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Original Research

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Objectively measured sleep patterns in obese youth

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ABSTRACT

Purpose: The purpose of this study was to describe sleep patterns in obese children and adolescents seeking treatment at a pediatric weight management program. **Methods:** Participants were 163 patients between the ages of 7 and 17 year (71 males, 92 females; mean 11.8 ± 2.6 year; mean body mass index percentile 97.8 ± 2.2), who were seeking treatment at a multi-disciplinary pediatric weight management program between June 2008 and January 2011. Participants wore the SenseWear Armband continuously for 7 days as part of baseline assessments. In order to be included in the analysis, participants were required to wear the armband for at least 14 h on at least 4 days of the week. Descriptive statistics were determined for the total sample and both sexes. Participants were classified based on sleep time according to three cut-points: 9 h/day, 10 h/day, and 6 h/day. Intra-individual variation was determined from the coefficient of variation (CV). Analyses were performed in October 2011. **Results:** Average daily sleep was 6.8 ± 1.1 h with no differences between sexes. Only 3.1% of the sample slept ≥9 h/day, while 1.2% slept ≥10 h/day. Conversely, 18.4% slept <6 h/day. The mean CV for sleep time was 16.9% and did not differ between sexes. **Conclusions:** These results suggest that few treatment-seeking obese youth meet sleep recommendations. Objective assessment of sleep characteristics is superior to self-report in that it allows for quantification of periods of wakefulness throughout the night that cannot be captured via self-report. Future studies should include evaluation of sleep efficiency and sleep latency to further characterize sleep habits and quality among obese youth.

KEY WORDS: Adolescents, children, multi-sensor motion device, overweight, sleep duration

INTRODUCTION

The secular increase in pediatric obesity seen over the last 30 years [1,2] has resulted in increased attention on lifestyle factors associated with obesity risk. Although physical activity and diet receive much of the attention, another overlooked but equally important factor is sleep [3]. Indeed, several papers have shown the association between short sleep duration and risk of overweight and obesity in children and adolescents [4-9] and a recent meta-analysis indicated a pooled odds ratio for shorter sleep duration of 1.58 (95% confidence interval: 1.26, 1.98) [10]. Furthermore, longitudinal studies have shown that sleep duration predicts subsequent overweight when young children (ages 5-11 year) are reassessed in later childhood [5] or adulthood [4]. The mechanisms by which shortened sleep duration might influence obesity include increased daytime sleepiness, increased sympathetic nervous system activity, altered secretion of hormones (i.e., cortisol, ghrelin, leptin), and impaired glucose tolerance [11,12]. Furthermore, shortened sleep duration is inversely associated with C-reactive protein levels, which may negatively influence vascular function, a parameter that may already be impaired in obese youth [13]. Specifically, sleeping <6 h/day may be associated adverse health conditions [14,15], behavior problems [16], and poor school performance [17,18].

Sleep difficulties that are most strongly associated with obesity include snoring, restlessness during sleep, and waking up throughout the night [19-21]. Among obese children and adolescents, the prevalence of obstructive sleep apnea (OSA) has been reported to range from 13-59% [22]. Recent reports also suggest that obese youth who experience poor sleep quality also experience excessive day time sleepiness and are more likely to exhibit symptoms of attention deficit hyperactivity disorder (ADHD), perhaps as a way to maintain wakefulness [23]. Moreover, severely obese children with OSA experience deficits in learning and memory that may negatively impact academic performance [24].

Most of the previous studies investigating the association between sleep and obesity have utilized self-reported [6,13] or parent-reported [4,5,8,25,26] sleep. There are a limited number of studies that have quantified the sleep habits of obese youth using objective measures. Adolescent-reported measures of sleep have been shown to underestimate sleep time by more than 1 h when compared to time-diaries [27], while parent-reported values fail to reflect night time wakefulness [28] and may overestimate sleep duration. Additionally, the ability of self-report to detect night time wakefulness and restless sleeping is limited. Many of the shortcomings of self-reported and parent-reported sleep assessment can be addressed through the use of objective assessment tools such as accelerometry to quantify sleep characteristics [29]. In light of this information, the purpose of this study was to describe objectively measured sleep habits in a sample of obese children and adolescents seeking treatment at a pediatric weight management program.

METHODS

Participants

This retrospective analysis includes participants who were seeking treatment at a multi-disciplinary pediatric weight management program in New Jersey. A total of 175 patients age 7-17 year who were enrolled in the program from June 2008 to January 2011 wore the SenseWear armband (SWA) for one week as part of standard baseline assessments. Of these, a total of 163 (71 males, 92 females) had at least four quality days of data and were included in the final analysis. The 12 subjects who did not have sufficient SWA data did not differ from those with sufficient data in terms of anthropometric characteristics or age. The general demographics of patients seen at the clinic are as follows: Insurance type – 91% Private, 8% Medicaid, 1% Uninsured; Ethnicity – 82% White, 13% Hispanic, 4% Black, 1% Asian. Data presented here were collected over a 7-day period at baseline, before participants began active treatment. The study protocol was approved by the Human Ethics Committee.

Data Collection

Anthropometrics were obtained during a routine clinic visit. Standing height was measured to the nearest 0.1cm using a wall-mounted Stadiometer (SECA 240). Body weight was measured to the nearest 0.1 kg using an electronic scale (InBody 520 Model MW160, Biospace, Korea). The body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2) and BMI percentile was determined according to the 2000 CDC growth charts [30]. All subjects were at or above the 85th age- and sex-specific percentile for BMI (overweight or obese). Subjects with a BMI at or above the 95th percentile were considered obese, while those at or above the 99th percentile were considered severely obese.

While wrist- and waist-mounted monitors are used most commonly in the literature, the SWA, which is worn on the upper arm and is used to measure physical activity, can also be used to evaluate sleep. The SWA integrates signals from an accelerometer and sensors to detect heat flux, near body ambient temperature, galvanic skin response, and skin temperature to assess movement and energy expenditure. The dual-axis accelerometer allows for determination of body position (i.e., sitting vs. lying down), and the integration of heat-related data allow for increased sensitivity to differentiate periods of sleep versus wakefulness. The skin sensors integrated in the SWA detect when the monitor is worn, allowing for exact measurements of the time the monitor was worn each day. The SWA sleep algorithm has been validated in both free-living and hospital-based environments and accurately identifies sleep onset, waking, and total sleep time [31].

Participants were instructed to wear the SWA 24 h/day for 1 week as part of baseline clinic assessments. Upon completion of 7 days of data collection, participants returned their monitors to the clinic and the data were downloaded and analyzed using SWA web software version 5.1 (Body media, Pittsburgh, PA, USA). In order to be included in these analyses, participants must have worn the armband for a minimum of 14 h (53.8% of the day) on at least 4 days.

Statistical Analyses

Descriptive statistics were determined for the total sample and both sexes. Participants were then classified based on sleep time according to three cut-points: 9 h/day, 10 h/day, and 6 h/day to allow for comparison to previous studies [14,15,17]. These cut points are also comparable to recommendations from the National Sleep Foundation, which suggest that children ages 5-12 year sleep at least 10 h/night [32] adolescents at least 9 h/night [33]. Analyses were completed for the total sample and by age group (children (ages 7-12 year) and adolescents (≥13 year). Age groups were compared for differences in average daily sleep using independent *t*-tests, and the percent of subjects meeting each cut-point was compared using chi-square. To extend beyond the group level descriptive statistics, we also calculated the coefficient of variation (CV = [standard deviation/mean]* 100), a useful statistic to summarize the variability within an individual. The CV was determined for each individual and reported as within-individual CV and group CV. All analyses were performed in October 2011 using SPSS version 19.0 (IBM, Armonk, USA, 2010).

RESULTS

Physical characteristics of the sample are shown in Table 1. Males were significantly taller than females; no other sex differences were found. The average age- and sex-specific BMI percentile was 97.8 ± 2.2 with 30% classified as severely obese (BMI ≥99th percentile). Mean SWA wear time was 1377.6 min/day (~ 23 h/day) and did not differ between boys and girls [Table 1].

Table 1: Physical characteristics of the sample

Characteristics	Males (*n*=71)	Females (*n*=92)	Total (*n*=163)
Age (years)	11.9 (2.6)	11.7 (2.6)	11.8 (2.6)
Height (cm)	154.0 (15.0)*	149.3 (13.7)	151.3 (14.4)
Height percentile	68.3 (29.3)	61.5 (29.4)	0.0 – 99.9
Weight (kg)	73.2 (25.0)	67.5 (19.5)	70.0 (22.2)
Weight percentile	96.8 (10.6)	96.0 (6.0)	96.4 (8.3)
BMI (kg/m²)	29.9 (5.6)	29.7 (5.6)	29.8 (5.6)
BMI percentile	98.2 (1.9)	97.6 (2.4)	97.8 (2.2)
Overweight (*n* [%])	6 (8.5)	7 (7.6)	13 (8.0)
Obese (*n* [%])	65 (91.5)	85 (92.4)	150 (92.0)
Wear time (min)	1375.4 (70.9)	1379.2 (54.4)	1377.6 (61.5)

Values are mean (Standard deviation).*Significant difference ($P<0.05$) between males and females. BMI: Body mass index

Frequency distributions for average daily sleep and daily variability (within-individual and overall mean CV) in sleep duration are shown in Figure 1 and additional aspects of sleep duration are provided in Table 2. Overall, the mean sleep duration was 6.8 ± 1.1 h and this did not differ by sex, age group, or severity of obesity. The mean daily CV for sleep time was 16.9% and did not differ between males and females, age groups, or severity of obesity.

Overall, very few of these overweight and obese youth met recommendations for daily sleep, whether classified according to the 9-h/day or 10-h/day cut-point [Table 2]. Additionally, 18.4% slept <6 h/day. The proportion of subjects meeting sleep recommendations did not differ between age groups; however, 4.3% of adolescents slept at least 10 h/day while none of the children met this criterion ($P = 0.08$). The relatively small sample of overweight participants precludes analysis of differences in the prevalence of meeting recommendations between the overweight and obese categories.

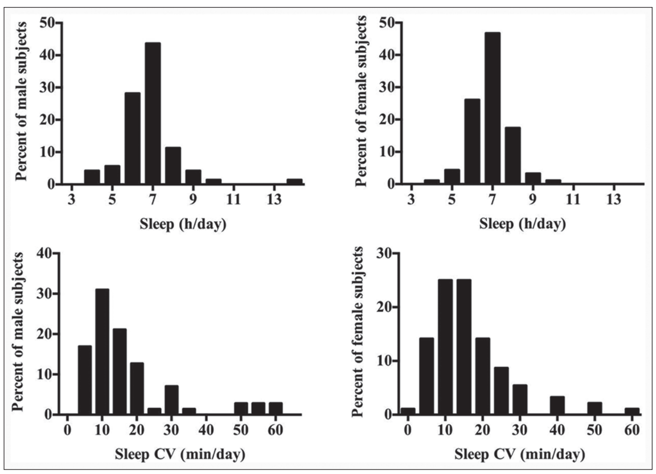

Figure 1: Descriptive statistics and frequency distribution of sleep per day and individual sleep coefficient of variation for males and females

Table 2: Sleep characteristics of overweight and obese youth seeking treatment at a pediatric weight management clinic

Total sample	Males (*n*=71)	Females (*n*=92)	Total (*n*=163)
Sleep (h/day)	6.8 (1.4)	6.9 (0.9)	6.8 (1.1)
≥9 h/day (*n* %)	3 (4.2)	2 (2.2)	5 (3.1)
≥10 h/day (*n* %)	1 (1.4)	1 (1.1)	2 (1.2)
<6 h/day (*n* %)	14 (19.7)	16 (17.4)	30 (18.4)
Ages 5-12 years	**Males (*n*=52)**	**Females (*n*=64)**	**Total (*n*=116)**
Sleep (h/day)	6.7 (1.0)	6.9 (0.9)	6.8 (0.9)
≥9 h/day (*n* %)	2 (3.8)	1 (1.6)	3 (2.6)
≥10 h/day (*n* %)	0 (0.0)	0 (0.0)	0 (0.0)
<6 h/day (*n* %)	11 (21.2)	10 (15.6)	21 (18.1)
Age≥13 years	**Males (*n*=19)**	**Females (*n*=28)**	**Total (*n*=47)**
Sleep (h/day)	6.9 (2.2)	7.0 (1.0)	6.9 (1.6)
≥9 h/day (*n* %)	1 (5.3)	1 (3.6)	2 (4.3)
≥10 h/day (*n* %)	1 (5.3)	1 (3.6)	2 (4.3)
<6 h/day (*n* %)	3 (15.8)	6 (21.4)	9 (19.1)

DISCUSSION

To our knowledge, this is one of the first papers to report free-living, objectively measured sleep in overweight and obese youth seeking treatment at a pediatric weight management center. A low portion (3.1%) of the sample met even the most minimal recommendations for sleep time (≥9 h/day). Moreover, almost 20% slept <6 h/day, a level of sleep that may be associated with adverse health conditions [14,15], behavior problems [16], and poor school performance [17,18]. These results suggest that the assessment of sleep and incorporating intervention components aimed at improving sleep habits is important in pediatric obesity treatment programs.

Previously reported sleep habits of overweight and obese youth vary widely based on the assessment method employed. The average sleep duration in the present study (6.8 ± 1.1 h/day) is slightly greater than that reported in a sample of obese youth complaining of sleep trouble whose sleep was assessed via overnight polysomnogram (6.2 ± 1.2 h/day)[15]. When compared to other studies of overweight and obese children [34] and adolescents [35], our sample slept approximately 1 h less per day (6.8 ± 1.1 h/day vs. 7.9 ± 0.8 h/day and 7.7 ± 0.6 h/day, respectively).

Several papers, examining primarily sleep quantity, indicate that overweight and obese youth tend to sleep less/night than their normal weight peers [8,9,34,35], and that the odds of overweight and obesity increase in an inverse dose-response manner with sleep duration. Other reported odds ratios are not as robust, ranging from 1.0 to 3.0 [34]. Unfortunately, most prior studies – including our own – have consisted of primarily Caucasian samples. The paper by Gupta and colleagues is unique in this sense, including approximately 37% African American and 31% Hispanic participants, respectively. In their study, the odds of overweight and obesity increased as much as eight-fold when youth sleeping <5 h/day were compared to those sleeping at least 8 h/day [35]. These inconsistencies suggest that the relationship between sleep and obesity may vary among children of differing ethnic and/or socio-economic backgrounds.

Clinically, the results of this study suggest that the assessment of sleep patterns during clinical assessment visits and intervention curriculum to improve sleep habits are important in pediatric obesity treatment programs. Poor sleep hygiene may lead to increased daily caloric intake, possibly because children snack late at night or eat more during the day, as has been shown in adults [36]. Pathophysiologically, sleep deprivation could influence the feeding behavior through several pathways including increased sympathetic activity, elevated cortisol and ghrelin levels, and decreased leptin [8,12]. From a behavioral standpoint, obese youth who experience excessive daytime sleepiness may fidget, have trouble concentrating, and otherwise "act out" during the school day. These behaviors may be interpreted as symptoms of ADHD and may result in misdiagnosis and failure to treat the true cause of the behaviors [23]. Moreover, poor sleep quality among obese youth may result from OSA, which may contribute to long-term risk of hypertension, ventricular dysfunction, and cardiovascular disease if left untreated [37]. Each of these concerns is important to address in a pediatric weight management setting as they contribute to overall health and quality of life for this population.

Strength of the present study is the use of the SWA to assess free-living sleep. The SWA integrates information from a bi-axial accelerometer and skin sensors that assess skin temperature, near-body ambient temperature, galvanic skin response, and heat flux to provide accurate estimates of movement and energy expenditure. Although studies employing overnight polysomnography provide highly accurate estimates of sleep time and other variables including time in bed, sleep latency, sleep efficiency, snoring, and even time in each sleep stage, they are limited to the hospital or clinic setting and generally are only prescribed for individuals seeking treatment for sleep difficulty. Other studies have used actigraphy in free-living settings [34,35]. Actigraphy, along with the SWA, allows for estimates of sleep quantity and quality that may more accurately reflect the typical day-to-day sleep habits of children and adolescents. The comparatively reduced cost of actigraphy and the SWA also allows for wider use and facilitates the study of larger samples that are representative of the population as a whole. Actigraphy and the SWA also improve upon self-report measures that may be subject to several biases and cannot accurately reflect night time sleep disturbances, such as short periods of wakefulness. The completion of a 24 h time diary improves on basic question-and-answer self-report, but this also increases subject burden such that it may be difficult to assess several nights of sleep. Additionally, mean SWA wear time was approximately 23 h/day, and as such is a good representation of the full day.

Conversely, the cross-sectional design of this study limits our ability to establish a causal relationship between obesity and sleep habits. More specifically, we are unable to say with certainty whether poor sleep habits have contributed toward weight gain among our sample, or whether their obesity may be contributing directly to their poor sleep habits. Additionally, our relatively small sample size and the lack of a normal weight control group limit our ability to generalize the results of this analysis to the larger population. Finally, we were not able to examine variation is sleep patterns between week days and weekend days.

The results of this study also allow for examination of day-to-day variability in sleep duration. Mean daily CVs for sleep duration were approximately 17%, or 70 min/day. The daily variation in sleep duration in this study is slightly more than that shown in a recent study by Wing *et al*. (1.2 vs. 0.9 h, respectively), in which catch-up sleep was associated with reduced risk of overweight and obesity compared to children who did not compensate for insufficient sleep [25]. Unfortunately, we are able to speculate whether catch-up sleep is reflected in the current study.

In summary, this paper provides evidence for the feasibility of using the SWA for assessing sleep in pediatric weight management clinics. The average sleep was 6.8 ± 1.1 h/day with very few individuals meeting recommendations for daily sleep. This documentation of shortened sleep duration should not be ignored and has important implications for pediatric weight management programs. Future studies including longitudinal designs and objective measures of sleep characteristics in a representative sample of children and adolescents are warranted. Additional assessment of sleep quality, including sleep onset latency, sleep efficiency, restlessness during sleep, and other variables is also important to better understand sleep characteristics of obese youth and guide clinical intervention for these issues.

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