

2.2.2.2. Eating in the absence of hunger (EAH). EAH was assessed at the child's home on a weekday. EAH protocols have been used in prior work with children as young as 3 years of age, with EAH operationalized as total kcals consumed (Lansigan et al., 2015). The current protocol as used with toddlers has been described previously (Asta et al., 2016) and required the mother to fast her child for 1 h then serve a typical lunch including at least 2 foods and 1 drink. The mother was asked to indicate to the research assistant when her child was full and then asked to sit back and not interact with her child during the remainder of the protocol. The research assistant then provided the child with a pre-measured array of sweet and salty foods and told the child, "Here are some special treats you can eat." The offered foods were the following: 4 Little Debbie Oatmeal Cream Pies (152 g, 680 kcals), 2 Little Debbie Cosmic Brownies with Chocolate Chip Candy (124 g; 560 kcals), 8 Nabisco/Chips Ahoy Chewy Chocolate Chip Cookies (124 g; 560 kcals), 8 Keebler Fudge Stripe Cookies (108 g; 560 kcals), 8 Little Debbie Mini Powdered Donuts (100 g, 440 kcals), and 3 Kellogg's Original Rice Krispy Treats (66 g, 270 kcals). Mothers were asked beforehand how often children had eaten any of these foods in the prior 4 weeks, and if so, the last time the child had eaten the food. To reduce the possibility of food neophobia, which can emerge during the toddler period (Cashdan, 1994), the research assistant ate 1 cookie off the plate and stated, "I'm going to have one, too. Mmm, this is really good. You can eat as much as you want." The child was given 10 min of free access to the food before the plate was removed and weighed. Remaining foods were weighed and subtracted from their initial weight to determine the grams consumed during the EAH protocol. Total kcals consumed during the EAH protocol was calculated using manufacturer information on calories per unit weight for each food.

2.3. Covariates

Child sex, race/ethnicity, and level of maternal education, characterized for analysis as "more than high school" and "high school or less", were obtained by maternal report for use as covariates. Child race/ethnicity was categorized as "white, non-Hispanic" vs. "other" for analysis. Child weight and height were measured by trained research assistants certified in standardized measurement techniques and used to calculate body mass index (BMI) and weight status (overweight, defined as BMI ≥ 85% vs. not overweight) using age and sex specific growth charts from the US Centers for Disease Control and Prevention (Kuczmarski & Flegal, 2000).

2.4. Statistical analyses

All analyses were conducted using SAS 9.4 (SAS Institute Inc., Cary, NC). Univariate statistics were used to describe the sample and bivariate analyses were conducted to test for associations between sleep predictors and eating behavior outcomes. Five multivariable regression analyses were conducted to test associations of weeknight sleep duration, weeknight-to-weekend bedtime delay, and sleep quality with each of 5 eating behavior outcomes. Listwise deletion was used for each analysis. All sleep variables were entered into each model. Covariates included child sex, race/ethnicity, and level of maternal education. For all analyses, alpha level for statistical significance was set at 0.05.

3. Results

Characteristics of the sample are shown in Table 1. With regard to demographics, the sample was 52.3% male, 56.0% non-Hispanic white, and 24.6% overweight. Among mothers, 43.1% had attained a high school education or less. With regard to sleep and eating behavior variables, on average, children slept 11.08 h per night on weekdays (SD 1.09), and 11.18 h per night on weekends (SD 1.10). Child bedtimes were an average of 0.40 h, or 24 min, later on weekends compared to weekdays. Children consumed an average of 123.41 kcal (SD 73.64) during the EAH protocol. Total EAH kcal consumed was not associated with the child's prior consumption of any of the EAH foods (all p's $>$ 0.05).

Bivariate analysis results indicated that shorter weeknight sleep duration was associated with more EOE ($r = -0.18$, $p = .04$) and EAH ($r = -0.22$, $p = .02$). Sleep duration was not associated with FR, EF, or SR (all p's $> .05$). Bedtime delay was not associated with any of the eating behavior variables. Poorer sleep quality was associated with more EOE ($r = -0.17$, $p = .04$), and marginally more FR ($r = -0.16$, $p = .054$).

Results of the multivariable linear regression analyses examining associations of sleep variables with each eating behavior variable are shown in Table 2. Results were that shorter weeknight sleep duration was associated with greater EAH kcal consumed ($\beta = -0.22$ (SE 0.09), $p = .02$), indicating that for every 1 SD decrease in sleep duration (about 1.09 h, or 65 min), there was an increase of 0.22 SD in kcal consumed during EAH (about 16 kcal). Sleep duration was unrelated to other eating behavior variables. Bedtime delay was unrelated to all eating behavior variables. Poorer sleep quality was associated with greater EOE, ($\beta = -0.20$ (SE 0.09), $p = .02$), and greater FR, ($\beta = -0.18$ (SE 0.09), $p = .04$), indicating that for every 1 SD decrease in sleep quality, there was an increase of 0.19 SD in EOE and 0.18 SD in FR. Sleep quality was unrelated to other eating behavior variables. Findings were unchanged when adjusting for child sex, race/ethnicity, or mother education level; results are presented adjusted for these covariates. Finally, we conducted an additional post-hoc regression analysis to test whether parent-reported napping (number of hours their child typically napped per day) was associated with any of the eating behavior variables when napping was entered in the model, and found no significant associations.

Table 1
Sample demographic characteristics, sleep and eating behavior descriptives (n = 134).

Variable	M (SD) or N (%)
Child Sex	
Female	64 (47.8%)
Male	70 (52.2%)
Child Race/Ethnicity	
White/Non-Hispanic	75 (56.0%)
Black	33 (24.6%)
Biracial/Other	26 (19.4%)
Child Overweight (BMI ≥ 85%)	31 (24.6%)
Maternal Education	
High school or less	51 (38.1%)
More than high school	83 (61.9%)
Sleep	
Weekday Night Sleep Duration (# hours per night)	11.08 (1.09)
Weekend Night Sleep Duration (# hours per night)	11.18 (1.10)
Weekday Night Bedtime	8:56 pm (56 min)
Weekend Night Bedtime	9:10 pm (2 h 6 min)
Bedtime Delay (hours)	0.40 (0.63)
CSWS Total Sleep Quality	4.30 (0.65)
Eating Behavior	
Observed EAH (kcal)	123.41 (73.64)
CEBQ-T Emotional Overeating	1.74 (0.67)
CEBQ-T Food Responsiveness	2.86 (0.88)
CEBQ-T Enjoyment of Food	4.11 (0.77)
CEBQ-T Satiety Responsiveness	2.89 (0.67)

Note. Bedtime Delay (hours); delay in bedtime on weekend compared to weekday. CSWS Total Sleep Quality: higher score, better quality.

4. Discussion

The current study had four main findings, with some of our hypotheses supported. First, among low-income toddler-aged children, shorter nocturnal sleep duration on weeknights was related to greater observed eating in the absence of hunger. Second, poorer sleep quality was associated with more parent-reported emotional over-eating and more food responsiveness. Third, bedtime delay was unrelated to any of the eating behaviors measured. Finally, no sleep variables were related to enjoyment of food or satiety responsiveness. These results suggest that during early childhood, nocturnal sleep duration and sleep quality may influence obesity risk through specific eating behavior pathways.

Our findings expand limited previous research on sleep and eating behaviors in young children. With regard to sleep duration, we found that shorter sleep duration on weeknights was associated with greater EAH, but not with food responsiveness, enjoyment of food, or satiety responsiveness. It is not clear why the parent-reported eating behaviors were generally unrelated to sleep duration; unlike the current report, prior studies of older, school-aged children found that short nighttime sleep duration was associated with greater external eating (Burt et al., 2014) and food responsiveness (McDonald et al., 2015) as reported by parents. Our sleep duration findings for EAH are consistent with existing work on dietary intake in a large sample of toddlers that found short nocturnal sleep to be associated with greater intake of fat, sugar, and carbohydrates (A. Fisher et al., 2014). EAH results are also consistent with experimental work with both toddler-aged children

Table 2
Adjusted associations between toddler sleep and eating behaviors.

	Emotional Overeating (n = 134)	Food Responsiveness (n = 134)	Enjoyment of Food (n = 134)	Satiety Responsiveness (n = 134)	EAH (n = 112)
Weeknight Sleep Duration	−0.17 (0.09)†	−0.01 (0.09)	0.05 (0.09)	−0.02 (0.09)	−0.22 (0.09)*
Bedtime Delay	0.10 (0.09)	0.01 (0.09)	0.06 (0.09)	−0.09 (0.09)	−0.07 (0.10)
Sleep Quality	−0.20 (0.09)*	−0.18 (0.09)*	0.03 (0.09)	−0.16 (0.09)†	0.01 (0.10)

Note. *p < .05. †p < .10. Standardized beta coefficients from multivariable linear regression models adjusting for child sex, race/ethnicity, and mother education.

(Mullins et al., 2017) and adolescents (Beebe et al., 2013) that has shown increased energy consumption after sleep restriction. Using experimental designs in future work to test whether eating behaviors, and perhaps specifically EAH, may change as a result of sleep restriction, or optimization, in young children may be important in understanding the malleability of such behaviors, with implications for intervention efforts.

We could not identify any published studies of young children that examined sleep in relation to EAH, which we measured objectively and is a unique contribution of the current report. EAH has been characterized as an indicator of poor eating self-regulation, specifically satiety responsiveness (Hughes, Power, O'Connor, & Fisher, 2015), although it has also been suggested that EAH protocols may also index multiple eating behaviors that could predispose children to obesity risk (French et al., 2012; Lansigan et al., 2015). Short nocturnal sleep may shape a child's propensity for EAH, in addition to other factors such as stress, parenting, or early life experience that have also been associated with EAH (Hill et al., 2016; Lansigan et al., 2015; Miller et al., 2018). Insufficient sleep is hypothesized to increase food cravings and dysregulated satiety cues through various neural (Greer, Goldstein, & Walker, 2013) and hormonal (Dashti, Scheer, Jacques, Lamon-Fava, & Ordovás, 2015) pathways, which may lead children to engage in more EAH and thus greater caloric consumption (Lansigan et al., 2015). Data from epidemiological and experimental studies indicate that short nocturnal sleep duration, particularly during the early childhood years is consistently associated with greater obesity during childhood and adolescence (Cappuccio et al., 2008; Fatima et al., 2016; Hart et al., 2011). Thus, EAH may be important to understand and monitor as an early-emerging eating behavior pathway through which short nocturnal sleep may increase risk for excessive weight gain over time.

With regard to sleep parameters beyond duration, we found no associations between any of our assessed eating behaviors and shifted sleep schedule as measured by bedtime delay. This was somewhat surprising because a prior study of toddlers showed that shifted sleep schedules (i.e., later sleep on weekends compared to weekdays) was associated with greater dietary intake (Petrov et al., 2017), and that later bedtimes were associated with increased snacking, among older children (Thivel et al., 2015). Recent work found that more shifted schedules were associated with adiposity indicators (Lee et al., 2018), but this study focused on school-aged children from a community sample in New Zealand. Only one of these studies included low-income toddlers, and the entire sample was obese and the sample size relatively small (n = 51) (Petrov et al., 2017). Furthermore, most of these studies measured dietary intake or adiposity rather than eating behaviors, which could also explain the differences across studies.

Our findings that poorer sleep quality was associated with more emotional over-eating and food responsiveness are generally consistent with prior work, and add to the literature by articulating these associations in a younger sample. In prior work with school-aged children, more self-reported emotional eating was associated with poorer sleep quality as measured by actigraphic estimates of number of wake bouts (Burt et al., 2014). Poorer sleep quality was also associated with more emotional and external eating among undergraduate females (Dweck, Jenkins, & Nolan, 2014), and daytime sleepiness, a likely result of poor sleep quality, was associated with more binge eating among female adolescents (Kelly et al., 2016).

There are many potential mechanisms that may account for the associations we detected between poorer sleep health and child eating behaviors that may promote obesity risk over time. Insufficient sleep may cause physiological and behavioral changes that in turn drive changes in eating behavior (Miller, Lumeng, et al., 2015). In studies of adults, biological changes in appetite-regulating hormones such as leptin and ghrelin have been shown to occur under conditions of short sleep duration (Spiegel, Leproult, & Van Cauter, 1999; Taheri, Lin, Austin, Young, & Mignot, 2004) and fragmented sleep quality (Copinschi, Leproult, & Spiegel, 2014; Gonnissen, Hursel, Rutters, Martens, & Westerterp-Plantenga, 2013). For example, experimental studies have shown that short sleep duration is associated with changes in hormone regulation leading to increases in appetite (Taheri et al., 2004). Adults also increase their energy intake irrespective of hormonal changes, suggesting that behavioral as well as hormonal mechanisms likely drive food intake (St-Onge, 2013). For example, acute sleep restriction has been shown to promote increased overall consumption and preference for snack foods (Hogenkamp et al., 2013) and brain mechanisms related to craving have been hypothesized to underlie such choices (Greer et al., 2013). Although we did not assess these mechanisms in the current study, such changes in response to insufficient sleep may make it difficult for a child to recognize or respond to satiety and also be more drawn to highly-palatable foods, resulting in overconsumption of such foods and risk for weight gain.

Emotion processing, which involves perceiving, appraising, experiencing, and regulating one's emotional responses, is one possible behavioral mechanism that may explain the associations that we found between poor sleep, specifically sleep quality, and emotional overeating. Shorter sleep duration (Berger, Miller, Seifer, Cares, & LeBourgeois, 2012; Miller, Seifer, Crossin, & LeBourgeois, 2015) and poorer sleep quality (Scher, Hall, Zaidman-Zait, & Weinberg, 2010) both impair emotion processing in toddler-aged children, who are just beginning to consolidate their independent emotion regulation skills (Calkins & Dedmon, 2000). Insufficient sleep may reduce young children's emerging capacity to manage emotional responses to stress effectively; children could emotionally overeat as a coping mechanism (Lundahl & Nelson, 2015; Miller et al., 2018), or tantrum over desired food items instead of being able to wait calmly. One study found that difficulties falling asleep were associated with increased anxiety and subsequent emotional eating in school-aged children, providing some evidence for the poor sleep quality-emotion processing difficulties pathway at least in older children (Nguyen-Rodriguez et al., 2010). Future work could examine these pathways among younger children in more detail.

With regard to food responsiveness and sleep quality, children who are tired due to not experiencing restorative sleep may be more distractible and responsive to external food cues. Sleep restriction studies in adults have found increased brain activation in regions associated with attention to food stimuli (Greer et al., 2013; St-Onge et al., 2012), and recent work with adults found that habitual sleep debt was associated with increased craving and brain response to food cues (Katsunuma et al., 2017). If children who experience poor sleep quality are also generally sleep restricted, they may be more likely to have their attention drawn to food cues, particularly tempting foods (McDonald et al., 2015), and this may be a mechanism through which poor sleep quality may increase risk for external eating in response to such cues.

Finally, we found that none of our assessed sleep parameters were associated with parent-reported child enjoyment of food, or with satiety responsiveness. It may be that enjoyment of food and satiety responsiveness are perceived as more trait-like by parents, and less sensitive to contextual cues in comparison to emotional overeating or food responsiveness, the other parent-rated eating behaviors evaluated in the current study. Recent research suggests, for example, that satiety responsiveness (Llewellyn, Trzaskowski, van Jaarsveld, Plomin, & Wardle, 2014; Monnereau, Jansen, Tiemeier, Jaddoe, & Felix, 2017) and some food preferences (Smith et al., 2016) may have genetic underpinnings. If SR and EF are eating behaviors that are more trait-like, then whether or not a child has experienced adequate sleep may not affect these behaviors as much as poor sleep may affect overeating in the presence of snack foods (as in EAH), in response to external food cues (FR), or as a coping mechanism when upset (EOE). Of course, despite evidence for the trait-like nature of eating behaviors, not all of the variation in eating behaviors is accounted for by heritability (Carnell & Wardle, 2008). It will be important to consider in future work how the relative contributions of heritability and environmental factors, such as sleep, may shape eating behaviors (see Schrempft, van Jaarsveld, Fisher, and et al. (2018) for example, in examining trait and environmental contributions to childhood obesity risk in this manner). It has also been noted that insufficient sleep may differentially impact various brain areas and functions (e.g., dopaminergic versus hypothalamic systems (Greer et al., 2013; Krause et al., 2017);), which in turn may drive different eating behaviors, for example food craving and emotional eating in response to changes in stress neurobiology (Sinha, 2018) versus lack of satiety responsiveness due to disrupted hypothalamic pathways (Herrera, Ponomarenko, Korotkova, Burdakov, & Adamantidis, 2017; Nicolaidis, 2006). Results of the current study suggest this could be the case, although future research would be important in order to help clarify these questions.

5. Study strengths and limitations

Strengths of the current study include a diverse sample of younger children than have been studied in most prior work, and both parent-reported and observational measures of child eating behavior. Our sample differs from those studied previously, as it was comprised of low-income toddlers, and was predominantly white/non-Hispanic. For this reason, findings from the current study may not generalize to higher income populations, or other low-income populations with more minority children. We also did not control for other factors that may be associated with the results, such as food insecurity, family chaos, or screen use. Additional limitations were that we assessed sleep variables, and some eating variables, per parent report rather than through objective measures (e.g., actigraphy), which could have led to inaccurate measurement, interpretation of the sleep/wake timing questions (i.e., how a parent may define bedtime vs. when a child actually falls asleep), or artificially high associations due to reporter bias. It has been noted, however, that despite the subjectivity of parent-reported sleep measures, they correlate moderately well with objective measures for children this age (Acebo et al., 2005), particularly when parents are reporting on weekday sleep and when they are reporting on sleep start and end times, versus estimating overall time slept, when calculating sleep duration (Matricciani, 2013). Finally, and importantly, our study was cross-sectional and thus does not speak to causal associations between sleep and eating behavior; it is certainly possible that child eating behavior can influence sleep, instead of vice versa.

6. Conclusions

The current study found that in a sample of toddler-aged children from low-income families, poor sleep health (specifically short duration and poor quality) was associated with eating behaviors that are associated with increased risk for obesity. Sleep and childhood obesity are clearly linked, as shown by numerous studies, and eating behavior may be an important pathway through which the association develops. Children who chronically experience insufficient sleep and engage in obesogenic eating behaviors from early childhood may be at elevated risk for obesity during later childhood and over the lifespan. Promoting sleep health among young children may be a helpful approach to reducing the occurrence of eating behaviors that, over time, could promote obesity risk.

Conflicts of interest

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

Funding source

All phases of this study were supported by the National Institutes of Health (NIH) grant number 1R01HD069179.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2019.01.006.

References

Acebo, C., Sadeh, A., Seifer, R., Tzischinsky, O., Hafer, A., & Carskadon, M. A. (2005). Sleep/wake patterns derived from activity monitoring and maternal report for healthy 1- to 5-year-old children. *Sleep, 28*(12), 1568–1577.

Andersen, L. B., Mølgaard, C., Ejlerskov, K. T., Trolle, E., Michaelsen, K. F., Bro, R., et al. (2015). Development of dietary patterns spanning infancy and toddlerhood: Relation to body size, composition and metabolic risk markers at three years. *AIMS public health, 2*(3), 332–357. https://doi.org/10.3934/publichealth.2015.3.332.

Asta, K., Miller, A. L., Retzloff, L., Rosenblum, K., Kaciroti, N. A., & Lumeng, J. C. (2016). Eating in the absence of hunger and weight gain in low-income toddlers. *Pediatrics, 137*(5), https://doi.org/10.1542/peds.2015-3786.

Bathory, E., & Tomopoulos, S. (2017). Sleep regulation, physiology and development, sleep duration and patterns, and sleep hygiene in infants, toddlers, and preschool-age children. *Current Problems in Pediatric and Adolescent Health Care, 47*(2), 29–42. https://doi.org/10.1016/j.cppeds.2016.12.001.

Beebe, D. W., Simon, S., Summer, S., Hemmer, S., Strotman, D., & Dolan, L. M. (2013). Dietary intake following experimentally restricted sleep in adolescents. *Sleep, 36*(6), 827–834.

Berger, R. H., Miller, A. L., Seifer, R., Cares, S. R., & LeBourgeois, M. K. (2012). Acute sleep restriction effects on emotion responses in 30-to 36-month-old children. *Journal of Sleep Research, 21*(3), 235–246.

Birch, L. L., & Fisher, J. A. (1995). Appetite and eating behavior in children. *Pediatric Clinics of North America, 42*(4), 931–953.

Birch, L. L., Fisher, J. O., & Davison, K. K. (2003). Learning to overeat: Maternal use of restrictive feeding practices promotes girls' eating in the absence of hunger. *American Journal of Clinical Nutrition, 78*(2), 215–220.

Braet, C., & Van Strien, T. (1997). Assessment of emotional, externally induced and restrained eating behaviour in nine to twelve-year-old obese and non-obese children. *Behaviour Research and Therapy, 35*(9), 863–873.

Burt, J., Dube, L., Thibault, L., & Gruber, R. (2014). Sleep and eating in childhood: A potential behavioral mechanism underlying the relationship between poor sleep and obesity. *Sleep Medicine, 15*(1), 71–75. https://doi.org/10.1016/j.sleep.2013.07.015.

Calkins, S. D., & Dedmon, S. E. (2000). Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. *Journal of Abnormal Child Psychology, 28*(2), 103–118.

Cappuccio, F. P., Taggart, F. M., Kandala, N.-B., Currie, A., Peile, E., Stranges, S., et al. (2008). Meta-analysis of short sleep duration and obesity in children and adults. *Sleep, 31*(5), 619–626.

Carnell, S., & Wardle, J. (2007). Measuring behavioural susceptibility to obesity: Validation of the child eating behaviour questionnaire. *Appetite, 48*(1), 104–113. https://doi.org/10.1016/j.appet.2006.07.075.

Carnell, S., & Wardle, J. (2008). Appetite and adiposity in children: Evidence for a behavioral susceptibility theory of obesity. *American Journal of Clinical Nutrition, 88*(1), 22–29. https://doi.org/10.1093/ajcn/88.1.22.

Cashdan, E. (1994). A sensitive period for learning about food. *Human Nature, 5*(3), 279–291.

Chaput, J. P. (2014). Sleep patterns, diet quality and energy balance. *Physiology & Behavior, 134*(Supplement C), 86–91. https://doi.org/10.1016/j.physbeh.2013.09.006.

Chaput, J. P., & St-Onge, M. P. (2014). Increased food intake by insufficient sleep in humans: Are we jumping the gun on the hormonal explanation? *Frontiers in*

Endocrinology, 5, 116. https://doi.org/10.3389/fendo.2014.00116.
Copinschi, G., Leproult, R., & Spiegel, K. (2014). The important role of sleep in metabolism. *Frontiers of Hormone Research, 42*, 59–72. https://doi.org/10.1159/000358858.
Dashti, H. S., Scheer, F. A. J. L., Jacques, P. F., Lamon-Fava, S., & Ordovás, J. M. (2015). Short sleep duration and dietary intake: Epidemiologic evidence, mechanisms, and health implications. *Advances in Nutrition, 6*(6), 648–659. https://doi.org/10.3945/an.115.008623.
Domoff, S. E., Miller, A. L., Kaciroti, N., & Lumeng, J. C. (2015). Validation of the children's eating behaviour questionnaire in a low-income preschool-aged sample in the United States. *Appetite, 95*, 415–420. https://doi.org/10.1016/j.appet.2015.08.002.
Dweck, J. S., Jenkins, S. M., & Nolan, L. J. (2014). The role of emotional eating and stress in the influence of short sleep on food consumption. *Appetite, 72*, 106–113. https://doi.org/10.1016/j.appet.2013.10.001.
El-Sheikh, M., Bagley, E. J., Keiley, M., Elmore-Staton, L., Chen, E., & Buckhalt, J. A. (2013). Economic adversity and children's sleep problems: Multiple indicators and moderation of effects. *Health Psychology, 32*(8), 849–859. https://doi.org/10.1037/a0030413.
Faith, M. S., Carnell, S., & Kral, T. V. E. (2013). Genetics of food intake self-regulation in childhood: Literature review and research opportunities. *Human Heredity, 75*(2–4), 80–89.
Fatima, Y., Doi, S. A. R., & Mamun, A. A. (2016). Sleep quality and obesity in young subjects: A meta-analysis. *Obesity Reviews, 17*(11), 1154–1166. https://doi.org/10.1111/obr.12444.
Fisher, J. O., & Birch, L. L. (1999). Restricting access to foods and children's eating. *Appetite, 32*(3), 405–419. https://doi.org/10.1006/appe.1999.0231.
Fisher, A., McDonald, L., van Jaarsveld, C. H., Llewellyn, C., Fildes, A., Schrempft, S., et al. (2014). Sleep and energy intake in early childhood. *International Journal of Obesity, 38*(7), 926–929. https://doi.org/10.1038/ijo.2014.50.
French, S. A., Epstein, L. H., Jeffery, R. W., Blundell, J. E., & Wardle, J. (2012). Eating behavior dimensions. Associations with energy intake and body weight. A review. *Appetite, 59*(2), 541–549. https://doi.org/10.1016/j.appet.2012.07.001.
Gonnissen, H. K., Hursel, R., Rutters, F., Martens, E. A., & Westerterp-Plantenga, M. S. (2013). Effects of sleep fragmentation on appetite and related hormone concentrations over 24 h in healthy men. *British Journal of Nutrition, 109*(4), 748–756. https://doi.org/10.1017/s0007114512001894.
Gooley, J. J. (2016). How much day-to-day variability in sleep timing is unhealthy? *Sleep, 39*(2), 269–270. https://doi.org/10.5665/sleep.5424.
Greer, S. M., Goldstein, A. N., & Walker, M. P. (2013). The impact of sleep deprivation on food desire in the human brain. *Nature Communications, 4*, 2259.
Hager, E. R., Calamaro, C. J., Bentley, L. M., Hurley, K. M., Wang, Y., & Black, M. M. (2016). Nighttime sleep duration and sleep behaviors among toddlers from low-income families: Associations with obesogenic behaviors and obesity and the role of parenting. *Childhood Obesity, 12*(5), 392–400. https://doi.org/10.1089/chi.2015.0252.
Hart, C. N., Cairns, A., & Jelalian, E. (2011). Sleep and obesity in children and adolescents. *Pediatric Clinics of North America, 58*(3), 715–733. https://doi.org/10.1016/j.pcl.2011.03.007.
He, F., Bixler, E. O., Berg, A., Imamura Kawasawa, Y., Vgontzas, A. N., Fernandez-Mendoza, J., ... Liao, D. (2015). Habitual sleep variability, not sleep duration, is associated with caloric intake in adolescents. *Sleep Medicine, 16*(7), 856–861. https://doi.org/10.1016/j.sleep.2015.03.004.
Herle, M., Fildes, A., van Jaarsveld, C. H., Rijsdijk, F., & Llewellyn, C. H. (2016). Parental reports of infant and child eating behaviors are not affected by their beliefs about their twins' zygosity. *Behavior Genetics, 46*(6), 763–771. https://doi.org/10.1007/s10519-016-9798-y.
Herman, C. P., & Polivy, J. (2008). External cues in the control of food intake in humans: The sensory-normative distinction. *Physiology & Behavior, 94*(5), 722–728. https://doi.org/10.1016/j.physbeh.2008.04.014.
Herrera, C. G., Ponomarenko, A., Korotkova, T., Burdakov, D., & Adamantidis, A. (2017). Sleep & metabolism: The multitasking ability of lateral hypothalamic inhibitory circuitries. *Frontiers in Neuroendocrinology, 44*, 27–34. https://doi.org/10.1016/j.yfrne.2016.11.002.
Hill, S. E., Prokosch, M. L., DelPriore, D. J., Griskevicius, V., & Kramer, A. (2016). Low childhood socioeconomic status promotes eating in the absence of energy need. *Psychological Science, 27*(3), 354–364. https://doi.org/10.1177/0956797615621901.
Hogenkamp, P. S., Nilsson, E., Nilsson, V. C., Chapman, C. D., Vogel, H., Lundberg, L. S., ... Schioth, H. B. (2013). Acute sleep deprivation increases portion size and affects food choice in young men. *Psychoneuroendocrinology, 38*(9), 1668–1674. https://doi.org/10.1016/j.psyneuen.2013.01.012.
Hughes, S. O., Power, T. G., O'Connor, T. M., & Fisher, J. O. (2015). Executive functioning, emotion regulation, eating self-regulation, and weight status in low-income preschool children: How do they relate? *Appetite, 89*, 1–9.
Katsunuma, R., Oba, K., Kitamura, S., Motomura, Y., Terasawa, Y., Nakazaki, K., ... Mishima, K. (2017). Unrecognized sleep loss accumulated in daily life can promote brain hyperreactivity to food cue. *Sleep, 40*(10), https://doi.org/10.1093/sleep/zsx137 zsx137-zsx137.
Kelly, N. R., Shomaker, L. B., Radin, R. M., Thompson, K. A., Cassidy, O. L., Brady, S., ... Yanovski, J. A. (2016). Associations of sleep duration and quality with disinhibited eating behaviors in adolescent girls at-risk for type 2 diabetes. *Eating Behaviors, 22*, 149–155. https://doi.org/10.1016/j.eatbeh.2016.06.019.
Kjeldsen, J. S., Hjorth, M. F., Andersen, R., Michaelsen, K. F., Tetens, I., Astrup, A., ... Sjödin, A. (2013). Short sleep duration and large variability in sleep duration are independently associated with dietary risk factors for obesity in Danish school children. *International Journal of Obesity, 38*, 32. https://doi.org/10.1038/ijo.2013.147.
Krause, A. J., Simon, E. B., Mander, B. A., Greer, S. M., Saletin, J. M., Goldstein-Piekarski, A. N., et al. (2017). The sleep-deprived human brain. *Nature Reviews Neuroscience, 18*, 404. https://doi.org/10.1038/nrn.2017.55.
Kuczmarski, R. J., & Flegal, K. M. (2000). Criteria for definition of overweight in transition: Background and recommendations for the United States. *American Journal of Clinical Nutrition, 72*(5), 1074–1081.
Lansigan, R. K., Emond, J. A., & Gilbert-Diamond, D. (2015). Understanding eating in the absence of hunger among young children: A systematic review of existing studies. *Appetite, 85*, 36–47. https://doi.org/10.1016/j.appet.2014.10.032.
LeBourgeois, M. K., & Harsh, J. R. (2016). Development and psychometric evaluation of the children's sleep-wake scale. *Sleep Health, 2*(3), 198–204. https://doi.org/10.1016/j.sleh.2016.04.001.
Lee, S., Nicholas, C., Leigh, S., Paula, S., James, F., Sally, L., ... Harriet, H. (2018). Sleep and adiposity in preadolescent children: The importance of social jetlag. *Childhood Obesity, 14*(3), 158–164. https://doi.org/10.1089/chi.2017.0272.
Llewellyn, C. H., Trzaskowski, M., van Jaarsveld, C. H. M., Plomin, R., & Wardle, J. (2014). Satiety mechanisms in genetic risk of obesity. *JAMA Pediatr, 168*(4), 338–344. https://doi.org/10.1001/jamapediatrics.2013.4944.
Lowe, M. R., & Butryn, M. L. (2007). Hedonic hunger: A new dimension of appetite? *Physiology & Behavior, 91*(4), 432–439. https://doi.org/10.1016/j.physbeh.2007.04.006.
Lundahl, A., & Nelson, T. D. (2015). Sleep and food intake: A multisystem review of mechanisms in children and adults. *Journal of Health Psychology, 20*(6), 794–805. https://doi.org/10.1177/1359105315573427.
Matricciani, L. (2013). Subjective reports of children's sleep duration: Does the question matter? A literature review. *Sleep Medicine, 14*(4), 303–311. https://doi.org/10.1016/j.sleep.2013.01.002.
McDonald, L., Wardle, J., Llewellyn, C. H., & Fisher, A. (2015). Nighttime sleep duration and hedonic eating in childhood. *International Journal of Obesity, 39*(10), 1463–1466. https://doi.org/10.1038/ijo.2015.132.
Miller, A. L., Gearhardt, A. N., Retzloff, L., Sturza, J., Kaciroti, N., & Lumeng, J. C. (2018). *Early childhood stress and child age predict increases in obesogenic eating from early to mid-childhood Acad Pediatr*.
Miller, A. L., Kaciroti, N., Lebourgeois, M. K., Chen, Y. P., Sturza, J., & Lumeng, J. C. (2014). Sleep timing moderates the concurrent sleep duration-body mass index association in low-income preschool-age children. *Acad Pediatr, 14*(2), 207–213. https://doi.org/10.1016/j.acap.2013.12.003.
Miller, A. L., Lumeng, J. C., & LeBourgeois, M. K. (2015). Sleep patterns and obesity in childhood. *Current Opinion in Endocrinology Diabetes and Obesity, 22*(1), 41–47. https://doi.org/10.1097/med.0000000000000125.
Miller, A. L., Seifer, R., Crossin, R., & LeBourgeois, M. K. (2015). Toddler's self-regulation strategies in a challenge context are nap-dependent. *Journal of Sleep Research, 24*(3), 279–287.
Mindell, J. A., Leichman, E. S., Composto, J., Lee, C., Bhullar, B., & Walters, R. M. (2016). Development of infant and toddler sleep patterns: Real-world data from a mobile application. *Journal of Sleep Research, 25*(5), 508–516. https://doi.org/10.1111/jsr.12414.
Mindell, J. A., & Owens, J. A. (2015). *A clinical guide to pediatric sleep: Diagnosis and management of sleep problems.* Lippincott Williams & Wilkins.
Monnereau, C., Jansen, P. W., Tiemeier, H., Jaddoe, V. W. V., & Felix, J. F. (2017). Influence of genetic variants associated with body mass index on eating behavior in childhood. *Obesity, 25*(4), 765–772. https://doi.org/10.1002/oby.21778.
Mooreville, M., Davey, A., Orloski, A., Hannah, E. L., Mathias, K. C., Birch, L. L., ... Fisher, J. O. (2015). Individual differences in susceptibility to large portion sizes among obese and normal-weight children. *Obesity, 23*(4), 808–814. https://doi.org/10.1002/oby.21014.
Mullins, E. N., Miller, A. L., Cherian, S. S., Lumeng, J. C., Wright, K. P., Jr., Kurth, S., et al. (2017). Acute sleep restriction increases dietary intake in preschool-age children. *Journal of Sleep Research, 26*(1), 48–54. https://doi.org/10.1111/jsr.12450.
Nader, P. R., O'Brien, M., Houts, R., Bradley, R., Belsky, J., Crosnoe, R., ... Human Development Early Child Care Research, N (2006). Identifying risk for obesity in early childhood. *Pediatrics, 118*(3), e594–601. https://doi.org/10.1542/peds.2005-2801.
Nguyen-Rodriguez, S. T., McClain, A. D., & Spruijt-Metz, D. (2010). Anxiety mediates the relationship between sleep onset latency and emotional eating in minority children. *Eating Behaviors, 11*(4), 297–300. https://doi.org/10.1016/j.eatbeh.2010.07.003.
Nicolaidis, S. (2006). Metabolic mechanism of wakefulness (and hunger) and sleep (and satiety): Role of adenosine triphosphate and hypocretin and other peptides. *Metabolism, 55*, S24–S29. https://doi.org/10.1016/j.metabol.2006.07.009.
Pan, L., May, A. L., Wethington, H., Dalenius, K., & Grummer-Strawn, L. M. (2013). Incidence of obesity among young U.S. children living in low-income families, 2008-2011. *Pediatrics, 132*(6), 1006–1013. https://doi.org/10.1542/peds.2013-2145.
Peltz, J. S., Rogge, R. D., Sturge-Apple, M. L., O'Connor, T. G., & Pigeon, W. R. (2016). Reciprocal influences among family processes and toddlers' sleep problems. *Journal of Family Psychology, 30*(6), 720–731. https://doi.org/10.1037/fam0000202.
Petrov, M. E., Vander Wyst, K. B., Whisner, C. M., Jeong, M., Denniston, M., Moramarco, M. W., ... Reifsnider, E. (2017). Relationship of sleep duration and regularity with dietary intake among preschool-aged children with obesity from low-income families. *Journal of Developmental and Behavioral Pediatrics, 38*(2), 120–128. https://doi.org/10.1097/DBP.0000000000000369.
Scher, A., Hall, W. A., Zaidman-Zait, A., & Weinberg, J. (2010). Sleep quality, cortisol levels, and behavioral regulation in toddlers. *Developmental Psychobiology, 52*(1), 44–53.
Schrempft, S., van Jaarsveld, C. M., Fisher, A., et al. (2018). Variation in the heritability of child body mass index by obesogenic home environment. *JAMA Pediatrics, 172*(12), 1153–1160. https://doi.org/10.1001/jamapediatrics.2018.1508.
Schwartz, C., Scholtens, P. A. M. J., Lalanne, A., Weenen, H., & Nicklaus, S. (2011).

Development of healthy eating habits early in life. Review of recent evidence and selected guidelines. *Appetite, 57*(3), 796–807. https://doi.org/10.1016/j.appet.2011.05.316.
Sinha, R. (2018). Role of addiction and stress neurobiology on food intake and obesity. *Biological Psychology, 131*, 5–13. https://doi.org/10.1016/j.biopsycho.2017.05.001.
Smith, A. D., Fildes, A., Cooke, L., Herle, M., Shakeshaft, N., Plomin, R., et al. (2016). Genetic and environmental influences on food preferences in adolescence. *American Journal of Clinical Nutrition, 104*(2), 446–453. https://doi.org/10.3945/ajcn.116.133983.
Spiegel, K., Leproult, R., & Van Cauter, E. (1999). Impact of sleep debt on metabolic and endocrine function. *Lancet, 354*(9188), 1435–1439. https://doi.org/10.1016/s0140-6736(99)01376-8.
St-Onge, M. P. (2013). The role of sleep duration in the regulation of energy balance: Effects on energy intakes and expenditure. *Journal of Clinical Sleep Medicine, 9*(1), 73–80. https://doi.org/10.5664/jcsm.2348.
St-Onge, M. P., McReynolds, A., Trivedi, Z. B., Roberts, A. L., Sy, M., & Hirsch, J. (2012). Sleep restriction leads to increased activation of brain regions sensitive to food stimuli. *American Journal of Clinical Nutrition, 95*(4), 818–824.
Taheri, S., Lin, L., Austin, D., Young, T., & Mignot, E. (2004). Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Medicine, 1*(3), e62. https://doi.org/10.1371/journal.pmed.0010062.
Thellman, K. E., Dmitrieva, J., Miller, A. L., Harsh, J. R., & Lebourgeois, M. K. (2017). Sleep timing is associated with self-reported dietary patterns in 9- to 15-year-olds. *Sleep Health*. https://doi.org/10.1016/j.sleh.2017.05.005.
Thivel, D., Isacco, L., Aucouturier, J., Pereira, B., Lazaar, N., Ratel, S., … Duche, P. (2015). Bedtime and sleep timing but not sleep duration are associated with eating habits in primary school children. *Journal of Developmental and Behavioral Pediatrics, 36*(3), 158–165. https://doi.org/10.1097/DBP.0000000000000131.
Wardle, J., Guthrie, C. A., Sanderson, S., & Rapoport, L. (2001). Development of the children's eating behaviour questionnaire. *Journal of Child Psychology and Psychiatry, 42*(7), 963–970.
Webber, L., Cooke, L., Hill, C., & Wardle, J. (2010). Associations between children's appetitive traits and maternal feeding practices. *Journal of the American Dietetic Association, 110*(11), 1718–1722.
Webber, L., Hill, C., Saxton, J., Van Jaarsveld, C., & Wardle, J. (2009). Eating behaviour and weight in children. *International Journal of Obesity, 33*(1), 21.