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A retrospective examination of the relationship between body mass index and polysomnographic measures of sleep in adolescents

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Abstract

Total sleep time is inversely related to body mass index (BMI) in adults and children, an observation not well characterized in the adolescent population. We conducted a retrospective chart review that indicated certain sleep disruptions were associated with increased BMI by polysomnography in this group.

Introduction

The prevalence of adolescent obesity in the United States has more than tripled since 1980 [1]. Researchers have listed an array of risk factors for adolescent obesity. One modifiable risk factor that has received little, if any, attention is sleep. However, recent studies in children and adults have shown that total sleep time (TST) is inversely associated with body mass index (BMI) [2–5], an observation not well characterized in adolescents. Individuals in this age group typically require more sleep than they obtain; only 15% of adolescents sleep the recommended 8.5 to 9.25 hours per night [6]. The 2006 *Sleep in America* poll indicates that adolescents typically sleep 7.6 hours on school nights [7]. This observation is likely a consequence of the normal circadian change in sleep that occurs during adolescence which leads to later bed and wake times in combination with early school start times, decreased parental control, and erratic social schedules [8, 9]. Consequences of insufficient sleep among adolescents include increased risk of accidental injury and death, poor academic performance, irritability, and increased stimulant use [10].

To begin a systematic investigation of the relationship between sleep and BMI, we conducted a retrospective chart review of a sample of adolescents who had undergone one night of laboratory based polysomnography (PSG). Based on previous evidence, we hypothesized that there would be a negative association between decreased TST and increased BMI.

Methods

Human subject approval was obtained from the university-hospital IRB. Of the 870 charts reviewed, the sample included 52 adolescents ages 12 to 18 who were evaluated at a university-based sleep clinic for sleep complaints in 2004. Sleep complaints included ruling out sleep apnea, snoring, insomnia, excessive daytime sleepiness (EDS), and ruling out restless leg syndrome (RLS). Exclusion criteria included a previous diagnosis of narcolepsy,

significant medical or psychological problems, or stimulant medication use. Included subjects had undergone a laboratory-based PSG with standard 16-channel montage using a Sonostar Pro Version 6-2b 2004 recording system. A board certified polysomnographer and technicians visually scored the records. Inter-rater reliability for PSG scoring was maintained in the lab above 90% during the study period. Sleep schedules were based on standard lab bed and wake times. Subjects were awakened at a scheduled time.

Height and weight were obtained via parental report, as recorded in the chart. Adolescents were categorized into normal weight (5th to 84th percentile), at risk of overweight (85th to 94th percentile), and overweight (> 95th percentile) groups based on the CDC BMI-for-age and gender specific graphs. Because of the preliminary nature of this study, the significance level was set at $\alpha = .10$. Descriptive and parametric measures (ANOVA, partial correlation) were used for data analysis.

Results

The demographic and clinical features of the sample according to BMI class and for total group are summarized in Table 1. The mean BMI for the total group was 30.3 ± 11.6 , with 53.9% in the overweight category, suggesting that obesity (or overweight) is prevalent in those with sleep complaints. The mean age for the total group was 14.3 ± 1.8 years. In comparison to those who were normal weight, overweight subjects were significantly older, indicating that the prevalence of obesity may increase with age ($F(2,49) = 4.13$, $p = .022$). However, there was no significant age difference observed in the normal versus at risk groups. No significant differences based on gender or race were noted between groups.

PSG measures of sleep for the three groups and the entire group are summarized in Table 2. The mean TST for the entire sample was 311 ± 64 minutes, reflecting a relatively short nocturnal sleep period. Although the non-rapid-eye-movement (NREM; %) sleep stage distribution was relatively unremarkable, a decrease in % REM or active sleep was observed. % REM typically declines during adolescence [9]. The mean sleep onset and REM latencies for the total group were markedly long at 102 ± 61 minutes and 148 ± 72 minutes, respectively. REM sleep latency is the time interval from sleep onset to the first appearance of REM sleep. Sleep efficiency ($71.2 \pm 15.3\%$) was reduced and wake after sleep onset (WASO, $41.5 \pm 54.5\%$) was increased. The prolonged sleep onset, REM latencies, and reduced % REM noted may reflect the first night effect (FNE) and/or delayed sleep phase. FNE is the alteration of the sleep structure and quality in the unfamiliar environment of a sleep laboratory. There were no significant differences between the three groups in TST, total recording time (TRT), % Stage 2, slow-wave sleep (SWS), respiratory disturbances index (RDI; number of apneas and hypopneas or shallow breaths per hour), and limb movements. Significantly more % Stage 1 was observed in the overweight versus normal group ($F(2,49)=3.09$, $p = .055$), reflecting lighter sleep in the overweight group. There was significantly more SWS (sleep stages 3 and 4 or deep sleep) observed in the at risk versus overweight group ($F(2,49)= 2.45$, $p = .097$).

Correlational analyses revealed that after controlling for age, BMI was positively associated with % Stage 1 sleep ($r = .87$, $p = .001$) and negatively associated with % Stage 4 sleep ($r = -.55$, $p = .10$). Taken together, the data indicate that lighter sleep and less deep sleep were associated with increased BMI.

A multiple regression analysis was conducted to predict the overall BMI from gender and age. The results of this analysis indicated that gender and age accounted for a significant amount of BMI $R^2 = .24$ ($F(2,48) = 7.47$, $p = .002$). Further analysis found TST, arousals per night, and RDI accounted for a significant proportion of the BMI variance controlling for the

effects of gender and age R^2 change = .09 ($F(1,45) = 6.37, p = .015$). From the model, only age and RDI were significant predictors.

Discussion

These results provide some provocative insights into the association between sleep and obesity in adolescents. Over 50% of this sample of adolescents with sleep-related complaints was overweight and older than normal weight teens. Thus, sleep problems appear to be associated with obesity and increasing age. BMI was not associated with TST, however BMI was associated with lighter and less deep sleep.

The study has several limitations because of its retrospective design, the single night of PSG, restriction of sleep lab procedures, and the parental report of weight. One night of PSG may not optimally reflect typical adolescent sleep. Thus, more accurate and simple measures, such as questionnaires and diaries completed by the adolescent along with wrist actigraphy over a longer time span, should be considered.

Further evaluation of this population may offer insights into the biological mechanisms underlying the relationship between sleep and obesity. Sleep loss may cause fatigue dissuading physical activity and hunger for carbohydrate-rich foods which could increase the risk of weight gain. Prior obesity interventions have had limited success, possibly because of the failure to appreciate the important potential association between sleep and obesity.

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Table 1

Demographic and clinical features of the sample

	Normal	At Risk of Overweight	Overweight	Total Group
N (%)	18 (34.6%)	6 (11.5%)	28 (53.9%)	52 (100%)
Age	13.4 ± 1.7	15.0 ± 2.0	14.8 ± 1.7	14.3 ± 1.8
Gender (%)				
Male	22.2%	33.3%	42.9%	34.6%
Female	77.8%	66.7%	57.1%	65.4%
Race N(%)				
White	10 (55.6%)	4 (66.7%)	13 (46.4%)	27 (51.9%)
Black	6 (33.3%)	2 (33.3%)	12 (42.9%)	20 (38.5%)
Hispanic	1 (5.6%)	-	3 (10.7%)	4 (7.7%)
Unknown	1 (5.5%)	-	-	1 (1.9%)
BMI	19.4 ± 2.1	25.1 ± 1.9	38.4 ± 9.9	30.27 ± 11.6
Sleep Complaints N (%)				
Sleep Apnea	6 (33.3%)	3 (50%)	16 (57.1%)	25 (48.1%)
Snoring	4 (22.2%)	1 (16.7%)	2 (7.1%)	7 (13.5%)
Insomnia	2 (11.1%)	1 (16.7%)	3 (10.7%)	6 (11.5%)
EDS	3 (16.7%)	-	3 (10.7%)	6 (11.5%)
RLS	3 (16.7%)	1 (16.7%)	1 (3.6%)	5 (9.6%)
Pre-op	-	-	3 (10.7%)	3 (5.8%)

Table 2

Sleep measures by weight group

	Normal Weight	At Risk of Overweight	Overweight	Total Group
PSG Sleep Measures				
Total Recording Time(min)	447 ± 39	437 ± 44	442 ± 44	443 ± 42
Total Sleep Time (min)	313 ± 57	263 ± 92	319 ± 60	311 ± 64
Sleep Latency (min)	120 ± 60	111 ± 48	88 ± 63	102 ± 61
REM-Latency (min)	156 ± 78	101 ± 15	154 ± 74	148 ± 72
Stage 1 (%)	2.5 ± 2.7*	4.8 ± 3.5	6.1 ± 5.9*	4.7 ± 4.9
Stage 2 (%)	44.8 ± 12.8	40.3 ± 6.3	47.8 ± 10.8	45.9 ± 11.2
SWS (%)	29.7 ± 10.7	42.0 ± 58.1*	22.5 ± 7.5*	27.2 ± 20.9
REM (%)	15.7 ± 9.3	16.7 ± 8.6	12.6 ± 7.2	14.1 ± 8.1
Sleep Efficiency (%)	70.8 ± 14.7	64.8 ± 17.7	72.9 ± 52.9	71.2 ± 15.3
WASO (%)	34.1 ± 48.6	63.6 ± 78.2	40.9 ± 52.9	41.5 ± 54.5
Sleep Disturbance Indices				
RDI (events/hour)	1.9 ± 3.9	.9 ± .8	6.9 ± 12.1	4.5 ± 9.5
Hypopnea (events/hour)	6.2 ± 15.9	.0 ± .0	25.2 ± 48.1	15.7 ± 37.2
Limb Movements (events/hr)	1.3 ± 3.7	9.1 ± 9.9	5.5 ± 11.8	4.5 ± 9.8

* Significances between groups occurred