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Associations of Sleep Duration and Regularity with Level of Obesity Among Youth in a Weight Loss Program

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Associations of Sleep Duration and Regularity with Level of Obesity Among Youth in a Weight Loss Program

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This study evaluated the association of sleep duration and irregularity (shifts in sleep duration and wake/bedtimes from weekday to weekend) with baseline level of obesity in youth enrolled in a weight management program. The 288 youth ranged in age from 6-18 years old; 61.1% were female, and 52.5% were Caucasian. In adjusted models, shorter sleep duration was significantly related to higher BMI z-scores. Two measures of sleep irregularity, bedtime and wake-time shift, were also each related to baseline BMI z-scores, but these relationships did not remain significant in adjusted models. In gender-stratified adjusted regression models, shorter sleep duration and greater wake-time shift for females were significantly associated with higher BMI z-scores. None of the sleep variables were significantly related to BMI z-scores for males in adjusted models. Taken together, the results of this study support the relationship between sleep duration and regularity with level of obesity in a racially diverse sample of predominantly obese, treatment-seeking youth.

Key words: sleep duration, sleep regularity, pediatric obesity, weight status, weight management program

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Within the past two decades, the percentage of children and adolescents who were overweight (body mass index [BMI] between the 85^{th} and 95^{th} percentile for gender and age) or obese (BMI $\geq 95^{th}$ percentile) increased from 28.9% to 34.8%, and the rate of obesity increased from 12% to 18.2% according to the National Health and Nutrition Examination Survey (NHANES) 1999-2000 and 2003-2004 (Ogden et al., 2006). Given emerging evidence of major morbidity associated with childhood obesity (e.g., diabetes, coronary heart disease, hypertension), substantive efforts to identify and better characterize potentially modifiable causes are underway to address this public health issue. One such factor is short sleep, which has been significantly related to children's weight status in large-scale cross-sectional and prospective studies conducted both in the United States and abroad (e.g., Agras, Hammer, McNicholas, & Kraemer, 2004; Bayer, Schaffrath Rosario, Wabitsch, & von Kries, 2009; Berkey, Rockett, & Colditz, 2008; Drescher, Goodwin, Silva, & Quan, 2011; Eisenmann, Ekkekakis, & Holmes, 2006; Ievers-Landis, Storfer-Isser, Rosen, Johnson, & Redline, 2008; Landhuis, Poulton, Welch, & Hancox, 2008; Lumeng et al., 2007; Magee, Caputi, & Iverson, 2013; Park, 2011; Sekine, Yamagami, et al., 2002; Shaikh, Patel, & Singh, 2009; von Kries, Toschke, Wurmser, Sauerwald, & Koletzko, 2002).

The case for the significant association of pediatric sleep duration with obesity has been strengthened via large cross-sectional studies that have supported a dose-response relationship between late bedtimes or short sleeping hours and obesity risk (Park, 2011; Sekine Yamagami, et al., 2002). For example, in a study of adolescents in South Korea, the likelihood of being overweight or obese increased by 7% for every one-hour decrease in sleep duration, even when controlling for covariates typically associated with obesity (Park, 2011). In cross-sectional studies, the relationship between sleep duration and weight status has remained significant even when considering a number of potential confounders, e.g., children's psychological functioning (e.g., internalizing and externalizing disorders) and parenting factors (i.e., parenting stress, household chaos, permissive parenting style) (Ievers-Landis et al., 2008; Lumeng et al., 2007). The role of sleep in the growing incidence of pediatric obesity has also consistently gained support via findings from prospective studies (Agras et al., 2004; Lumeng et al., 2007; Magee et al., 2013). In one study, children who developed obesity by the age of 9.5 years had slept an average of 30 minutes less per day between the ages of 3 to 5 compared to those who maintained a normal weight during that time period (Agras et al., 2004). Furthermore, the longitudinal relationship between childhood sleep duration and weight category extends into adulthood after adjusting for adult sleep time, early childhood BMI, parental BMI, and other lifestyle factors (Landhuis et al., 2008).

Weight gain may be a secondary effect of short sleep duration with the following possible causal pathways: 1). increased caloric intake due to more opportunity to eat and altered appetite regulation, and 2). lower energy expenditure because of fatigue leading to decreased physical activity or changed thermoregulation (Patel & Hu, 2008). Altered appetite regulation among individuals with shorter sleep duration may partially be caused by reduced leptin levels and elevated ghrelin (Spiegel, Tasali, Penev, & Van Cauter, 2004; Taheri, Lin, Austin, Young, & Mignot, 2004). Leptin is a hormone released by the adipocytes that suppresses appetite; ghrelin is a peptide in the stomach that stimulates appetite (Meier & Gressner, 2004). The relationship between sleep and obesity is likely bi-directional and influenced by a large number of possible moderating or mediating variables that may relate to sleep, weight status, or both, including daytime sleepiness (e.g., Calhoun et al., 2011), physical activity level (e.g., Jerrin et al., 2013), electronic use (e.g., Berkey et al., 2008; Chahal, Fung, Kuhle, & Veugelers, 2013), or chronotype (i.e., individual differences in circadian rhythm; Schaal, Peter, & Randler, 2010; Urban, Magyarodi, & Rigo, 2011). See the previously cited literature for additional information on alternative explanations for the pediatric sleep/obesity relationship and other potential moderating/mediating variables.

Cross-sectional and longitudinal research in this area suggests that the association of pediatric sleep duration and obesity may be different for males versus females, although discrepancies exist between studies. The majority of studies have found significant associations between BMI z-scores or obesity risk and shorter sleep duration for males but not for females (e.g., Ievers-Landis et al., 2008; Eisenmann et al., 2006; Storfer-Isser, Patel, Babineau, & Redline, 2012). Lytle, Pasch, and Farbakhsh (2011) found that the relationship between sleep and BMI z-score was moderated by both gender and grade level, with the relationship strongest in middle-school males, still significant in middle-school females, and non-significant in high-school students. Similarly in a longitudinal study, Storfer-Isser, Patel, Babineau, and Redline (2012) examined sleep duration and weight status at three time points: 8-11 years, 12-15 years, and 16-19 years. For females, sleep duration was not correlated with BMI z-scores at any age. For males, sleep duration was inversely related to BMI z-score, with the magnitude of the association decreasing with age until no longer statistically significant at 16-19 years of age. In contrast, Drescher et al. (2011) found no differences between males and females in the relationship between parent-reported total sleep time and standardized BMI.

Another issue to consider is whether other characteristics of sleep besides duration, e.g., regularity, have an impact on weight status. In general, a prominent difference in sleep duration exists between weekdays and weekends/holidays among school-aged youth (e.g., Wing, Li, Li, Zhang, & Kong, 2009). Therefore, the timing of their main sleep period shifts between the school week and weekend. To our knowledge, the relationship between sleep irregularity and weight status has only been examined in two studies, and these have had mixed results. Jerrin, McGrath, and Drake (2013) examined weekday to weekend irregularity in three ways: weekend oversleep (difference in total sleep duration), weekend delay (difference in bedtime), and weekend awakening delay (difference in wake time). Only weekend delay was correlated with BMI z-scores in unadjusted and adjusted models, but this variable was not a significant predictor of BMI z-scores when using more conservative Bonferonni corrections. The other study found that irregular sleep may actually serve as a protective factor against obesity for certain individuals. Wing and colleagues reported that among Chinese children who slept less than 8 hours during weekdays, those who compensated for their sleep deficit by sleeping more than 8 hours on weekends partly ameliorated the risk of being overweight (Wing et al., 2009). Considered together, these findings suggest that sleep irregularity may have important implications for children's weight status, which merit further examination.

The above-mentioned studies have examined the relationship between short sleep and weight in children and/or adolescents across the entire weight spectrum (i.e., including normal weight individuals). In the one study that examined sleep duration and disruption in youth who were overweight or obese from a weight management clinic, sleep behaviors were compared between the clinical group and normal-weight controls (Beebe et al., 2007). Although participants in the clinical sample reported a significantly shorter sleep duration on average compared to controls, within-group analyses were not conducted in the clinical sample of overweight/obese children. Bayer and colleagues' 2009 study of sleep duration and weight across the entire BMI distribution in children 3-10 years of age provided additional justification for closer examination of these relationships in an obese sample. A quantile regression was conducted, and findings were that the middle and upper tail of the BMI distribution were most affected by sleep duration. The results of these studies suggest that the relationships between shorter sleep duration and greater weight may be even more significant in children who are overweight or obese, although this question has not yet been examined in a predominantly obese sample of older children seeking weight loss treatment. This question is vital for determining to what extent sleep is a risk factor in this population and whether behavioral sleep medicine interventions should be included as a regular component of weight control programs.

There is initial data to suggest that increasing sleep duration for youth who are overweight or obese may support weight loss. Specifically, Sallinen and colleagues (2013) conducted a chart review of 83 youth with obesity referred to an outpatient multidisciplinary, family-based weight management program. After three months of treatment, reductions in BMI were predicted by more weekly sleep at baseline. Specifically, 30 minutes more daily sleep at baseline predicted a greater BMI reduction of 0.2 kg/m^2. Although these results provide initial evidence that weight management interventions would benefit from inclusion of a sleep component, additional research is needed to empirically examine the associations of sleep duration and regularity with level of obesity in a treatment-seeking sample of children and adolescents who are already obese.

Despite growing evidence that short sleep duration is associated with an increased propensity for pediatric obesity, this phenomenon has not yet been examined to determine if: 1). sleep duration is related to degree of obesity in a sample of youth who are already obese and enrolled in a weight loss program, 2). other aspects of sleep (such as irregularity, i.e., differences between weekday and weekend sleep habits) are associated with degree of obesity within a primarily obese population, and 3). the association between sleep and degree of obesity is significant in gender-stratified samples within a primarily obese population. Thus, the primary goal of the current study was to expand existing research by evaluating the association of sleep duration and irregularity with baseline level of obesity in youth (ages 6-18 years) being evaluated for enrollment in a weight loss program. It was hypothesized that youth with shorter and more irregular sleep would have greater BMI z-scores and that these relationships would be identified in males but not in females in gender-stratified analyses.

Method

Study Participants and Procedures

The study sample consisted of 288 children ages 6-18 years old enrolled in Healthy Kids/Healthy Weight (HKHW) from 2005-2009. HKHW is a Rainbow Babies & Children's Hospital-affiliated weight management intervention program that provides multi-disciplinary evaluation and treatment for children and adolescents who are overweight or obese. At the time of data collection, the intervention program was provided at no cost to families with the exception of health insurance being billed for the initial medical evaluation. This clinical research program has received Institutional Review Board approval through University Hospitals of Cleveland, Ohio. Children are predominantly physician referred and must have a BMI $\geq 85^{th}$ percentile for their gender and age group. Participants first complete an evaluation to define the severity, causes, and development of co-morbid conditions secondary to their overweight/obesity. This evaluation includes a medical examination, psychological screening, laboratory testing, and assessment of physical fitness, body composition, and diet. Referrals to appropriate hospital-based specialists treating obesity-related conditions are also made. After completing the evaluation component, children who are eligible to participate in a group format (e.g., those without severe behavioral or psychiatric disturbances) are referred to the intervention. The twelve-week intervention is comprised of weekly two-hour sessions held over approximately three months. The sessions involve group classes led by a team including a dietitian, exercise physiologist, and behaviorist. At each visit, families set goals focusing on diet, exercise, and behavior and self-monitor their progress in attaining these goals (Heinberg et al., 2010). For the current study, inclusion criteria included: consent of patient data utilization for research, complete sleep data, no history of sleep apnea or other sleep disorders, completion of initial evaluation with results indicating eligibility for group treatment, and attending more than one intervention session.

Measures

Demographics. Demographics were taken from standard parent-report measures that included questions about race/ethnicity, marital status, highest level of education, total family income, and occupational status of the primary and secondary caregivers.

Weight/height. Weight was measured via a scale that is calibrated daily. Height was measured by a mounted stadiometer, which is also calibrated. BMI z-score was calculated using a SAS program from CDC growth charts (Kuczmarski et al., 2002).

Sleep variables. Measures of sleep irregularity and duration were determined from questions on the Children's Sleep Habits Questionnaire provided by parents during the evaluation component (Owens, Spirito, & McGuinn, 2000). Parents were asked to record the usual time their child goes to bed and wakes up on schooldays/weekdays and on non-schooldays/weekends. Sleep duration was calculated as a weighted average of weekday and weekend sleep duration. Sleep irregularity was defined by three measures: sleep duration shift (weekend minus weekday sleep duration), wake-time shift (weekend minus weekday wake time), and bedtime shift (weekend minus weekday bedtime). Sleep variables were calculated in hours. The validity of parental report of sleep duration has been confirmed by actigraphy (Sekine, Chen, et al., 2002; Tikotzky & Sadeh, 2001), suggesting that parental report may reasonably be used in studies examining relative differences in sleeping hours.

Data Analysis

Continuous variables were described using means and standard deviations. Nominal variables were described using frequencies and percentages. Unadjusted relationships of baseline BMI z-scores, sleep variables, and covariates (age, gender, race/ethnicity, marital status, and family income) were examined. Spearman correlation coefficients were estimated when both variables were continuous; two-sample tests (Wilcoxon rank sum tests) were used when one variable was nominal and the other continuous. Multiple regression analyses were used to assess the contribution of the sleep variables to the explanation of the variability of BMI z-score, after adjustment for socio-demographic factors. The variables were selected because they related to overweight/obesity status in prior research. (Gibson, Byrne, Davis, Blair, Jacoby, & Zubrick, 2007; Singh, Kogan, Van Dyck, & Siahpush, 2008; Strauss & Knight, 1999; Wang & Beydoun, 2007). Unstandardized *beta*s, standard errors of the *betas*, and cumulative R^2s are reported; significant changes in R^2 are identified. Finally, similar regression models are presented for males and females separately in gender-stratified analyses. Regression models were conducted separately for each of the four sleep variables. All analyses were carried out using SAS v. 9.2 (the SAS Institute, Carey NC).

Results

The study population of 288 participants included slightly more females (approximately 61%) than males. The mean age was 11.8 years (*SD* = 2.73). Caucasians made up almost 53% of the sample followed by African-Americans (39%), Latinos (3%), and 6% in other ethnic categories. For the purpose of data analysis, race/ethnicity was subsequently dichotomized as White versus non-White. Forty-eight percent of families had a total annual family income of ≥$50,000, 63% of primary caregivers were married, and 84% had education levels exceeding high school. Demographic variables were dichotomized in all subsequent analyses.

The mean BMI percentile in this sample was 98.8 (*SD* = 1.21), and mean BMI z-score for age and sex was 2.39 (*SD* = 0.33). Only 3 participants had a BMI percentile < 95% (i.e., 98.9% of the study sample was obese rather than overweight). Daily average parent-reported weekday sleep duration was 8.69 hours (*SD* = 1.18); daily average weekend sleep duration was 9.53 hours (*SD* = 1.37), similar to that reported in previous studies of same-aged youth across BMI categories (Jerrin et al., 2013; Wing et al., 2009). Average parent-reported bedtime on the weekend was 1.26 hours (*SD* = 1.02) later compared to the weekday, and average parent-reported wakeup time was delayed 2.10 hours (*SD* = 1.54) on the weekend (Table 1).

In bivariate analyses, higher BMI z-score was significantly associated with male gender, non-White race/ethnicity, unmarried marital status, and lower family income (all *p*'s < .05). Age was significantly associated with all sleep variables, including sleep duration (r=-0.59, p< 0.001), bedtime shift (r=0.13, p = 0.03), wake-time shift (r=0.44, p< 0.001), and sleep duration shift (r=0.37, p< 0.001). Gender was associated with wake time and sleep duration shift, with females evidencing greater shifts (p's=0.01, <0.001, respectively). Non-White race/ethnicity was significantly related to greater bedtime and wake-time shifts (p's<0.001). Unmarried marital status and lower family income were associated with bedtime shift (p's$=0.01$, <0.001, respectively).

As hypothesized, there was a significant negative association between average sleep duration and BMI z-scores ($r=-0.16$, $p=0.01$), with children who slept less having higher levels of obesity. Also as predicted, the two measures of sleep irregularity, bedtime and wake-time shift, were each significantly related to BMI z-scores ($r=0.16$, $p=0.01$; $r=0.14$, $p=0.03$; respectively). Thus, participants with greater shifts between weekday and weekend bedtimes and wake times had higher levels of obesity. There was no statistically significant bi-variate relationship between sleep duration shift and BMI z-scores.

Adjusted Regression Models

Separate adjusted regression models were computed for the four sleep variables as predictors of BMI z-scores. To control for covariates (race/ethnicity, family income, marital status, gender, and age; Table 2), each variable was entered sequentially to the model with the sleep variable added last. As hypothesized, average sleep duration contributed a significant amount of additional variance in the prediction of BMI z-scores after controlling for demographic variables ($p<0.05$). Contrary to expectation, bedtime shift, wake-time shift, and sleep duration shift did not contribute significant additional variance in the adjusted models to predict BMI z-scores. In all four models, male gender, non-Caucasian race/ethnicity, and family income < $50,000 were significantly associated with higher BMI z-scores.

Gender-stratified Adjusted Regression Models

In females, shorter sleep duration and wake-time shift were significantly associated with higher BMI z-scores after controlling for demographic covariates (*p*'s<0.05) (Table 3). Thus, females who slept less overall and those who slept in later on the weekends than during the week had higher levels of obesity. The other two measures of sleep irregularity (sleep duration shift and bedtime shift) did not contribute significantly to the prediction of BMI z-scores for females in the adjusted models.

Contrary to our expectations, none of the sleep variables contributed significantly to the prediction of BMI z-scores for males when covariates were included first in the models. Specifically, there was only a trend for sleep duration to predict sleep after controlling for demographics (*p*=0.08). Sleep irregularity variables were not significantly related to BMI z-scores for males in the adjusted models.

Discussion

This is the first study to our knowledge to find a significant relationship of sleep duration with level of obesity within a sample of children or adolescents who are already obese and seeking treatment for weight loss. In this sample of 288 youth (ages 6-18 years) enrolled in a weight loss program, our findings are that shorter sleep is associated with higher BMI z-scores, even after adjustment for socio-demographic factors. Thus, even among those children and adolescents whose weight status is within the highest BMI-for-age percentiles, sleep duration remains a significant factor for predicting level of obesity. Results are consistent with previous research showing that children with shorter sleep durations are more likely to be overweight or obese in samples including all weight ranges (underweight, normal, overweight, and obese). Although this was not a prospective study and causality cannot be assumed, our findings lend support to the notion that intervening to increase sleep duration for those children or adolescents who do not sleep enough for their age could be considered as a strategy of weight loss programs. In fact, one study found that baseline sleep duration was a predictor of treatment outcome in a weight management intervention for youth (Sallinen et al., 2013). Another study found that sleep quantity and quality were improved during the course of a weight management program (Vanhelst et al., 2010). Despite these intriguing results, whether sleep habits are a beneficial or even essential target of weight management treatment paradigms has not yet been fully explored. Should sleep duration be identified as having a causal role in weight gain/loss, including it in weight loss programs may increase the robustness of these interventions.

In addition, this study was the first to examine the role of another sleep variable, sleep irregularity, for predicting the level of obesity in a sample of children and adolescents seeking weight loss treatment. We found preliminary evidence that greater bedtime and wake-time shift (later weekend bed/wake-times) is related to higher BMI z-scores. In controlled analyses containing both genders, however, certain socio-demographic factors were significant confounders for the relationship between later weekend bed/wake-times and greater level of obesity, including male gender, non-Caucasian race/ethnicity, and family income < $50,000. Our finding of sleep irregularity relating to obesity level in unadjusted models only is similar to a study of sleep irregularity and weight status with participants across all weight categories (Jerrin et al., 2013). Similar to the results of the current study, sleep irregularity was related to a measure of adiposity (i.e., hip circumference) and to BMI until obesity-related covariates were included. After including covariates in the Jerrin study, only bedtime shift remained significantly related to BMI, although the magnitude of this relationship was small. These results suggest that other factors impact the extent to which changes in sleep patterns from weekdays to weekends have an impact on weight.

In contrast to the majority of previous research, the current study within an obese population of treatment-seeking youth found that the relationship between sleep and BMI z-scores is strongest among females. Interestingly, in gender-stratified regression analyses of baseline weight and sleep variables, the results are opposite of what has been reported in a number of prior studies (Eisenmann et al., 2006; Ievers-Landis et al., 2008; Knutson, 2005). In the current study, the association between sleep duration and degree of overweight/obesity is statistically significant in controlled models for females but was only a trend for males. This may in part be an issue of lack of power because the sample size for males was smaller than for females in the present study. However, the sample size for females was smaller than in many prior studies that did not find significant relationships, lending further credence to the lower sleep duration/higher BMI z-score link in this particular female population.

The finding that sleep duration is related to level of obesity for females but not for males in gender-stratified analyses was duplicated for one of the sleep irregularity variables, wake-time shift. The current study is the first to identify a statistically significant association between sleep irregularity and level of obesity for females. The relationship between sleep duration and weight has been supported in a female-only sample of adolescents (Berkey et al., 2008). Furthermore, in an adult sample, sleep quality and daytime dysfunction were each associated with BMI after controlling for demographic and medical history covariates for women but not for men (Bidulescu et al., 2010). Additional factors should be considered in studies of sleep/weight status containing both genders. As an example, one study found that gender and grade level moderated the relationship between sleep and obesity risk (Lytle et al., 2011). These findings may be related to a more complex interplay between age, pubertal status and biological sex differences. Exploratory analyses in the longitudinal study by Storfer-Isser and colleagues

(2012) found that leptin levels were lower in males than females, were inversely related to testosterone levels in males, and were positively correlated with estradiol levels in females. Perhaps biological differences in sex hormones moderate the impact of sleep irregularity on metabolism, appetite, caloric intake, or other factors related to weight gain. Therefore, sleep/weight relationship differences between males and females could be associated with hormonal effects, thus meriting further examination.

As this study was cross-sectional in nature, these results cannot exclude the possibility of a third variable that could have a moderating or mediating effect on the relationship between sleep habits and weight status, especially for females. One variable that should be considered in the future is chronotype, i.e., diurnal preference of morningness versus eveningness. Chronotype has been found to impact health-related behaviors in adolescents, including engagement in more physical activity among morning-type adolescents and preference for more sedentary behavior among evening-type adolescents (Olds et al., 2011; Schaal et al., 2010; Urban et al., 2011). Although sex differences in chronotype have been small, males are more likely to be evening-types (Adan & Natale, 2002; Randler, 2007). As eveningness is also related to physical inactivity, this is an important mediator to consider in future studies of sleep/weight status for males and females.

Alternately, the gender-specific findings of the current study offer preliminary evidence that even though sleep duration among children and adolescents who are obese and seeking treatment may be relevant to the level of obesity in both genders, perhaps this is even more important for females. The incongruence with some prior research may be due to differences in study populations. Much of the prior research has included participants across the entire weight spectrum, and those who were overweight or obese were not necessarily seeking weight-loss treatment. The findings from our gender-specific analyses will need to be confirmed by future studies within obese populations, including those seeking treatment for weight loss. There may be salient differences between these groups, including higher parental concern for their children's health among those seeking weight loss treatment that may influence child sleep patterns or parents' willingness to follow up on referrals from their children's medical providers. One strength of the current study is the inclusion of a diverse sample seeking treatment for weight management. Another strength is that because participants were included in the study regardless of their ability to pay for the intervention, we may have been able to capture a more diverse sample than many other clinical samples with participants who were paying for intervention services.

Limitations

The main limitation of this study was that it was cross-sectional, and causation cannot be determined. In a review of this area, theoretically derived rationales were provided to suggest that weight status is likely impacted by sleep habits (Patel & Hu, 2008), but the alternative could be just as likely. Our findings suggest multiple future avenues to be examined to clarify this issue of bi-directionality and inform treatment outcomes. A second limitation is that this study used parental reports of their child's sleep rather than more objective measures (e.g., wrist actigraphy). Evidence indicates that parent self-report and objectively measured sleep duration are highly correlated (Sekine, Chen, et al., 2002; Tikotzky & Sadeh, 2001). We acknowledge, however, that sleep surveys are subject to reporting biases and reflect quantity but not quality of sleep. There was an attempt to control for poor sleep quality by excluding participants with diagnosed obstructive sleep apnea, but some children or adolescents in our sample may have had fragmented sleep due to undiagnosed sleep apnea or other sleep disruptions. Relatedly, children were excluded from this study if they had major psychological or behavioral disturbances that would have interfered with the group treatment format. However, additional psychological variables or medical co-morbidities were not examined as part of this study. In the future, considering psychological variables or additional medical co-morbid symptoms (e.g., hypothyroidism) may be important given the possible mediating effect of many of these variables. Another limitation is that the sleep measure calculates sleep duration based on parent-reported bedtime to wake time. Although sleep duration is often measured in this manner for children and adolescents (e.g., Eisenmann et al., 2006; Shaikh et al., 2009), this does not take into consideration the amount of time that it takes youth to fall asleep and thus may overestimate sleep duration in some youth. Despite the increased possibility of reporting error by obtaining parent-report of sleep habits, relationships between sleep duration and irregularity and weight status were still found within this study, suggesting the strength of these relationships. Seasonal changes in sleep schedules throughout the year were also not taken into account as participants were evaluated for the program throughout the year, including during summer break. This was a diverse sample of children and adolescents referred via multiple means (e.g., physicians, self-referrals, community events), and data about the type of school participation (i.e., brick-and-mortar school, on-line classes, home-schooled, summer school, etc.) and school schedule (e.g., morning versus afternoon kindergarten, earlier versus later start times) were not systematically collected.

Implications for Practice

The present findings, in combination with the existing literature in this area, offer preliminary evidence that pediatricians, weight management providers, and other clinicians within family-centered care practices should inquire regularly about sleep habits and provide assistance and referrals for empirically supported behavioral sleep medicine treatment (e.g., Cognitive Behavioral Therapy for Insomnia [CBT-I]) if indicated, especially when working with pediatric patients who are overweight or obese. Coupled with the mounting evidence from previous studies, our unique focus on sleep and level of obesity within a sample of children and adolescents seeking treatment for weight loss suggests that research examining the integration of empirically-supported behavioral strategies as part of weight loss treatment may be beneficial. Whether or not irregularity should be addressed in weight loss programs is a matter for some debate due to our preliminary findings on sleep irregularity contributing to level of obesity and the findings of a recent Chinese study. Specifically, Wing and colleagues found that children across the weight spectrum who made up for sleep deficits during the week by sleeping more on weekends were less likely to be overweight/obese (Wing et al., 2009). Our findings of sleep irregularity mattering for females merit further investigation, because in our sample females who slept in more on weekends had higher BMI z-scores. Greater research focus is urgently needed in the area of sleep/weight status to inform scientific theories/models, future intervention studies and clinical practice.

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Table 1: Characteristics of the study population

	Overall N = 288	**Males** n = 112 (38.9%)	**Females** n = 176 (61.1%)
Race/ethnicity: Caucasian	52.5%	58.2%	48.9%
Family income < $50,000	51.7%	54.2%	50.0%
Unmarried marital status	37.2%	38.5%	37.3%
Age in years (range: 6-18 yrs)	11.8 (2.7)[a]	11.7 (2.7)	12.0 (2.4)
BMI z-score (range: 1.23-3.26)	2.39 (0.33)	2.45 (0.31)	2.34 (0.34)
Average sleep duration (hours)	8.92 (1.04)	8.90 (0.98)	8.93 (1.08)
Bedtime shift	1.26 (1.02)	1.28 (0.95)	1.25 (1.06)
Wake-time shift	2.10 (1.53)	1.73 (1.41)	2.34 (1.57)
Sleep duration shift	0.85 (1.48)	0.45 (1.29)	1.11 (1.54)

[a] Mean (*SD*) presented unless otherwise noted

Table 2: Multiple regression results

Predictor variables	Beta	SE	Cumulative R^2
Race (White/Non-White)	0.09*	0.04	0.05**
Family income (<$50,000/≥$50,000)	0.16**	0.04	0.11**
Marital status (married/unmarried)	0.01	0.04	0.11
Gender	0.10**	0.04	0.13**
Age	-0.01	0.01	0.13
Average daily sleep	-0.06*	0.02	0.16*
Race (White/Non-White)	0.09*	0.04	0.05**
Family income (<$50,000/≥$50,000)	0.15**	0.05	0.11**
Marital status (married/unmarried)	0.01	0.05	0.11
Gender	0.11**	0.04	0.14**
Age	0.01	0.01	0.14
Bedtime shift	0.02	0.01	0.15
Race (White/Non-White)	0.09*	0.04	0.05**
Family income (<$50,000/≥$50,000)	0.15**	0.04	0.11**
Marital status (married/unmarried)	0.00	0.05	0.11
Gender	0.11**	0.04	0.13**
Age	0.00	0.01	0.13
Wake-time shift	0.02	0.01	0.14
Race (White/Non-White)	0.10*	0.04	0.05**
Family income (<$50,000/≥$50,000)	0.15**	0.05	0.11**
Marital status (married/unmarried)	0.01	0.05	0.11
Gender	0.10*	0.04	0.13**
Age	0.01	0.01	0.13
Sleep duration shift	-0.01	0.01	0.13

Note: Dependent variable is BMI z-score. Beta scores are unstandardized. Variables were added sequentially in each model.
**p < .01, *p < .05

Table 3: Multiple regression results for males and females

Predictor variables	Males			Females		
	Beta	SE	Cumulative R^2	Beta	SE	Cumulative R^2
Race (White/Non-White)	0.05	0.07	0.01	0.13*	0.05	0.11**
Family income (<$50,000/≥$50,000)	0.11	0.07	0.03	0.18**	0.06	0.18**
Marital status (married/unmarried)	-0.04	0.07	0.03	0.05	0.06	0.18
Age	0.01	0.01	0.07	-0.02*	0.01	0.19
Average daily sleep	-0.06	0.03	0.10	-0.07*	0.03	0.22*
Race (White/Non-White)	0.04	0.07	0.01	0.14*	0.06	0.11**
Family income (<$50,000/≥$50,000)	0.10	0.07	0.03	0.18**	0.06	0.19**
Marital status (married/unmarried)	-0.01	0.07	0.03	0.01	0.06	0.19
Age	0.02	0.01	0.07	-0.01	0.01	0.19
Bedtime shift	0.01	0.02	0.07	0.03	0.02	0.20
Race (White/Non-White)	0.04	0.07	0.01	0.14*	0.05	0.11**
Family income (<$50,000/≥$50,000)	0.10	0.07	0.03	0.18**	0.06	0.18**
Marital status (married/unmarried)	-0.01	0.07	0.03	0.01	0.06	0.18
Age	0.02	0.01	0.07	-0.02	0.01	0.19
Wake-time shift	-0.00	0.02	0.07	0.04*	0.02	0.21*
Race (White/Non-White)	0.05	0.07	0.01	0.15**	0.05	0.11**
Family income (<$50,000/≥$50,000)	0.10	0.07	0.03	0.20**	0.06	0.18**
Marital status (married/unmarried)	-0.01	0.07	0.03	0.02	0.06	0.18
Age	0.02	0.01	0.07	-0.01	0.01	0.19
Sleep duration shift	-0.01	0.02	0.07	0.02	0.02	0.19

Note: Dependent variable is BMI z-score. Beta scores are unstandardized. Variables were added sequentially in each model.
** $p < .01$, * $p < .05$