CLINICAL SCHOLARSHIP

Sleep, Hunger, Satiety, Food Cravings, and Caloric Intake in Adolescents

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Sleep, adolescent health, obesity, food cravings

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Abstract

Background and Purpose: Prevalence of adolescent obesity has increased worldwide. Although diet and exercise patterns are major determinants of weight, recent studies with adults and children have shown that total amount of sleep is inversely associated with body mass index (BMI). The purpose of this study was to examine associations among total sleep time (TST), hunger, satiety, food cravings, and caloric intake in a sample of healthy adolescents.

Design-Methods: Participants were recruited from the community and a local high school. Demographic data such as sleeping habits, pubertal status, food cravings, caloric intake, physical activity, height, and weight were collected between October 2006 and April 2007. Participants also completed a 7-day sleep-hunger-satiety diary. Descriptive and parametric procedures were used for data analyses ($\alpha=.05$).

Findings: The sample ($N=85$) included 56% females ($n=48$), 76% African American ($n=65$) adolescents. Mean age was 15.6 ± 1.4 years and mean BMI was 24.3 ± 5.4 kg/m². Mean reported 7-day cumulative nocturnal sleep was $52.9 (\pm 6.0)$ hours; mean reported cumulative daytime sleep (or napping) was $3.7 (\pm 3.4)$ hours. Multiple regression analyses showed age, gender, and race were associated with feelings of hunger, satiety, total food cravings and caloric intake. A greater total food-cravings score was associated with increased daytime sleep.

Conclusions: These findings indicate an unexpected association between increased daytime sleep and eating behaviors that potentially lead to obesity. Longitudinal studies using objective measures of sleep, appetite regulation, and caloric intake are needed to better understand relationships between appetite and sleep in adolescents from varying racial and gender groups.

Clinical Relevance: By carefully considering adolescent sleep (especially daytime sleep), race, and gender, clinicians and school health nurses in the US and other countries are in a unique position to develop novel approaches to prevent and reduce obesity.

Obesity is a significant problem and is increasing worldwide (Popkin & Gordon-Larsen, 2004). Increases in obesity rates are noted in both developed and developing countries (Kosti & Panagiotakos, 2006). In 2004, 17.4% of U.S. adolescents aged 12–19 years were overweight as compared to 5% in 1980 (Ogden et al., 2006). An ar-

ray of nonmodifiable (e.g., genetic disorder) and modifiable (e.g., diet, physical activity) risk factors for adolescent obesity compounds this problem globally (Centers for Disease Control [CDC], 2007).

One modifiable risk factor that has received little attention is quantity of sleep. Adolescents typically require

more sleep than they obtain and are at high risk for the consequences of sleep deprivation (Carskadon, 2002). Recent studies in children and adults have shown that TST is inversely associated with body mass index (BMI), but similar studies are needed in adolescents (Gangwisch, Malaspina, Boden-Albala, & Heymsfield, 2005; Reilly et al., 2005). Sleep-deprivation-related changes are believed to adversely affect selected endocrine system function and metabolic pathways, leading to decreased satiety and energy expenditure, and increased hunger, food cravings, and caloric intake in adults (Spiegel, Tasali, Penev, & Van Cauter, 2004; Taheri, Lin, Austin, Young, & Mignot, 2004).

The adolescent developmental period may be an optimal time to address modifiable risk factors, since obesity in adolescence is a strong predictor of obesity in adulthood (Gordon-Larsen, Adair, Nelson, & Popkin, 2004). Previously tested interventions aimed at adolescent diet and physical activity patterns have had limited success (Johnson-Taylor & Everhart, 2006), possibly because of failure to appreciate an association between TST and appetite regulation. Thus, the purpose of this study was to examine associations between TST (daytime and nocturnal sleep) and outcomes of hunger, satiety, food cravings, and caloric intake in a sample of otherwise healthy adolescents.

Conceptual Framework

The theoretical context for this study was a biobehavioral-ecological framework, derived by the

researcher from a synthesis of scientific and theoretical literature (see **Figure**). The framework, which is not fully tested, is focused on demographic, biologic, and behavioral-environmental risk factors for and consequences of decreased TST that could ultimately contribute to increased BMI.

Demographic factors That contribute to decreased TST in adolescents include age, race, and gender. Longitudinal sleep studies show that older teenagers sleep less than do younger teens, delay bedtime, and increase weekend TST to compensate for sleep deprivation accumulated during the school week (Carskadon, 2002). Gender and race are associated with differences in reported sleeping and waking patterns in children (Crosby, LeBourgeois, & Harsh, 2005; Giannotti & Cortesi, 2002).

Biological changes in sleep also contribute to decreased TST. Well-controlled studies have indicated that a marked linear decline in slow-wave sleep (NREM sleep stages 3 and 4) occurs as teens age (Carskadon, 2002). In addition, adolescents experience a significant increase in sleep tendency during the daytime (greater sleepiness) at higher maturation levels (Carskadon, 1990). They also experience a shift in circadian rhythm in which they tend to stay up later at night and to sleep later in the morning, delaying the timing or phase of their nocturnal sleep period. This pattern has been reported in numerous studies from a variety of countries (Gau & Soong, 2003; Giannotti & Cortesi, 2002; Wolfson & Carskadon, 1998).

TST can be influenced by behavioral and environmental factors, including decreased parental control over curfews and volitional behaviors such as socializing with

Figure. Decreased total sleep time and increased BMI in adolescents.

peers, increased TV viewing and computer use, and evening social activities (Carskadon, 2002). Adolescents also have increased academic obligations, often overcommit to extracurricular activities and part-time employment, and tend to experiment with drugs (including nicotine) and alcohol, which can interfere with TST. Also, adolescents in the US must often rise early in the morning because of school start times, which typically become progressively earlier as students progress from middle to high school (Wolfson & Carskadon, 1998).

Consequences of decreased TST. Only 9% of 9th to 12th graders sleep optimal amounts (>9 hours) on school nights (Summary of Findings, 2006). Inadequate amount of sleep can lead to a variety of cognitive changes and alterations in endocrine system function and metabolic pathways. Cognitive consequences of decreased TST include sleepiness (inability to maintain the awake state (Wolfson & Carskadon, 1998). Fatigue (mental or physical exhaustion) may occur in response to decreased TST, but the relationship of fatigue to daytime sleepiness and TST is unclear (Ancoli-Israel, 2005). Both sleepiness and fatigue may decrease the motivation to maintain a healthy balance between energy consumption and expenditure.

Many hormones (e.g., insulin, hypocretin) may mediate interactions between decreased TST and increased BMI. A decrease in TST has been associated with reduction of the normal nocturnal secretion of leptin (a hunger-suppressing hormone) and reduced suppression of ghrelin (a hunger-stimulating hormone) in young adults, leading to alterations in appetite and energy balance (Spiegel, Leproult, & Van Cauter, 1999; Taheri et al., 2004).

In summary, evidence links decreased TST and increased BMI in adults and young children. Adolescents are known to have reduced TST. Demographic, biological, behavioral, and environmental factors contribute to their risk for sleep loss. Decreased TST and adolescence could, in turn, be associated with altered hunger, satiety, food cravings, and caloric intake.

Methods

Population and Sample

A majority of the sample was recruited from the community and a large public high school (grades 9–12), with a predominantly African American (>90%) racial profile. In order to participate in the study, participants had to be: (a) age 14–18 years old, (b) able to speak and read English, (c) enrolled full-time in school, and (d) reachable by telephone. Exclusion criteria included: (a) a history of chronic or underlying conditions associated with

sleep disturbances, (b) routinely taking medications that may adversely affect sleep, and (c) a BMI < 5th percentile. Because of limited numbers of prospective Asian and Hispanic participants, only African American and Caucasian students were included in the study. The final sample consisted of 85 healthy adolescents.

Measures

Participant screening form, school sleep habits survey, and pubertal status. The participant screening form included demographic data such as age, gender, race, and exclusion criteria. Descriptive data on certain sleeping and waking behaviors (such as part-time employment) during the previous 2 weeks were assessed using a previously validated School Sleep Habits Survey (Wolfson & Carskadon, 1998). Pubertal status was assessed using the Self-Rating Scale for Pubertal Development (Carskadon & Acebo, 1993), on which participants report growth in height and body hair, skin changes, and facial-hair growth (boys only) and breast development and menarche (girls only). For each item, scores range from 1 (prepubertal) to 4 (full maturation). Coefficient alphas for the pubertal scale were .67 (boys) and .58 (girls).

Body mass index. BMI (kg/m^2) was calculated from measures of height and weight. BMI is accepted as a reliable and valid index of relative adiposity in adolescents (Mei et al., 2002). Height was measured using a portable stadiometer (Seca Portable Stadiometer Model 214) and weight with a calibrated scale (Tanita Electronic Scale BWB-800S). BMI was transformed into age- and sex-specific percentiles and classifications (normal, at risk for overweight, overweight) as defined per Centers for Disease Control and Prevention guidelines (CDC, 2008).

Caloric intake and energy expenditure (from physical and sedentary activity). Caloric intake and energy expenditure were measured using standardized-format interviews. For caloric intake, the researcher used standardized probe questions to elicit specific details of all foods, including cooking methods and brand names, and beverages consumed in the previous 24 hours. Empty containers (e.g., 20 oz. plastic soda bottle), a set of measuring cups, household items, and unused cafeteria dishes were used to quantify portion sizes. The list of food and beverages was entered into Nutritionist Pro™ (Axxya Systems LLC; Stafford, TX), a nutrition-analysis software program to calculate total energy consumption (kilocalories [kcal]). A previous study comparing the 24-hour diet recall with the Block Kids Questionnaire of adolescents aged 12–17 years resulted in a modest correlation for caloric intake ($r=0.58$; Cullen, Watson, & Zakeri, 2008). For energy expenditure (i.e., kcal expended),

physical and sedentary activity were assessed using the interviewer-administered Physical Activity Checklist Interview (PACI; Sallis et al., 1996), then the metabolic equivalent (MET) value and duration (hours) of each activity were multiplied by body weight in kilograms. The PACI allows measuring a student's participation in various physical and selected sedentary activities (television viewing, computer use, and playing video games) during one 24-hour period. All activities were summed to determine the total estimated minutes spent doing physical activity and the physical activity MET scores. Previous reports on the PACI indicating self reported and interviewer-administered activity recall found intraclass correlations ranging from .64 to .79 (Sallis et al., 1996).

Food cravings. Food cravings of a participant were measured using the Food Craving Inventory (FCI-II; White, Whisenhunt, Williamson, Greenway, & Nete-meyer, 2002). The FCI-II is a 28-item self-report measure of specific food cravings during the past month, scored on a Likert scale (1=*Never* to 5=*Always*, Almost every day). It has four subscales: sweets, carbohydrates-starches, high fat foods, and fast-food fats (e.g., pizza). The responses were averaged to obtain a "Total Food Cravings Score." Reported internal consistency for the four subscales ranges from .76 to .93 (White et al., 2002), and for this sample, coefficient alphas ranged from .68 to .83.

Seven-day sleep, hunger, and satiety diary. Participants were asked to complete a sleep diary beginning on a Monday for 7 consecutive nights. They recorded their bedtime and awake time each day, and the number and duration of naps. "Cumulative nocturnal sleep" was the sum of the number of hours recorded between bedtime and wake-up time for all 7 nights. "Cumulative daytime sleep" (or naps) was the sum of the number of hours of sleep recorded from awake-time to bedtime for all 7 days. "Cumulative nocturnal-daytime sleep" was the sum of nocturnal and daytime sleep. Sleep diaries have shown satisfactory validity ($r=0.97$) in comparison to objective measures (actigraphy) in the adolescent population (Gaina, Sekine, Chen, Hamanishi, & Kagamimori, 2004).

Hunger and satiety were also measured based on sleep diary methodology using a 7-day diary. Participants responded to the following questions each day: "How hungry were you when you woke up?" "How hungry were you after school (or mid-day)?" and "How hungry do you feel right now, before bed?" Responses were rated on an 11-point horizontal scale with 0=*Not hungry at all* to 10=*Extremely hungry*. Higher scores represent greater perceived hunger. Cumulative hunger scores for waking up, after school (mid-day), and before bed were calculated as the sum of the hunger scores for all 7 days. Participants

also responded to questions about how full they felt 30 minutes after breakfast, lunch, and dinner on an 11-point scale with 0=*Not full at all* to 10=*Extremely full*. Higher scores indicate greater perceived satiety or fullness. If a participant skipped a meal, "Did not eat" was noted. Cumulative satiety scores for breakfast, lunch, and dinner were calculated as the sum of the satiety scores for all 7 days.

Procedures

The study was conducted from October 2006 to April 2007, excluding school breaks, standardized testing periods, and the week following the transition to daylight savings time. The Institutional Review Board for Protection of Human Subjects at Emory University and the county school district approved the study. Potential high school participants were recruited at the beginning of class; the researcher gave a short presentation describing the study. Forms were distributed to assess student interest, obtain contact information, and request permission to call parents-guardians. For all prospective participants, parents-guardians were contacted to request a meeting at their home or a designated school office with their child. Those volunteering to participate gave written informed consent and assent. Immediately after obtaining consent, interviews on physical activity and diet were conducted, surveys administered, height and weight measured, and a 7-day sleep-hunger-satiety diary initiated. Participants were given verbal and written instructions on how to complete and return the diary and received phone or e-mail prompts during the week reminding them to complete the diary.

Data Analysis

All analyses were performed using SPSS software version 15.0. A mean cumulative bedtime, wake-up time, or hunger score was entered for any missing data in the participant's sleep diary (<1.0% missing data for each variable). Participants who reported skipping a specific meal on the satiety diary were excluded from regression analyses predicting satiety for that specific meal. We used descriptive statistics to summarize sample demographic and clinical features. The variables kilocalories and hunger before bed were transformed to correct for moderate skewness of the data. Cumulative daytime sleep was recoded into a categorical variable with three levels (no daytime sleep, between 0–2.9 hours, >2.9 hours per week; the latter two categories were based on a median split) yielding groups of approximately equal sample size. This variable was transformed into two dummy variables for inclusion in the regression analysis. Separate backward

Table 1. Demographic, Biological, and Behavioral/Environmental Features of the Sample (N=85)

Variable	Mean (SD)	Minimum	Maximum
Demographic variables			
Age (years)	15.6 (1.4)	14.0	18.0
Females (n/%)	48/ 56.5%		
African American (n/%)	65/ 76.5%		
BMI (kg/m ²)	24.3 (5.4)	16.6	43.4
Behavioral-environmental variables			
Total minutes physical activity (24-hr period)	128.3 (85.4)		
Total minutes sedentary activity (24-hr period)	197.2 (137.4)		
School-night bedtime (SD in minutes)	11:40 pm (61)		
School-day wake time (SD in minutes)	6:30 am (32)		
Weekend bedtime (SD in minutes)	11:55 pm (77)		
Weekend wake time (SD in minutes)	9:02 am (98)		
Part-time job (n/%)	12/ 14.1%		
Extra-curricular activities (n/%)	33/ 38.8%		
Sports (n/%)	40/ 47.1%		
Tobacco use—once or twice per day (n/%)	1/ 1.2%		
Illicit drug use—once or twice per day (n/%)	3/ 3.5%		
Alcohol use—once or twice per day (n/%)	3/ 3.5%		

multiple linear regression analyses were performed to determine which independent variables from the conceptual framework (TST [daytime and nocturnal sleep], age, gender, race, puberty category, energy expenditure [from physical and sedentary activity]) explained the greatest amount of variance in each dependent variable (satiety, hunger, food cravings, and caloric intake) separately. Effect sizes for the multiple regressions were measured using Cohen's f^2 calculation. Cohen's f^2 effect sizes of .02, .15, and .35 are considered small, medium, and large, respectively (Cohen, 1988). A significance level of $\alpha=.05$ was selected for all analyses.

Results

Sample demographic features are shown in **Table 1**. Over 40% of the sample was overweight (>85th percentile). The sample spent more time participating in sedentary than in physical activities. Sleep, hunger, satiety, food cravings, caloric intake, and energy expenditure variables are shown in **Tables 2 and 3**. The mean reported school night nocturnal sleep for the sample was approximately 7.5 hours; this is much less than the optimal 9 hours of sleep per school night (Summary of Findings, 2006). Cumulative nocturnal sleep did not significantly differ between race and gender. Mean reported school night and weekend nocturnal sleep were statistically different ($t=-7.73$, $df=84$, $p<.01$) and indicates participants accumulated a "sleep debt" over the week. Independent t -tests showed that mean nocturnal sleep for

those who napped was significantly lower than for those who did not nap ($t=2.03$, $df=83$, $p=.05$).

Results of the multiple regression analyses are shown in **Table 4**. Race was an independent predictor for the hunger and satiety regression models indicating that African American adolescents had decreased hunger

Table 2. Nocturnal, Daytime, Nocturnal-Daytime Sleep Variables of the Sample (N=85)

Variable	Mean (SD)
Nocturnal sleep (hours)	
Cumulative nocturnal sleep	52.9 (6.0)
Mean school-night nocturnal sleep	7.37 (.9)
Mean weekend nocturnal sleep	8.04 (1.3)
Daytime sleep (hours)	
Cumulative daytime sleep	3.7 (3.4)
Mean school daytime sleep	1.23 (.8)
Mean weekend daytime sleep	1.73 (1.4)
Daytime sleep categories (%)	
No daytime sleep	38.8%
Between 0–2.9 hours	29.4%
>2.9 hours	31.8%
Nocturnal-daytime sleep (hours)	
Cumulative nocturnal-daytime sleep	55.1 (6.4)

Note. Cumulative Nocturnal, Daytime, and Nocturnal-Daytime Sleep are the sum of the number of reported hours of sleep for all 7 days. Mean School Night and Weekend Nocturnal Sleep and Mean School and Weekend Daytime Sleep are the number of reported hours of sleep per day. Cumulative daytime sleep was recoded into a categorical variable with three levels (no daytime sleep, between 0–2.9 hours, and >2.9 hours per week).

Table 3. Hunger, Satiety, Food Cravings, Caloric Intake, and Energy Expenditure of the Sample (N=85)

Variable	Mean (SD)	Minimum	Maximum
Hunger			
Upon awakening	27.9 (15.2)	0.0	62.0
After school mid-day	39.1 (12.7)	6.3	65.0
Before bed	18.7 (13.0)	0.0	52.0
Satiety			
After breakfast ^a	39.4 (13.2)	12.8	70.0
After lunch ^b	43.9 (10.9)	14.0	69.0
After dinner ^c	50.4 (12.9)	19.8	70.0
Food cravings			
High fats	2.1 (.7)	1.0	4.1
Sweets	2.9 (.9)	1.0	4.6
Carbohydrates-starches	2.3 (.7)	1.0	3.8
Fast foods	2.9 (1.0)	1.0	4.5
Total score	2.5 (.7)	1.1	3.9
Caloric intake	2194.2 (820.7)	642.0	4398.1
Energy expenditure	916.6 (451.3)	234.0	2298.3

Note. Upon Awakening, After School/Mid-day, Before Bed, After Breakfast, After Lunch, and After Dinner are the sum of the hunger and satiety scores for all 7 days. Possible scores range from 0 to 77. Higher scale values indicate greater perceived hunger or satiety. Food-craving scores range from 1 to 5 with 1 indicating *Never* and 5 indicating *Always-Almost every day*. Caloric Intake and Energy Expenditure are in kilocalories per 24 hours. ^aN=48 because of excluding those who did not eat breakfast. ^bN=75 because of excluding those who did not eat lunch. ^cN=83 because of excluding those who did not eat dinner.

upon awakening and decreased feelings of satiety (or fullness) after breakfast and lunch compared to Caucasian adolescents. Race and daytime sleep were the only significant predictors in the regression model indicating that

perceived total food cravings were greater in younger African American adolescents than in other adolescents in the sample and were associated with increased daytime sleep. Age and gender were the only significant predictors in the model indicating that caloric intake was higher in younger male adolescents. There were no significant predictive models for satiety after dinner or hunger after school and before bed. The models resulted in “medium” effect sizes for satiety after breakfast, total food cravings, and caloric intake.

Discussion

Our findings are similar to those of other studies of sleep in adolescents in terms of reported decreased TST, late school-night bedtimes, late rising times on weekends, and early school times (Carskadon, 1990; Wolfson & Carskadon, 1998). One outcome of this lifestyle for certain adolescents is insufficient nighttime sleep, possibly manifesting as compensatory napping (or daytime sleep). In this study, increased daytime sleep was associated with decreased nocturnal sleep; it significantly predicted total food cravings. The findings support an unexpected association between daytime sleep and eating behaviors that potentially lead to obesity. Nonetheless, many adolescents have too little sleep at the incorrect circadian phase (Carskadon, Acebo, & Jenni, 2004). This pattern is associated with increased risk for daytime sleep and may disrupt the diurnal rhythm of appetite-regulating hormones. Future studies including appetite markers such as serum leptin may help explain these unexpected results.

Table 4. Results of Multiple Regressions to Predict Hunger, Satiety, Food Cravings, and Caloric Intake (N=85)

Variable	B	SE	t	P-value	Model	f ²
Variables to predict hunger upon awakening	−7.59	3.81	−	.05*	R ² = .05, F (1, 83)=3.97, p=.05	.05 ^a
Race			1.99			
Variables to predict satiety after breakfast	−	3.69	−	.01*	R ² = .16, F (1,46 ^c)=8.78, p<.01	.19 ^b
Race	10.94		2.96			
Variables to predict satiety after lunch	−8.26	2.72	−	<.01*	R ² = .11, F (1,73) ^d =9.24, p<.01	.13 ^a
Race			3.04			
Variables to predict total food cravings	−0.09	0.05	−	.06	R ² = .18, F (3,81)=5.89, p<.01	.22 ^b
Age	0.43	0.16	1.89	.01*		
Race	0.31	0.15	2.60	.04*		
Daytime sleep (>2.9 hours)			2.10			
Variables to predict caloric intake	−1.39	0.64	−	.03*	R ² = .14, F (3,81)=4.31, p=.007	.16 ^b
Age	−5.76	1.92	2.18	<.01*		
Gender	3.97	2.04	−	.06		
Daytime sleep (>2.9 hours)			3.00			
			1.94			

Note. Race (Caucasian=0, African American=1). Gender (Male=0, Female=1). B=unstandardized beta coefficient. f²=Cohen's f², ^asmall effect size, ^bmedium effect size. *p=.05. ^cN=48 because of excluding those who did not eat breakfast. ^dN=75 because of excluding those who did not eat lunch.

Our understanding of the role of sleep in the regulation of appetite is relatively limited, especially in adolescents. Leptin, a hormone released by the adipocytes in adipose tissue, provides information about energy status to hypothalamic regulatory centers (Ahima, Saper, Flier, & Elmquist, 2000). Leptin levels are reciprocally related to changes in hunger and typically fluctuate in a diurnal pattern with lower levels during the day in relation to periods of increased hunger and higher levels during the night in relation to normally low hunger levels (Chin-Chance, Polonsky, & Schoeller, 2000). In contrast to the anorexigenic effects of leptin, ghrelin is a peptide produced predominantly in the stomach that stimulates appetite (van der Lely, Tschop, Heiman, & Ghigo, 2004). Ghrelin concentrations also follow a diurnal rhythm with higher levels during the day in association with increased hunger and lower levels during the night when hunger is normally low (Muccioli et al., 2002). Thus, leptin and ghrelin have a reciprocal relationship, and sleep loss seems to alter these hormones in a way that could promote food intake and the development of obesity (Mullington et al., 2003).

A leading study in adults exhibited decreased levels of leptin, increased levels of ghrelin, and an increase in reported hunger and appetite for calorie-dense foods with high carbohydrate content after a 2-night sleep restriction (Spiegel et al., 2004). In this study, further analysis of the total food cravings score subscales showed similar findings. Cravings for carbohydrate-starch and high fat foods were greater in those with increased daytime sleep. Thus, the amount of daytime sleep observed in this study may alter normal endocrine and metabolic processes thus affecting certain food cravings.

Results of this study suggest possible racial and gender differences in hunger, satiety, caloric intake, and food cravings, which may predispose a certain race or gender to risk of obesity. Although racial and gender differences in sleep among adolescents are not well described in the literature, such differences in appetite regulation are striking. A recent study of African American youth aged 7- to 12-years-old indicated lower ghrelin suppression after eating a meal when compared to Caucasian youth (Bacha & Arslanian, 2006). Alteration in meal-induced ghrelin suppression could account for the hunger and satiety differences between African American and Caucasian adolescents. In addition, an earlier study indicated significantly higher serum leptin levels in female participants compared to male participants during pubertal development (Blum et al., 1997). In addition, the most recent U.S. National Health and Nutritional Examination Survey (NHANES) data (2003–2004) indicates continuing significant differences in obesity prevalence by racial group for both sexes. For adolescents

aged 12–19 years, the prevalence rate of overweight was highest among non-Hispanic Caucasian male participants (19.1%) and non-Hispanic African American female participants (25.4% females; Ogden, et al., 2006). Thus, race and gender might be considered significant predictors of appetite regulation and BMI indicating direction for further research.

Several intrinsic limitations to this study are noted. Sleep data were reported subjectively. Self-report sleep diaries are subject to recall biases and missing data, as well as imprecision with respect to reporting bed and wake times. Likewise, use of a single 24-hour diet recall may not have sufficiently described an individual's usual caloric intake; multiple pass 24-hour recalls on the same individual over several days are required to increase reliability (Gibson, 2005). Similarly, in this study, we did not measure socioeconomic and physiological variables in association with appetite regulation and BMI. In addition, this study is a cross-sectional analysis using a non-random sampling procedure that means only associations are presented and generalizability of the results is limited. Nonetheless, the study indicates preliminary support for future studies to understand the causal pathway of how TST of adolescents may foster weight gain and possibly obesity by affecting appetite regulation, food cravings, and caloric intake.

Conclusions

These data show an unexpected association between daytime sleep (which may reflect an increased need for nocturnal sleep) and behaviors, such as greater food cravings that can potentially lead to obesity. They also indicate that targeted attention could be given to age, racial, and gender differences that may influence hunger, satiety, food cravings, and caloric intake and put adolescents from different racial and gender groups at greater risk for obesity. The regression models indicate that daytime sleep was a significant predictor of total food cravings after controlling for age, gender, race, puberty status, and energy expenditure. Future studies that incorporate longitudinal design, random selection sampling to assure external validity, and objective measures of sleep, appetite regulation, and caloric intake are required to better understand how daytime sleep may affect appetite regulation.

The conceptual framework used in this study indicated demographic, biologic, and behavioral-environmental risk factors for and consequences of decreased TST in the sample; it also showed which variables (TST, age, gender, race, puberty category, energy expenditure) explained the greatest amount of variance in satiety, hunger, food cravings, and caloric intake. While the conceptual model

was not fully tested, support for its continued study is warranted to determine if changes in satiety, hunger, food cravings, and caloric intake can ultimately contribute to an increase in BMI. The rising epidemic worldwide in overweight and obese adolescents requires urgent attention. Clinicians and school health nurses in the US and other countries are in a unique position to develop novel approaches to preventing and reducing obesity.

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Clinical Resources

- Web site for International Obesity Taskforce: <http://www.ietf.org>
- Web site about teens and sleep from National Sleep Foundation: <http://www.sleepfoundation.org>
- Teen obesity Web site from CDC: <http://www.cdc.gov/nccdphp/dnpa/obesity/childhood/index.htm>

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