Associations of Weekday and Weekend Sleep with Children's Reported Eating in the Absence of Hunger

by

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05/28/2019

ABSTRACT

Associations of Weekday and Weekend Sleep with Children's Reported Eating in the Absence of Hunger

Sarah LeMay Russell, BS, 2019

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Abstract: Sleep duration has been inconsistently associated with poor diet quality and obesity risk in youth, suggesting that average sleep duration may not be the sleep characteristic most linked to adiposity. We hypothesized that variations in weekday and weekend sleep duration would be associated with disinhibited eating behaviors that in turn might be involved in the relationship between sleep and weight. We therefore examined, among healthy, non-treatment seeking youth, the associations of average, weekend, and weekday sleep duration with eating in the absence of hunger (EAH), a disinhibited eating behavior associated with disordered eating and obesity. Sleep was assessed via actigraphy for 14 days. Participants completed a self-report measure of EAH. Adiposity was assessed with dual-energy X-ray absorptiometry. Linear regressions were used to test the associations of sleep duration with EAH. Among 123 participants (8-17y; 52.0% female; 30.9% with overweight), there was no significant association between average weekly sleep and EAH. However, average weekday sleep was negatively linked, and average weekend sleep was positively associated, with EAH

($ps<0.02$). Weekend catch-up sleep was thus positively associated with EAH ($p<0.01$). Findings indicate that shorter weekday sleep and greater weekend catch-up sleep are associated with EAH, which may place youth at risk for the development of excess weight gain over time. Prospective studies are needed to determine whether EAH plays a role in the development of adverse weight outcomes.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: Introduction

OBESITY

In the United States, over one-third of the pediatric population currently has overweight and nearly 20% have obesity (16; 19). Youth with a body mass index [kg/m^2; BMI; (52)] at or above the 95th percentile for age and sex are considered to have obesity (51). The etiology of childhood obesity is complex involving an interaction of genetic, environmental, and behavioral components (36). Childhood obesity is associated with numerous physiological and psychosocial consequences including high blood pressure, asthma, high cholesterol, greater bullying, poorer self-esteem, and depression (4; 17; 57). Obesity in youth has also been shown to be predictive of adult obesity, increased risk for lifetime cardiovascular disease, stroke, type 2 diabetes, poorer self-esteem, and depression (57; 58; 70). Consequently, medical costs for individuals with obesity are thirty percent greater than annual medical care expenses for individuals without obesity (80). Further, while literature supports that a modest weight loss is associated with significant health improvements across domains, effective long-term treatment of obesity is limited (56).

Given the negative long-term health impacts of obesity (56; 58; 70), elucidation of early, modifiable risk factors for excess weight gain is necessary to improve the effectiveness of obesity prevention and treatment in children and adolescents. Two such factors that have been associated with excess weight and adiposity among youth are insufficient sleep (12; 49) and disinhibited eating behaviors (76).

SLEEP AND OBESITY

Sleep plays an important role in healthy child and adolescent healthy development. For example, sufficient sleep is associated with support and maintenance of brain and skeletal development, emotional regulation, adiposity accumulation, and cardiovascular health (10). Indeed, data support a link between more hours of nightly sleep and decreased adiposity, better cardiometabolic health, better emotion regulation, and higher academic achievement among youth (10). Throughout childhood, sleep is developmentally patterned such that as children grow and mature, their sleep needs vary in a predictable manner (43). Most research indicates that younger children require more sleep while older children and adolescents need less (43). As such, the American Academy of Sleep Medicine recommends the following guidelines for sleep for every 24 hours by age: infants (4 months to 12 months) should sleep 12-16 hours including naps, children ages 1-2 years should sleep 11-14 hours including naps, children ages 3-5 years should sleep 10-13 hours including naps, children 6-12 years should sleep 9-12 hours, and adolescents age 13-18 should sleep 8-10 hours (55). Beyond the change in sleep requirement throughout childhood and adolescence that is developmentally normative, data indicate that children's sleep duration across all ages is shorter than it was in the past (44). Overall sleep among youth in the last 100 years has decreased by approximately one hour per night. Poor sleep quality and later bedtimes are both becoming more common among youth (30; 44; 66). While the drivers of these decrements are not entirely clear, data indicate that increased screen time and increased educational and extra-curricular demands may be contributing (18; 30).

Reduced sleep may be linked to obesity in childhood and adolescence. Indeed, studies generally support a relationship between fewer than eight reported hours of nightly sleep and greater risk for developing higher BMI, overweight and obesity (2; 11; 26; 49; 64; 69; 73). However, the data are not entirely consistent (26; 40). For example, Jarrin et al. (26) reported that when accounting for relevant covariates (such as sex, age, physical activity, screen time, pubertal status, and parental education), the negative association between fewer hours of sleep and obesity was attenuated and no longer significant. Likewise, another study found no statistically significant prospective relationship between decrease in self-reported sleep and increase in BMI or percent body fat in either adolescent boys or girls (40). Together, these data highlight the need to better understand the link between sleep and risk for overweight and obesity (Figure 2).

FACETS OF SLEEP

The mixed results between sleep and body weight suggest there may be other factors impacting or contributing to the association and highlight a need to understand better the mechanisms linking poor sleep and risk for overweight and obesity. One possible factor relates to the fact that there are many dimensions of sleep beyond the average number of hours spent in bed (26) (for list of sleep constructs and definitions, see Table 1). For example, poor sleep quality and evening chronotype (preference for delayed sleep) are also associated with excess weight in youth (2; 6; 53; 77). Additionally, specific characteristics of sleep such as bedtime, bedtime shift (going to bed at different times on weekdays versus weekends), and weekend versus weekday sleep duration have been associated with greater severity of overweight, greater screen time, and increased intake of sugar-sweetened beverages (25; 31; 39; 48; 78). Again, data are mixed. For example, Wing et al. found that self-reported weekend and holiday “catch up” sleep is associated with a lower risk of overweight and obesity in children (79). Conversely, another study reported that greater weekend mid-sleep shift, or shifting bedtimes on the weekend leading to circadian rhythm misalignment, was associated with decreased medial prefrontal cortex and striatal reactivity to reward, suggesting decreased regulatory responses and increased reward sensitivity (22). It is possible that individuals experiencing a decreased ability to engage in self-regulation could lead to disinhibited eating behaviors as other studies have shown poorer inhibitory control associated with greater eating in response to negative affective states and in response to external food cues (27). Supporting this notion, another study reported that later weekend bedtime compared to weekday bedtime was associated with decreased eating-related self-efficacy such that participants had greater self-reported difficulty regulating negative affect in order to make healthy food choices (e.g. consuming more whole grains and fruits and vegetables than saturated fats and sugary beverages) (25). These results underscore the need to investigate not only average sleep duration, but also specific sleep characteristics such as weekday versus weekend sleep and weekend catch-up sleep, with subsequent reward-based disinhibited eating behaviors known to be associated with obesity (38) (Figure 3).

Facets of Sleep and Eating in the Absence of Hunger (EAH)

Disinhibited eating behaviors are characterized by eating involving a lack of healthy restraint (68). These include, but are not limited to, emotional eating, loss of control eating, binge eating, and eating in the absence of hunger. Such behaviors are believed to be driven by decreased inhibitory control (29). Specific disinhibited eating behaviors, such as loss of control eating and binge eating, have been associated with greater adiposity as well as predictive of the development overweight and obesity in youth (13; 71; 72; 74; 76).

Eating in the absence of hunger (EAH) is one disinhibited eating pattern that may play a role in obesity risk. EAH is characterized by eating when not hungry or past satiation in response to fatigue, negative affect, and when cued by external circumstances (28; 75). Among children, EAH appears to increase with age (14; 15) and cross-sectional data have shown the behavior (whether measured in the laboratory or by self-report) is positively correlated with fat mass and BMIz (28). Yet, prospectively, EAH has not been shown to predict increases in BMI, BMIz or fat mass over a 1-year period among youth (7; 14; 28). Nevertheless, studies have shown that overweight and obesity track with EAH such that children with overweight and obesity have higher levels of EAH than their counterparts without the behavior, and this relationship persists over time (38). While EAH has been studied considerably in pediatric populations, these findings highlight that its clinical significance is still not well understood.

Taken together, the extant studies suggest that both sleep behavior and EAH have associations with weight status, however data are mixed and the mechanisms are largely unknown. Further data indicate that facets of sleep, such as weekday versus weekend sleep and weekend catch-up sleep, are associated with reward-based behavior problems, decreased eating-related cognitive control, and poorer dietary intake (23-25; 27), which could lead to disinhibited eating behavior such as EAH. Therefore, it is possible that sleep duration or other sleep characteristics may promote EAH and contribute to excess weight (4).

THE PRESENT STUDY

An important first step in understanding this potential relationship involves examining the association between overall average weekly sleep duration and weekday versus weekend sleep with EAH. Therefore, we examined the association of average weekly sleep duration across all seven nights, weekday versus weekend sleep, and weekend catch-up sleep using an objective measure of sleep behavior with self-reported EAH among a sample of non-treatment seeking youth. We hypothesized that individuals with less average weekly sleep and fewer hours of weekday sleep (and more need for weekend catch-up sleep) would have greater fat mass. Further, we expected individuals with less average weekly sleep and fewer hours of weekday sleep (and therefore more need for weekend catch-up sleep) would report greater EAH. Finally, in an exploratory analysis, we hypothesized that EAH would mediate the relationship between facets of sleep and fat mass such that fewer hours of average weekly or weekday sleep and greater catch-up sleep would lead to greater EAH and greater fat mass.

AIMS AND HYPOTHESES

Aim 1: Examine the association between facets of sleep (average weekly, weekday, weekend, and weekend catch up sleep) and EAH with fat mass.

Hypothesis 1a: Fewer hours of average weekly sleep, weekday sleep, weekend sleep and more hours of weekend catch-up sleep will each be associated with greater fat mass.

Hypothesis 2a: Greater EAH will be associated with greater fat mass.

Aim 2: Examine the association between facets of sleep (average weekly, weekday, weekend, and weekend catch up sleep) with EAH.

Hypothesis 2: Fewer hours of average weekly sleep, weekday sleep, weekend sleep and more hours of weekend catch-up sleep will each be associated with greater EAH.

Exploratory Aim: Test whether EAH mediates the relationship between facets of sleep (average weekly, weekday, weekend, and weekend catch up sleep) and fat mass.

Hypothesis 3: EAH will mediate the relationship between each facet of sleep and fat mass such that fewer hours of average weekly sleep, weekday, weekend, and more hours of weekend catch-up sleep will lead to greater EAH and be linked with greater fat mass.

Chapter 2: Methods

RESEARCH DESIGN

A correlational design was used to examine sleep and EAH in a convenience sample of healthy youth. Participants were enrolled in a six-year longitudinal observational study.

PARTICIPANTS AND RECRUITMENT

Participants were healthy, non-treatment-seeking male and female youth (8-17 years old) recruited to participate in the Children's Growth and Behavior Study (Clinical Trials Identifier: NCT02390765). This study was designed to understand eating behaviors in relation to body weight in children as they develop. All participants were in relatively good health, with the exception of minor, well-controlled ailments. Exclusion criteria included: 1) history of major illness, brain injury or pregnancy; 2) use of medication known to affect body weight or caloric intake; 3) significant and recent weight loss (>5%

body weight); 4) BMI kg/m^2 < 5^{th} percentile; 5) current and regular use of illicit substances; 6) presence of a full-threshold psychiatric disorder; and 7) full scale intelligence quotient score ≤ 70 (45).

Participants were recruited through mailings to parents in the greater Washington DC area and flyers posted at the National Institutes of Health (NIH) in Bethesda, Maryland, and local public facilities (e.g. libraries). Additionally, flyers were distributed through local primary and secondary schools and parent listservs.

Study Procedures

Participants were seen at the outpatient Pediatric Clinic at the National Institutes of Health Hatfield Clinical Research Center. In order to evaluate overall health, children were examined by a physician or nurse practitioner. Following an overnight fast, height (cm) was measured in triplicate to the nearest millimeter by a calibrated stadiometer. Weight (kg) was also measured in triplicate using a calibrated scale after participants removed heavy clothing and shoes. BMI percentiles were calculated according to the Centers of Disease Control and Prevention growth standards, which adjust for sex and age (35). Overweight was defined as having a BMI between the 85^{th} - $<95^{th}$ percentiles, and obesity defined as having a BMI above the $\geq 95^{th}$ percentile. Dual-energy X-ray absorptiometry (DEXA; iDEXA system, GE Healthcare, Madison, WI) was used to measure body composition, including adiposity (fat mass). As detailed below, participants completed questionnaires to assess eating in the absence of hunger and depressive symptoms and were given wrist-mounted triaxial accelerometers to wear for a fourteen-day period.

MEASURES

Sleep

Wrist-mounted triaxial accelerometers (ActiGraph LLC, Pensacola, FL, model GT3X) were configured [based on height (cm), weight (kg), race, age, and handedness] to collect information in 60 second-epochs. Participants were asked to wear accelerometers throughout 14 days and nights. They were also asked to complete sleep diaries during this period as well as to make notes of anything that might have significantly influenced their sleep (e.g., staying over at a friend's house). To be included in analyses, participants were required to have valid data from ≥ 3 weekday nights of sleep and ≥ 1 weekend night of sleep. As described in Mi et al, 2019 (48), sleep data were downloaded from devices using Actilife software version 6.13.3 (Agrigraph, Pensacola, FL). The Sedeh sleep detection algorithm, which has been previously validated for adolescents (61), was applied to data in order to detect periods of sleep. Data were also visually inspected and confirmed by cross-referencing sleep diaries. In-bed time was defined as the first of a five-minute period in which activity counts were all zero and the subsequent activity counts were determined to be sleep by the Sedeh algorithm. Wake up time was similarly defined as the first of a five-minute period in which activity counts were above zero and the subsequent activity was determined by the Sedeh algorithm to be awake time. Average nightly sleep (min/night; total time in bed minus sleep onset minus minutes of wakeful activity after sleep onset) was also calculated. A nap was considered part of total nightly sleep if occurred less than 60 minutes from the wake-up time. If naps occurred outside of sleep time, they were calculated as a separate variable not included in analyses. Average weekly sleep duration (hour/night) of all nights (Sunday-Saturday) was calculated. Additionally, the average duration (hour/night) of weeknights (Sunday-Thursday), and weekend nights (Friday-Saturday) were calculated. Finally, weekend catch-up sleep was calculated by subtracting average weekday sleep from average weekend sleep (hour/night). Actigraphy has been previously validated for objective sleep duration measurement, with an overall agreement rate of >90% when compared to polysomnography (PSG) in normal adult subjects (37; 60). In a study done in healthy youth (5-12y), actigraphy also demonstrated acceptable validity for average weekly sleep when compared to PSG (for list of sleep constructs and definitions, see Table 1) (47).

Eating in the Absence of Hunger (EAH)

EAH was measured with the Eating in the Absence of Hunger Questionnaire for Children and Adolescents [EAH-C (75)]. Participants were asked to complete the questionnaire consisting of 14 questions which assess: eating when not hungry or past satiation in response to external cues (e.g. "how often do you keep eating because others are still eating?"), fatigue or boredom (e.g. "how often do you keep eating because you are feeling bored"), or negative affect (e.g. "how often do you keep eating because you are feeling anxious or nervous?"). Items are rated using a 5-point Likert scale ranging from 0= "never" to 4= "always." The average total score of all items on the EAH-C was used with higher scores indicating greater EAH. The EAH-C has demonstrated good psychometric properties including convergent validity and temporal stability for all scales, and good internal consistency within this sample [Cronbach's α=0.85 (75)].

Depressive Symptoms

Depressive symptoms were assessed using the Children's Depression Inventory (32-34). This measure asks respondents to indicate to what degree they are experiencing depressive symptoms in the last two weeks. Each item response ranges in order from 0-2 and total scores range between 0 and 52. Higher total scores indicate more depressive symptoms. The Children's Depression Inventory is a commonly used measure with very good validity (62), and good reliability within the present sample (Cronbach's α=0.86).

HUMAN SUBJECTS PROTECTION

The Eunice Kennedy Shriver National Institute of Child Health and Human Development, NIH and USUHS institutional review board approvals were obtained for this study. Parents/caregivers signed informed conset and minors signed informed asset.

DATA ANALYTIC APPROACH

SPSS for Windows version 25 (SPSS, INC., Chicago, IL) was used to conduct all analyses. Data were screened for normality using skewness and kurtosis values. Neither EAH-C total scores nor depressive symptom total scores were normally distributed; therefore, scores were log base 10 transformed to achieve normality. For all analyses, $p<0.05$ was considered significant.

Aim 1: Fat Mass

Four multiple linear regressions were conducted to examine the associations of: 1) average weekly sleep (hr/night), 2) average weekday and weekend sleep time (entered into the same model; hr/night), 3) weekend catch-up sleep (hr/night), and 4) EAH-C total score in relation to fat mass (kg). Given the links of depressive symptoms with sleep in children (59; 82), depressive symptoms score was considered as a covariate for all models. Additionally, all models were adjusted for age, sex (0=male, 1=female), race (1=Non-Hispanic white, 0=other), and height (cm).

Aim 2: EAH

Three multiple linear regressions were conducted to examine the associations of 1) average weekly sleep (hr/night), 2) average weekday and weekend sleep time (entered into the same model; hr/night), and 3) weekend catch-up sleep (hr/night) with EAH-C total score. Given the links of depressive symptoms with sleep in children (59; 81), for all models, depressive symptoms score was considered as a covariate. Additionally, all models were adjusted for age, sex (0=male, 1=female), race (1=Non-Hispanic White, 0=other), height (cm), and total fat mass (kg).

Given data showing that sleep differs by age group (10; 43; 55), secondary analyses were conducted in order to examine if patterns of results differed by age group (child= <12 years; adolescent= ≥12 years). Though sample sizes were not adequately powered for statistical interpretation, patterns of results did not differ from the total sample, therefore all subsequent results are represented with the age groups combined.

Exploratory Aim: Mediation Model

The Preacher and Hayes indirect Mediation macro for SPSS (65) was used to conduct an exploratory mediation model. The model examined whether eating in the absence of hunger mediated the relationship between facets of sleep and fat mass when adjusting for age, sex (0=male, 1=female), race (1=Non-Hispanic White, 0=other), height (cm), and depressive symptoms (total score). 95 % confidence intervals for indirect effects was estimated using bootstrapping with 1000 resamples.

Chapter 3: Results

One-hundred-forty-eight children participated. Twelve youths were excluded from analyses due to non-compliance with actigraphy-wearing protocol and ten were excluded due to technological issues downloading their actigraphy data. Student's t-tests revealed that participants with missing actigraphy data did not differ significantly from the included sample with regard to race, sex, age, or BMIz (*p*s>.22). One participant was excluded for missing Children Depression Inventory data, and two participants were excluded due to missing DEXA data. The total sample included one-hundred-twenty-three participants.

SAMPLE CHARACTERISTICS

Youth ranged in age from 8 to 17 years, with a mean of 12.7 years (*SD*=2.6). Slightly over half of the sample were female (52.0%). Less than half of the participants were Non-Hispanic White (43.9 %), and the sample included a wide range fat mass (*M*=15.4, *SD*=9.0, range= 4.0 – 54 kg). Average weekly sleep was 7.3 (*SD*=0.7 hr/night), weekday sleep was 7.2 (*SD*= 0.8 hr/night), weekend sleep was 7.5 (*SD*=1.0 hr/night), and weekend catch-up sleep was 0.3 ± 1.0 hr/night (Table 2).

RESULTS FOR AIM 1: FAT MASS

Adjusting for age, sex, height, race, and depressive symptoms, none of the facets of sleep [average weekly $F(6,116)=3.76$, $\beta=-0.07$, $p=0.42$, $R^2=0.16$; weekday

F(7,115)=3.76, β=0.001 p=0.99, R^2=0.17; weekend F(7,115)=3.79, β=-0.12, p=0.22, R^2=0.18, or weekend catch-up F(6,116)=3.79, β=-0.08, p=0.38, R^2=0.16] were significantly associated with fat mass. Moreover, EAH-C total score was not significantly associated with fat mass [F (6,116)=3.74, β=-0.06, p=0.47, R^2=0.16].

RESULTS FOR AIM 2: EAH

Adjusting for covariates, average weekly sleep duration (hr/night) was not significantly associated with EAH-C total score [F(7,115)=1.57, $\boldsymbol{\beta}$ =-0.09, p=0.37, R^2=0.09, Figure 5A]. Weekday average sleep time (hr/night) was inversely associated with EAH-C total score [F(8,114)=2.46, $\boldsymbol{\beta}$=-0.25, p=0.01, R^2=0.15; Figure 5B] such that participants with greater weekday sleep reported lower EAH. Weekend average sleep time (hr/night) was positively associated with EAH-C total score [F(8,114)=2.46, $\boldsymbol{\beta}$=0.23, p=0.02, R^2=.15; Figure 5C] such that participants with more weekend sleep reported greater EAH. Finally, weekend catch-up sleep (hr/night) was positively associated with EAH-C total score [F(7,115)=2.79, $\boldsymbol{\beta}$=0.26, p=0.004, R^2=0.15, Figure 5D] such that individuals with greater weekend catch-up sleep reported greater EAH.

RESULTS FOR EXPLORATORY AIM: MEDIATION MODEL

Adjusting for covariates, EAH did not mediate the relationship between any facet of sleep (average weekly, weekday, weekend, weekend catch-up) and fat mass (95% CI: -0.002 to 0.01; 95% CI: -0.006 to 0.01; 95% CI: -0.01 to 0.004; 95% CI: -0.01 to 0.005), respectively (Figure 1).

Chapter 4: Discussion

SUMMARY AND INTERPRETATION OF STUDY FINDINGS

Using actigraphy, which yielded an objective measure of sleep duration, we found no association between average weekly sleep duration and self-reported eating in the absence of hunger (EAH). However, when sleep duration was examined separately for weekday and weekend days, significant associations emerged such that weekday sleep was negatively associated with EAH and weekend sleep and weekend catch-up sleep were positively associated with EAH.

Contrary to our hypothesis, there was no significant association between average weekday sleep and EAH. It is possible that examining sleep as a continuous variable rather than categorically by sufficiency attenuated the strength of this association. Indeed, previous literature often has categorized youth sleep duration into "inadequate" or "adequate" when examining it in relation to weight outcomes (12). Among adults, studies suggest that sleeping too little (less than 8 hours per night) or too much (more than eleven hours per night) sleep may be more robustly associated with eating behaviors and obesity risk than average sleep duration alone (9; 42; 54). However, given the lack of consensus on specified hours of nightly sleep recommended for certain age ranges (12), the present study analyzed the sleep data continuously rather than categorized by sleep sufficiency.

Notably, both weekday and weekend sleep were significantly associated with EAH. More specifically, EAH was inversely associated with weekday sleep, but positively associated with weekend sleep and weekend catch-up sleep. These findings highlight the potential importance of sleep variability. A study by He et al. (24) made use of objective measures of sleep and found that habitual sleep variability (intra-subject standard deviation of average sleep duration) was significantly associated with abdominal adiposity among adolescents. Notably, however, there was no significant association between total average sleep duration and abdominal adiposity. Such findings are consistent with other reports indicating that sleep variability may be associated with eating behaviors and excess weight over and above sleep duration alone (23-25; 31; 78). Our results complement and build on this literature in that differences in sleep duration between weekday and weekend may have unique associations with disinhibited eating behaviors.

Similarly, our findings indicated that children with greater weekend catch-up sleep reported greater EAH. This supports previous literature, which suggests that weekend catch-up sleep may be uniquely associated with reward-based disinhibited behaviors due to circadian rhythm misalignment (79). While there are no studies to date examining the link between circadian rhythm shift and eating behaviors among youth, a recent experimental study found that individuals who work night shifts are more likely to choose a high-fat breakfast option than individuals who work regular hours (8). These findings highlight the potential impact of circadian rhythm shift not only on disinhibition, but also on dietary intake. Data further suggest that sleep restriction and circadian misalignment are associated with decreased concentrations of leptin, an appetite hormone important for satiety, and with increased concentrations of ghrelin, an appetite hormone linked to feelings of hunger (5; 20; 46; 50; 63). It is possible that youth experiencing a shift in their biological circadian rhythm by engaging in weekend catch-up sleep may have decreased levels of leptin and increased levels of ghrelin resulting in increased eating behaviors. Future research is warranted to assess the impact of weekday versus weekend sleep, weekend catch-up sleep, and circadian misalignment on these hormones.

We did not find a significant association between any sleep variable or EAH with fat mass. Previous literature is mixed regarding the association of sleep and EAH with adiposity (20; 24; 29; 31; 38). Though neither sleep nor EAH was associated with fat mass, the significant association of weekend and weekday sleep with EAH may highlight an important risk factor for the development of excess weight gain over time. In exploratory analyses, EAH also did not significantly mediate the relationship between any facet of sleep and fat mass. This may be due to the small sample size as well as the cross-sectional nature of the data. Longitudinal data from large samples are needed to investigate these relationships further.

STUDY STRENGTHS

Study strengths include the use of actigraphy to analyze participants' sleep, which provides an objective measure of a difficult variable to quantify by self-report Additionally, our study included a racially and ethnically diverse sample of healthy youth with a broad range of ages and weights. Finally, we utilized a widely used self-report measure of EAH (75).

STUDY LIMITATIONS

Limitations of this study include use of observational cross-sectional data, therefore no mechanistic or causal conclusions can be drawn from findings. An additional limitation is that our sample was not large enough to examine the variability of sleep needs across development (43). Further, our sample had a relatively low mean duration of average weekly sleep. According to American Academy of sleep recommendations, youth in our sample should be getting 8-12 hours of sleep nightly in order to promote overall health (55). Interestingly, there are very few objectively measured data to support these recommendations and most studies have relied on parent and self-report measures (10; 49). As such, future cross-sectional and longitudinal studies using objective measures of sleep are needed to better fully understand the amount of sleep necessary for optimal health among youth. Finally, given the nature of the EAH-C as a self-report measure, it may not reflect actual energy intake (41; 67); however, the measure is positively associated with daily energy intake among obesity-prone youth (41) and therefore may highlight a disinhibited eating behavior that places youth at risk for excess weight. Future studies should investigate sleep variability in relation to eating in the absence of hunger in the laboratory.

CONCLUSION

In conclusion, this study builds on previous literature to suggest that sleep characteristics such as weekday versus weekend sleep and weekend catch-up sleep may be associated with higher self-reported disinhibited eating behavior (25; 31; 78). Prospective data are needed to determine if this association contributes to the relationship between sleep and excess weight gain risk, as eating in the absence of hunger may be a modifiable target for reducing the high rates of pediatric obesity.

Table 1. Definitions of Sleep Constructs

Construct	Definition
Bedtime	The time one falls asleep defined as the first minute of a 5-minute period of no actigraphy-detected activity (48).
Chronotype	Subjectively reported preference for time of day waking and activity (typically more morning or more evening) (2).
Circadian rhythm misalignment	Sleep and wake cycles which are not appropriately related to the biological night (3).
In bed time	The amount of time one lies in bed (48).
Sleep quality	Subjectively reported number of awakenings through the night, experienced tiredness after waking and throughout the day, and experienced restfulness of sleep (21).
Weekday sleep	Average sleep Sunday night through Thursday nights (39; 48).
Weekend bedtime shift	Remaining awake later on weekends versus weekdays (25).
Weekend catch-up sleep	The difference between weekend sleep and weekday sleep [i.e. average weekend sleep (Friday-Saturday nights)-average weekday sleep (Sunday-Thursday nights)] (39).
Weekend sleep	Average sleep across Friday and Saturday nights (39; 48).
Weekend waketime shift	Sleeping later on weekends versus weekdays (1; 25)

Table 2. Sample Characteristics

Characteristics[a]	Sample *with* Overweight (*N*=38)	Sample *without* Overweight (*N*= 85)	Total Sample (*N*=123)	Total Sample Range
Age (years)	12.4 ± 2.5	12.9 ± 2.6	12.7 ± 2.6	8.0 − 17.9
Sex (% female)	58	49	52.0	
Non-Hispanic White (%)	31.6	49.4	43.9	
Fat Mass (kg)	24.9 ± 9.4*	11.2 ± 4.4*	15.4 ± 9.0	4.0 − 54
Overweight (percentile ≥ 85th %ile, %)			30.9	
Average Weekly Sleep Duration (hr/night)	7.1 ± 0.8	7.3 ± 0.7	7.3 ± 0.7	4.9 − 8.8
Weekday Sleep Duration (hr/night)	7.0 ± 0.8	7.2 ± 0.8	7.2 ± 0.8	4.6 − 8.7
Weekend Sleep Duration (hr/night)	7.3 ± 1.0	7.6 ± 1.0	7.5 ± 1.0	5.3 – 9.6
Catch-Up Sleep Duration (hr/night)	0.2 ± 0.9	0.3 ± 1.0	0.3 ± 1.0	-1.5 – 4.5
Eating in the Absence of Hunger-Child Report	1.1 ± 0.5	1.1 ± 0.5	1.1 ± 0.5	0.5 – 3.0

[a]Values presented are mean ± standard deviation, unless otherwise noted as percentage. Mean values were significantly different between sample with overweight and sample without overweight for fat mass; *p<0.05.

Table 3. Results of Mediation Model

Mediation: (95% CIs)	EAH-C Total Score
Average Weekly Sleep	-0.002 to 0.01
Weekday Sleep	-0.006 to 0.01
Weekend Sleep	-0.01 to 0.004
Weekend Catch-up Sleep	-0.01 to 0.005

Values presenetd are for 95% confidence intervals of the indirect effect (a*b path)

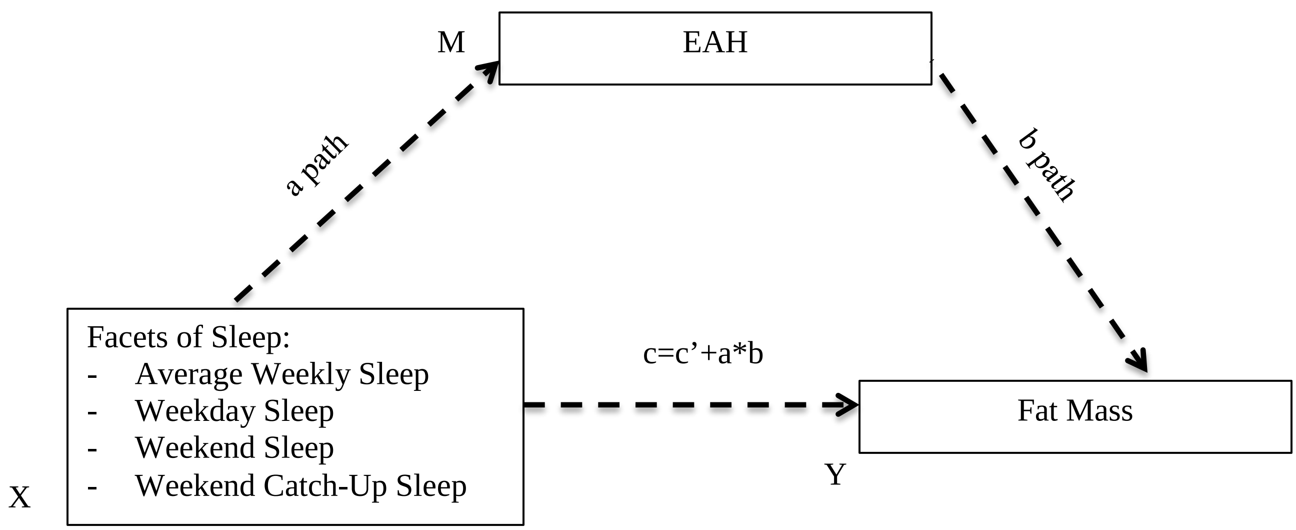

Figure 1. Indirect Mediation Model

Figure 2. The poorly understood relationship between sleep and risk for overweight/obesity (BMIz) among youth

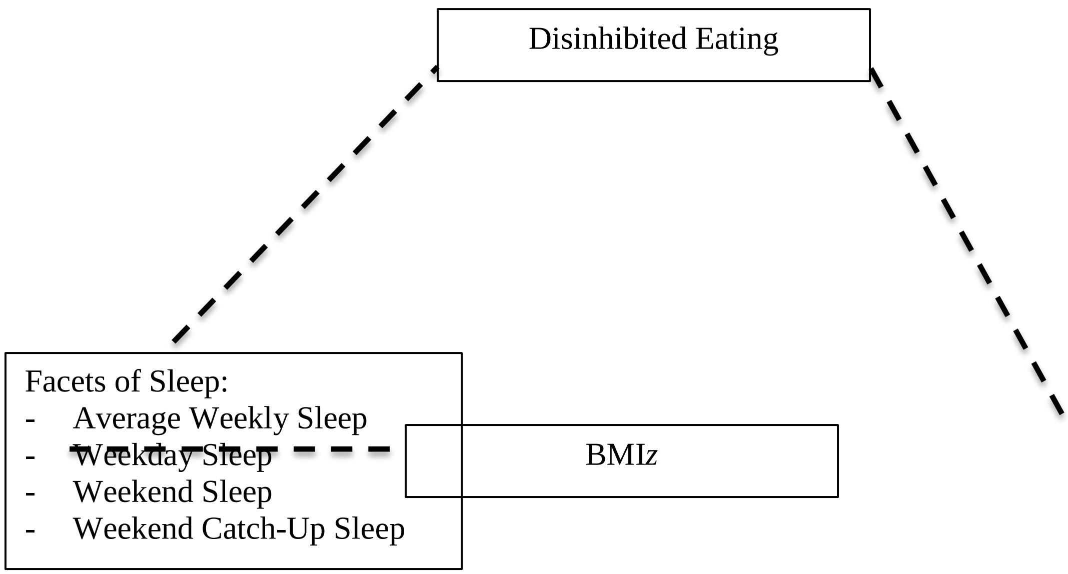

Figure 3. Conceptual model of the link between facets of sleep, disinhibited eating behaviors, and risk for overweight/obesity (BMIz) among youth

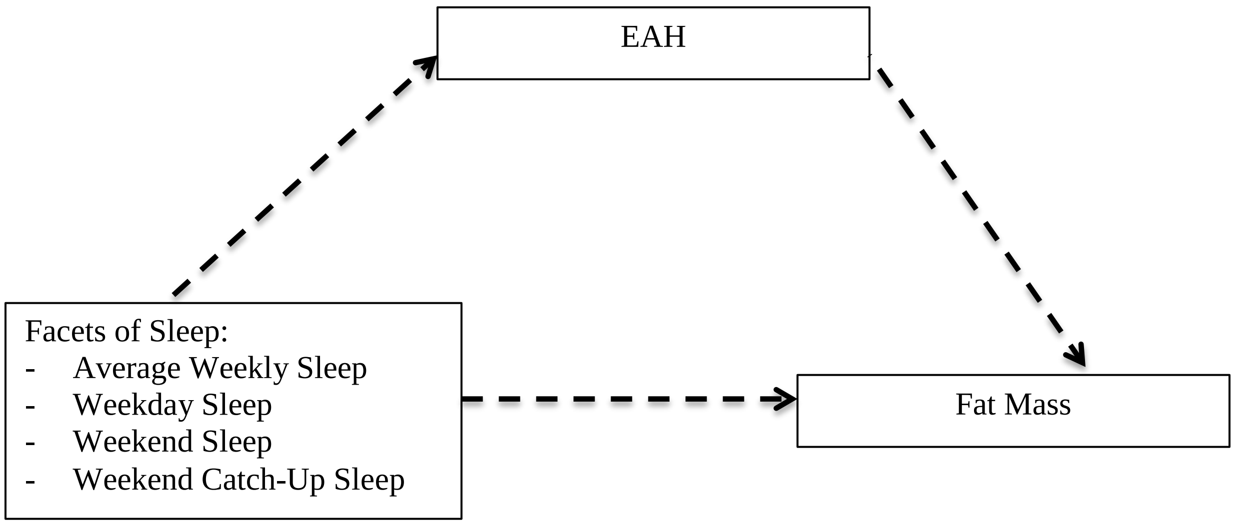

Figure 4. Conceptual model of the link between facets of sleep, eating in the absence of hunger (EAH) and adiposity in youth.

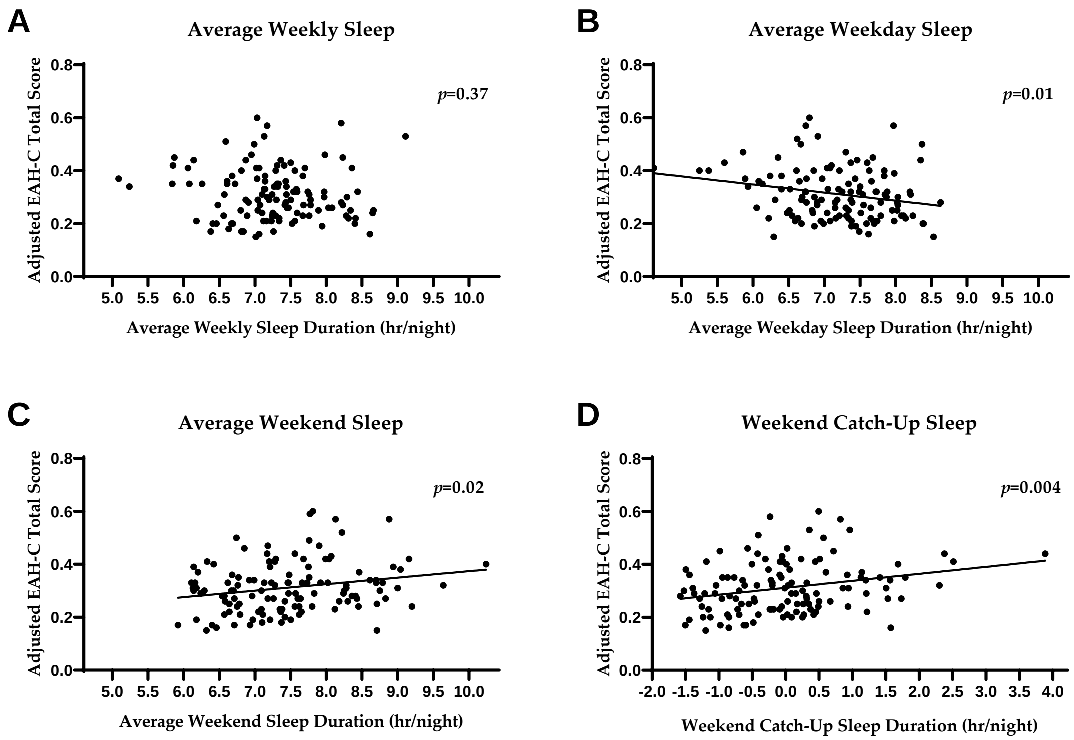

Figure 5: Associations between sleep and total score of the eating in the absence of hunger for children (EAH-C) questionnaire.

There was no association between average weekly sleep and EAH-C total score (*p*=0.37; Figure 5A). There was a significant inverse association between EAH-C total score and average weekday sleep (*p*=0.01; Figure 5B), and a significant positive association between average weekend sleep and EAH-C total score (*p*=0.02, Figure 5C). There was a significant positive association between EAH-C total score and weekend catch-up sleep (*p*=0.004, Figure 5D). All analyses adjusted for age, sex (0=male, 1=female) race (1=Non-Hispanic White, 0= other), height (centimeters), and total fat mass (kilograms), and depressive symptoms.

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