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Sleep Patterns and Quality Are Associated with Severity of Obesity and Weight-Related Behaviors in Adolescents with Overweight and Obesity

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Abstract

Background: Inadequate sleep duration, sleep patterns, and sleep quality have been associated with metabolic, circadian, and behavioral changes that promote obesity. Adolescence is a period during which sleep habits change to include less sleep, later bedtimes, and greater bedtime shift (*e.g.*, difference between weekend and weekday bedtime). Thus, sleep may play a role in adolescent obesity and weight-related behaviors. This study assesses sleep duration, quality, and schedules and their relationships to relative weight and body fat percentage as well as diet, physical activity, and screen time in adolescents with overweight/obesity.

Methods: Adolescents between 12 and 17 years old ($n = 186$) were weighed and measured, reported typical sleep and wake times on weekdays and weekends, and responded to questionnaires assessing diet, physical activity, and screen time habits.

Results: Controlling for sleep duration, later weekend bedtime and greater bedtime shift were associated with greater severity of overweight ($\beta = 0.20$; $\beta = 0.16$) and greater screen time use ($\beta = 0.22$; $\beta = 0.2$). Later bedtimes on the weekdays and weekends were associated with fewer healthy diet practices ($\beta = -0.26$; $\beta = -0.27$). In addition, poorer sleep quality was associated with fewer healthy diet habits ($\beta = -0.21$), greater unhealthy diet habits ($\beta = 0.15$), and less physical activity ($\beta = -0.22$). Sleep duration was not associated with any weight or weight-related behavior.

Conclusions: Sleep patterns and quality are associated with severity of overweight/obesity and various weight-related behaviors. Promoting a consistent sleep schedule throughout the week may be a worthwhile treatment target to optimize behavioral and weight outcomes in adolescent obesity treatment.

Keywords: adolescents; childhood obesity; diet; physical activity; screen time; sleep

Introduction

Sleep is a risk factor linked to the development and maintenance of obesity. It is hypothesized that sleep impacts weight through a variety of biological and behavioral pathways. For example, sleep restriction has been shown to negatively impact energy and glucose metabolism, alter appetitive hormones, and allow for more time to engage in obesogenic behaviors (*e.g.*, television watching, poor diet choices, and so on).[1,2] During adolescence, physiological sleep patterns (*e.g.*, reduced depth of REM sleep) and psychosocial influences on sleep (*e.g.*, increased homework) change, research shows that adolescents have shorter sleep durations, later bedtimes, and greater discrepancies between weekday and weekend sleep schedules.[3–6] As such, adolescents may be particularly vulnerable to sleep-related changes in their weight.

The majority of research of sleep and weight in adolescents has focused on the associations between sleep duration and sleep quality. The extant literature supports the cross-sectional link between shorter sleep duration and elevated weight status in both children and adolescents.[7,8] Moreover, longitudinal data suggest that shorter sleep duration in middle childhood is associated with increased risk

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of obesity in early adulthood[1] and that children with obesity with shorter sleep duration may experience more cardiovascular risk factors.[9] Shorter sleep duration is also associated with behavioral diet and activity correlates of obesity. Adolescents who sleep less engage in greater unhealthy diet behaviors, less physical activity, and more screen time.[10,11]

Sleep quality has been implicated as a risk factor for obesity as well. Poor sleep quality may impact overall sleep duration and additionally may interfere with the natural cycles of sleep waves throughout the night, which can alter metabolism.[2] Adolescents with overweight and obesity have more disrupted sleep and greater sleep onset latencies than healthy weight controls,[7] and sleep disturbance and sleep efficiency have been negatively related to physical activity and positively related to sedentary activity.[12,13]

More recently, studies suggest that patterns of sleep, in addition to sleep duration and quality, may be related to weight status and may provide a more comprehensive picture of the relationship between weight and sleep.[1,14,15] Specifically, later bedtimes show positive relationships with obesity as well as greater consumption of energy-dense, nutrient-poor foods and negative relationships with physical activity and fruit and vegetable consumption in children and adolescents.[10,16,17] Furthermore, later bedtimes on weekends than weekdays, termed ''bedtime shift,'' may dysregulate circadian rhythms, as the circadian system is slow to adapt to rapid shifts in sleep, which can then influence metabolic processes.[4] Bedtime shift has also been tied to higher weight status,[16] greater technology use, and less physical activity in children and adolescents.[18,19]

Most studies to date have looked at adolescents across the weight spectrum; however, assessing the relationship of sleep patterns to weight and other weight-related lifestyle behaviors in a treatment-seeking population of adolescents with overweight and obesity may have relevant treatment implications. Multicomponent weight-loss interventions are evidence-based treatments for obesity.[20,21] They work to reduce weight by targeting diet and physical activity through behavior modification strategies.[21] If sleep duration and timing are related to severity of obesity as well as weight-related behaviors, inclusion of strategies to promote sleep hygiene (*e.g.*, consistent and early bedtimes and so on) within a multicomponent intervention may optimize outcomes.

However, only limited studies assessing sleep in child and adolescent populations with overweight and obesity exist. Of these, one study of 6–18 year olds suggests shorter sleep duration, and greater bedtime shift is associated with higher body mass index-for-age z-score (zBMI).[22] Another study in 8–18 year olds with obesity found that children and adolescents with later bedtimes consume more calories and engage in more screen time than those with earlier bedtimes independent of sleep duration.[18] Both these studies utilized combined child and adolescent samples; however, given the changes in sleep habits unique to adolescents,[3–6] focusing on this population may provide a more specific understanding of the relationship between sleep and adolescent weight status.

The current study seeks to examine the relationships of a more comprehensive set of sleep variables than thats have been previously assessed,[18,22] including duration, quality, bedtime, and variability in weekday and weekend bedtimes, to weight, body fat percentage, and weight-related behaviors (*i.e.*, diet, physical activity, and screen time) in a sample of treatment-seeking adolescents with overweight and obesity.

Methods

Study design and participants

The current study utilized baseline data from a community-based, randomized controlled efficacy trial that assessed a 12-week web-based treatment program designed to reduce weight in adolescents with overweight and obesity against a general health education control intervention (Australian National Health and Medical Research Project Grant 1003813). Participants were recruited from a large, metropolitan city in Australia through school and local advertisements and referrals from general practitioners.

Participants were included if they were between the ages of 12 and 17, met overweight or obesity criteria according to the age- and gender-specific BMI data from the International Obesity Task Force,[23] and had Internet access at home or at an easily accessible location. Exclusion criteria included known endocrine or chromosomal cause for obesity status, medications resulting in weight changes (*e.g.*, Prednisolone), complications that prevented moderate physical activity engagement, a past or current eating disorder, or a significant health disability or condition. All study procedures were approved by the Human Research Ethics Committee at the Royal Children's Hospital, Melbourne.

Measures

Sleep timing and duration. Sleep hours were determined by four self-report items asking what time adolescents usually went to bed and woke up on the weekdays and weekends. These questions were adapted from the Pittsburgh Sleep Quality Index to provide measurement of bed and wake times on weekdays and weekends separately.[24] Participants responded by indicating their bed and wake times to the nearest hour and the times were used to calculate sleep duration. Sleep duration shift (differences in sleep duration on weekdays and weekends) and bedtime shift (differences in bedtimes on weekends and weekdays) were calculated by subtracting weekends from weekdays, thus, higher scores represent greater sleep duration and later bedtime, respectively, on weekends compared with weekdays.

Sleep quality. Sleep quality was assessed using the Insomnia Severity Index (ISI), which is a seven-item scale assessing insomnia variables, such as difficulty falling and staying asleep and problems waking up.[25] Participants respond on a five-point Likert scale, with higher summed

scores indicating greater sleep quality. The ISI has been shown to be a reliable and valid measure of insomnia in adolescents[16] and has shown high convergent validity with other measures of sleep quality, such as the Pittsburgh Sleep Quality Index.[26]

Anthropometry. Weight and body fat were measured using a Tanita SC-240 Total Body Composition Analyzer (Illinois), a regularly calibrated digital scale that performs bioelectrical impedance, and height was measured using an Invicta portable stadiometer (Oadby, Leicester, United Kingdom). All measurements were taken according to the International Society for the Advancement of Kinanthropometry.[27] Participants were weighed and measured in street clothes without shoes and other heavy clothing items.

Diet. Diet was assessed using the nutrition-related questions from the Youth Risk Behavior Scale,[28] the fruit and vegetable items from a survey created for the Patient-centered Assessment and Counseling for Exercise plus Nutrition program,[29] and the Healthy Neighborhoods Survey.[30] Two subscales were created similar to the subscales used in Jacka et al., which were created in that study to reflect the Dietary Guidelines for Children and Adolescents in Australia. A healthy diet score was created from four items, with participants getting scores based on their responses. Participants were given points if they reported the following: (1) they ate breakfast at least five times a week, (2) drank milk at least once per day, (3) consumed at least two servings of fruit a day, and (4) consumed at least four servings of vegetables per day. An unhealthy diet score was summed from three items that assessed consumption of nondiet soft drinks, sweet and savory high-energy snacks, and frequency of food consumption from takeaway restaurants.

Physical activity. A modified version of the Physical Activity Questionnaire for Adolescents (PAQ-A), which has demonstrated good reliability and validity in adolescents, was utilized to assess physical activity.[31] Three items using a five-point Likert scale assessed physical activity after school, on weekends, and during lunch in the past week. A summary score was calculated by averaging the three responses, with higher scores indicated greater physical activity.

Screen time. Four items from the Adolescent Sedentary Activity Questionnaire (ASAQ)[32] were modified and used to assess screen time. Specifically, participants were asked ''On a typical [weekday/weekend day], how many hours do you spend [watching TV/on a computer or playing video games such as xbox, PS3, PSP, wii, *etc*.]?.'' Possible response options included none, less than an hour, 1–2 hours, 2–4 hours, 4–6 hours, and more than 6 hours and responses were coded from zero to five. A summary score was created by multiplying weekday responses by five, multiplying weekend responses by two, and then summing the scores. A higher score indicates greater screen time.

Statistical analyses

SPSS software, version 22, was used to conduct all statistical analyses. Given the exploratory nature of the current study, corrections were not made for multiple comparisons, and an α level of $p < 0.05$ was set to determine significance; however, exact p-values are presented for application of more conservative α levels, if desired. Separate linear regression models were completed to assess the relationship between sleep variables and adolescent zBMI, diet, physical activity, and screen time. Age and gender were controlled for in all models, as previous studies have demonstrated that these are associated with sleep variables in adolescents.[8,33] In models in which sleep duration was not a variable of interest, sleep duration on weekdays and weekends was also included as a covariate, given its previously identified relationship to weight and weight-related lifestyle behaviors.

Results

Baseline characteristics of participants are shown in Table 1. Adolescents ($n = 186$) had a mean age of 14.66 years with an average zBMI of 2.06. Females comprised 62.4% of the sample. Responses to weight-related behavior questionnaire items are shown in Supplementary Table S1 (Supplementary Data are available online at www.liebertpub.com/chi).

Results from linear regressions predicting anthropometrics are presented in Table 2 and results from linear regressions predicting weight-related behavior variables are presented in Table 3. No anthropometric or behavioral variables were related to weekday or weekend sleep

Table 1. Baseline Demographics and Sleep Variables

Variable ($N = 186$)	Mean ± SD
Age	14.66 ± 1.61
Gender (M/F)	(70/116)
zBMI	2.06 ± 0.41
Weekday sleep duration	8.83 ± 1.24
Weekend sleep duration	9.83 ± 1.45
Sleep duration shift	0.99 ± 1.47
Sleep quality	8.05 ± 5.40
Weekday bedtime[a]	22:20 ± 1:20
Weekday wake time[a]	7:10 ± 1:06
Weekend bedtime[a]	23:43 ± 1:34
Weekend wake time[a]	9:32 ± 1:31
Bedtime shift	1.37 ± 1.07

[a]Bedtimes and wake times are expressed in 24-h clock.
zBMI, body mass index-for-age z-score.

Table 2. Adjusted Univariate Linear Regression Models with Sleep Variables Predicting Anthropometrics

	zBMI				Body fat percentage			
Sleep variable	B	SE	R^2	*P*	B	SE	R^2	*p*
Weekday sleep duration[a]	–0.017	0.026	0.002	0.516	–0.421	0.445	0.004	0.345
Weekend sleep duration[a]	–0.017	0.021	0.002	0.432	–0.184	0.366	0.001	0.616
Sleep duration shift[a]	–0.005	0.021	0.000	0.807	0.099	0.364	0.000	0.786
Sleep quality[b]	–0.005	0.006	0.000	0.434	–0.089	0.100	0.003	0.378
Weekday bedtime[b]	0.016	0.031	0.002	0.596	0.650	0.525	0.007	0.217
Weekend bedtime[b]	0.053	0.025	0.017	0.035*	0.614	0.429	0.009	0.154
Bedtime shift[b]	0.062	0.03	0.015	0.042*	0.264	0.524	0.001	0.615

[a]Model adjusted for age and sex of adolescent (and zBMI when not the primary outcome).

[b]Model adjusted for age, sex, weekend, and weekday sleep duration (and zBMI when not the primary outcome).

*$p < 0.05$.

SE, standard error; R^2: percent of the variance accounted for by the individual variable of interest in the model (R^2 change)

duration or sleep duration shift in the adjusted linear regression models.

Sleep quality was associated with diet variables, such that adolescents who had greater healthy diet scores and lower unhealthy diet scores showed less sleep disturbance. In addition, sleep quality was related to physical activity. Adolescents who were more physically active had lower rates of sleep disturbance. Sleep quality was not related to zBMI, body fat percentage, or screen time.

With regard to bedtimes, zBMI was not related to weekday bedtimes; however, a significant linear relationship was found between weekend bedtimes and zBMI as well as bedtime shift and zBMI, such that for each hour later that adolescents went to bed on the weekends, their zBMI increased by 0.053, and that for each hour later that adolescents went to bed on the weekends compared with the weekdays, their zBMI increased by 0.062. No sleep variables were related to body fat percentage. Behavioral variables also demonstrated relationships with bedtimes and bedtime shift. Adolescents with healthier diet scores had earlier bedtimes on both weekdays and weekends. In addition, screen time use was positively related to weekend bedtimes and bedtime shift, such that adolescents had greater screen time use if they went to bed later on the weekends and had greater discrepancies between weekday and weekend bedtimes. Bedtimes and bedtime shift were not related to physical activity.

Discussion

This study found that in a treatment-seeking adolescent population with overweight and obesity, later weekend bedtimes and greater bedtime shift from weekdays to weekends were significantly associated with severity of overweight. This mirrors findings in adolescents across the weight spectrum[16,17] and extends the literature by demonstrating that within adolescents with overweight and obesity, sleep patterns may be a relevant indicator of obesity severity risk. This finding may be driven, in part, by biological factors. Variability in sleep schedules has been shown to lead to alterations in circadian rhythms, which may then influence energy and glucose metabolism.[1,2,4] While zBMI generally correlates highly with body fat percentage,[34] this study found a lower correlation ($r = 0.56$) and did not find any relationship between sleep and body fat percentage, suggesting that in children with overweight/obesity, it is not fat-mass alone that is related to sleep.

Behavioral patterns are also an important factor. In this study, at least one sleep variable was related to each of the weight-related behaviors assessed. Specifically, in addition to severity of overweight, later weekend bedtimes and greater bedtime shift were also associated with greater screen time usage. A large literature shows that screen time is adversely associated with both sleep outcomes[35] and obesity,[36,37] and a previous study in children and adolescents with overweight and obesity showed later bedtimes were related to increased screen time.[18] As such, screen time may be a causal mechanism. Adolescents may be staying up later to watch TV and/or play video games on the weekend, which then delays bedtime and creates a greater discrepancy between weekday and weekend bedtime, which subsequently negatively affects weight status. However, given the cross-sectional nature of the data, future research is needed to confirm this proposal. In this study, later weekday and weekend bedtimes were also found to be associated with fewer healthy eating practices (*i.e.*, less consumption of fruits, vegetables, and milk and less breakfast consumption). This finding is supported by previous literature demonstrating that individuals with later bedtimes eat fewer fruits and vegetables and have less healthy diet patterns.[10,38]

Table 3. Adjusted Univariate Linear Regression Models with Sleep Variables Predicting Weight-Related Behaviors

	Healthy diet score				Unhealthy diet score				Physical activity score				Screen time score			
Sleep variable	B	SE	R^2	p	B	SE	R^2	p	B	SE	R^2	p	B	SE	R^2	p
Weekday sleep duration[a]	0.079	0.071	0.007	0.27	−0.215	0.173	0.008	0.216	−0.018	.0490	0.001	0.710	−0.417	0.745	0.001	0.751
Weekend sleep duration[a]	0.018	0.059	0.000	0.765	−0.091	0.145	0.002	0.530	0.042	.0410	0.005	0.302	0.096	0.876	0.002	0.554
Sleep duration shift[a]	−0.035	0.058	0.002	0.545	0.056	0.142	0.001	0.693	0.054	0.040	0.008	0.185	0.369	0.605	0.004	0.400
Sleep quality[b]	−0.043	0.016	0.041	0.006*	0.076	0.039	0.021	0.050*	−0.035	0.011	0.045	0.002*	0.198	0.168	0.008	0.236
Weekday bedtime[b]	−0.221	0.083	0.037	0.008*	0.286	0.209	0.010	0.174	−0.089	0.058	0.011	0.128	0.608	0.897	0.001	0.734
Weekend bedtime[b]	−0.198	0.069	0.043	0.005*	0.232	0.169	0.010	0.173	−0.006	0.049	0.000	0.897	1.759	0.714	0.029	0.019*
Bedtime shift[b]	−0.063	0.085	0.003	0.456	0.071	0.214	0.001	0.742	0.081	0.059	0.009	0.170	2.139	0.896	0.035	0.009*

[a]Model adjusted for age and sex of adolescent (and zBMI when not the primary outcome).

[b]Model adjusted for age, sex, weekend, and weekday sleep duration (and zBMI when not the primary outcome).

*$p < 0.05$.

SE, standard error; R^2, percent of the variance accounted for by the individual variable of interest in the model (R^2 change).

Finally, sleep quality was found to be associated with physical activity, such that adolescents with overweight and obesity reporting poorer quality of sleep also reported engaging in less physical activity. Individuals with poorer sleep quality experience more fatigue throughout the day, which may then influence their ability and desire engage in physical activity.[1] Physical activity contributes to maintenance of energy balance and is associated with a variety of cardiovascular and psychosocial outcomes, thus would be important to promote for weight management and overall physical and mental health. Poorer quality of sleep in the study was also related to fewer healthy eating practices and greater unhealthy eating practices. Studies in adults and adolescents suggest that disturbed sleep leads to increased energy consumption, specifically of high energy-dense foods, and also has a deleterious effect on metabolism.[2,7,10]

Of note, sleep duration was not related to weight, activity, or diet variables, which is contrary to the majority of the extant literature.[1,7,8,10,11] Within the two previous studies assessing children and adolescents with current overweight and obesity, findings are mixed. Adamo et al. show no relationship between sleep duration and severity of overweight, while Chuang et al. do. Discrepant findings may reflect differences in power, as the Chuang et al. study had close to 300 participants. Given assessing adolescents with overweight and obesity alone restricts variance in weight, more subjects may be needed to find the effect than the number in the current study or the previous study by Adamo et al. This lack of variance may also explain the null findings between sleep and body fat percentage. Another explanation may be that the adolescents in the current study reported sleep duration averages on the weekdays and weekends that were within the recommended 8–10 hours of sleep.[39] Specifically, only 13% and 5% of the sample reported less than 8 hours of sleep on the weekdays and weekends, respectively. Given these adolescents were generally meeting recommendations, they may have been less susceptible to weight- and behavior-related consequences that accompany a consistent sleep deficit. Notably, even while reaching recommended levels of sleep, sleep patterns and quality still had weight-related and behavioral associations in this sample, highlighting emerging themes in the literature that sleep is likely important for weight control above and beyond duration.

Findings from this study suggest that it is relevant to target sleep hygiene within the context of adolescent obesity treatments. Effective sleep hygiene strategies for children include a consistent sleep schedule and bedtime routine, reduced daytime naps, reduction of strenuous activities, screen time before bed, and others.[40] By teaching and setting goals around these behavioral skills during obesity treatment, adolescents may improve sleep, which may in turn help optimize weight and behavioral outcomes. Indeed, a recent study utilizing a newly designed intervention to target sleep in youth showed that adolescents who participated in the 6-week treatment made healthier food choices at breakfast than those in the psychoeducational control group.[41] Preliminary interventions

in younger children and adults also demonstrate promise. A randomized controlled pilot study of 14 children 8–11-year old showed a family-based behavioral sleep intervention that included behavioral strategies (*e.g.*, goal setting, preplanning, self-monitoring, and so on) to increase child time in bed by 1.5 hours showed an improvement in sleep quantity and improved food reward.[42] A fully-powered randomized controlled trial of the intervention is currently underway, which will assess weight outcomes.[42] In adults, a pilot study demonstrated that a behavioral weight loss intervention combined with a sleep intervention resulted in faster weight loss than the behavioral weight loss intervention alone.[43] Obesity treatment also presents an optimal time to assess for potential underlying conditions that may contribute to poor sleep habits, including sleep apnea.[44]

This study adds additional evidence and extends the current literature on the association of sleep to weight and weight-related behaviors in adolescents with overweight and obesity. By assessing a comprehensive number of sleep variables, this study was able to provide a more thorough examination of how sleep relates to obesity and weight-related behaviors. Limitations of the study include that the data, with the exception of anthropometrics, were self-reported and bed and wake time questions adapted from a validated and reliable scale were not independently tested for psychometrics. Future studies should use multimethod measures of sleep (*e.g.*, polysomnography, actigraphy, sleep diaries, and so on), diet (*e.g.*, 24-hour recalls), and activity (*e.g.*, accelerometers) and may consider complete compositional analysis of daily activity to ensure comprehensive and accurate measurement, particularly as self-reported sleep duration tends to be overestimated.[14,15,45] Moreover, additional anthropometric measures could be used, as zBMI may be less sensitive for extreme obesity.[46] In addition, given the exploratory nature of the study, corrections were not made to account for multiple comparisons, which may increase the possibility of a Type 1 error. Instead, *p*-values are presented in Tables 2 and 3 for the interpretation of the reader. Finally, due to the cross-sectional nature of the study, insight into directionality of relationships between sleep and weight and weight-related behaviors is also not available. Others have proposed bidirectional relationships for sleep variables and weight, as well as for sleep variables and diet, physical activity, and sedentary activity. For example, while fatigue related to poor sleep habits may make it more difficult to engage in physical activity, physical activity has been shown to promote sleep, potentially due to anxiolytic, antidepressant, thermogenic, and circadian influences.[47] Additional longitudinal and experimental research is needed to determine directionality of all observed relationships.

Findings from the study demonstrate that certain sleep patterns of adolescents with obesity are cross sectionally related to severity of obesity and weight-related behaviors, independent of sleep duration. Future directions should include assessment of mediation of behavioral variables on relationship between weight and sleep and a randomized controlled trial to test whether interventions to maintain a more consistent sleep schedule are beneficial to obesity outcomes in treatment.

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