NEW RESEARCH

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Caffeine and Screen Time in Adolescence: Associations with Short Sleep and Obesity

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SCIENTIFIC INVESTIGATIONS

Objective: To investigate the associations between sleep duration and obesity incidence and risk factors among pre-adolescents and adolescents.

Design: Cross-sectional study of a community based cohort

Setting: The Tucson Children's Assessment of Sleep Apnea follow-up study (TuCASA) cohort.

Participants: 319 Caucasian and Hispanics between 10-17 years.

Main Outcome: Parent-reported sleep duration and BMI z-score.

Outcome Measures: Surveys of electronic screen time, dietary and caffeine intake, exercise and sleep habits by parents, and anthropometric measures.

Results: Parent-reported total sleep time (TST) was inversely associated with BMI z-score, but not significantly correlated with any of the examined nutritional variables or exercise components. Hispanic ethnicity was associated with significantly lower parent-reported TST and higher BMI z-score. Parent-reported TST was inversely related to electronic screen time and caffeine use, but these findings were differentially related to age. Caffeine consumption was associated with decreasing parent-reported TST primarily in older adolescents. Electronic screen time was associated with lower parent-reported TST in younger adolescents.

Conclusions: Hispanic ethnicity and parental reports of TST were found to be the most closely associated with BMI z-score. Decreased TST and increased caffeine intake and screen time may result in higher obesity risk in the adolescent population.

Keywords: Obesity, adolescent, sleep, caffeine, Hispanic, video games

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The epidemic increase in adolescent obesity as well as the risk of negative health and quality of life consequences has been well documented.[1,2] Environmental factors contributing to this trend include lack of physical activity, increased consumption of energy dense foods (which are heavily marketed toward the adolescent age group), and increased inactivity, associated with the pervasive use of electronic media (screen time). Laurson and others found that children not meeting the American Academy of Pediatrics recommendations for daily bouts of 60 min of physical activity or the 2-h screen time limits, were 3 to 4 times more likely to be overweight than those complying with both recommendations.[3]

A commentary on this article appears in this issue on page 343.

Studies of diet and exercise habits alone do not fully explain obesity risk. Another factor is inadequate sleep, defined as < 8 h, which has been reported in up to 90% of middle and high school students[4] and is associated with increased odds of being obese.[5] Insufficient sleep is hypothesized to promote obesity through sympathetic and hormonal mechanisms that regulate carbohydrate metabolism and increase the appetite for high sugar or fatty foods,[6-8] or by increasing time available to eat.[9] Factors which may adversely affect an adolescent's sleep include social, employment, and school-related activities; hormonal changes in puberty, which change circadian sleep cycles favoring later bedtimes; electronic screen time; and caffeine intake. In a recent study of U.S. adolescents, it was found that many adolescents with insufficient sleep used multiple forms of technology late into the night, and this was related to consumption of caffeinated beverages.[10]

Obesity in U.S. children is typically defined by a body mass index (BMI) ≥ 95th percentile distribution relative to gender and age on the 2000 Centers for Disease Control growth charts. BMI as an indicator of obesity presents some limitations in adolescents. In this age group, as the body grows, ratios of muscle and bone to height continue to change, which subsequently alters the relationship between BMI and fatness.[11] Ethnic differences may also confound the accuracy of BMI as a measure of obesity.[1] Hispanic children (who account for an increasing

BRIEF SUMMARY

Current Knowledge/Study Rationale: The prevalence of childhood obesity is increasing in the United States. The current study utilizes data from the community-based Tucson Childrens Assessment of Sleep Apnea Study (TuCASA) to determine the associations between adolescent obesity, and dietary intake, physical activity patterns, electronic screen habits, and sleep duration.

Study Impact: Adolescent obesity was found to be related to Hispanic ethnicity and parent-reported total sleep time. The latter was associated with greater amounts of electronic screen time in younger adolescents, and higher caffeine consumption in older adolescents suggesting that interventions targeted at reducing electronic media use and caffeine consumption maybe useful adjuncts in the prevention of obesity.

percentage of American children), have relatively more body fat compared to Caucasian children of the same BMI.[1] Therefore, health-related criteria such as body fat measures might be more valid for classifying obesity in adolescents than definitions based on weight and height.[11]

The purpose of this study was to investigate the relationships between important risk factors for obesity in adolescents in a community-based population including dietary intake, physical activity patterns, electronic screen habits, and sleep duration. In addition to using BMI defined obesity, we included triceps skinfold measures to determine whether this alternative marker of obesity would relate to the aforementioned risk factors.

METHODS

Study Population

The Tucson Children's Assessment of Sleep Apnea study (TuCASA) was designed to investigate the incidence, prevalence, and correlates of objectively measured sleep related breathing disorders in a prospective cohort study of preadolescent Hispanic and Caucasian children ages 6 to 11 years. A detailed description of the protocol has been published previously.[12] The present study is based on data obtained in a follow-up assessment conducted approximately 5 years after the initial phase. Briefly, children who participated in the initial phase of TuCASA were enrolled after obtaining informed consent of a parent or guardian, and assent of the participating children. They were 10-17 years of age at the time of the follow-up study, which was conducted throughout the calendar year. The children and parents completed a battery of questionnaires pertaining to dietary habits, amount of physical activity, electronic screen time (television, internet, computer, and video games), sleep habits, and underwent a repeat home polysomnogram (PSG) to characterize their sleep. Additionally, anthropometric data including, triceps skinfold thickness, height and weight, were obtained.

Sleep Habits Questionnaire

Information regarding parent-reported bedtimes, wake times, TST, and snoring were obtained from a comprehensive Sleep Habits Questionnaire (SHQ).[12] The SHQ was modified slightly from its original administration during the first TuCASA examination to account for the increase in age of the cohort and inclusion of some additional questions regarding other sleep disorders.

Polysomnography

The TuCASA home polysomnography (PSG) methodology and quality assurance procedures have been described elsewhere.[12] Briefly, the PSG includes a recording of the electroencephalogram, electrooculogram, chin electromyogram, chest and abdominal effort, airflow by thermistor and nasal pressure, electrocardiogram, and pulse oximetry. Criteria for scoring of sleep and respiratory events have been documented previously.[12] Children were considered to have obstructive sleep apnea if their apnea-hypopnea index was ≥ 1 event/h TST.[12]

Physical Activity and Electronic Screen Time

The Block Kids Physical Activity Screener was used for assessment of the children's physical activity and time spent using electronic media.[13] This screening tool is designed for school-age children aged 8-17 years. It inquires about frequency and duration of activities in the past week. It quantifies the amount of time spent in leisure and school activities, chores, part-time jobs, and interaction with electronic media. For the purposes of this study, "screen time" was defined as the amount of time per day spent watching television, playing video or computer games, and using the Internet.

Dietary Intake

The Rockett Youth/Adolescent Questionnaire (YAQ), a self-administered food frequency questionnaire designed for children ages 9-18 years, was used to assess dietary habits.[14] The YAQ has been tested qualitatively and quantitatively on this age group.[15] It includes 152 questions pertaining to food intake over the last year. It acquires data related to caffeine containing beverages, although it does not specifically mention caffeinated energy drinks which are consumed by some adolescents. It provides data on nutrients and mg of caffeine consumed as well as eating habits such as snacking and restaurant meals. We excluded as implausible energy intakes < 500 kcal/day or > 5000 kcal/day.[14]

Anthropometric Measures

Standardized procedures and identical equipment were used to obtain weight to the nearest 0.1 kg and height to the nearest 0.1 cm. Subjects were measured without shoes on a horizontal surface with heads in the Frankfurt Plane. BMI was calculated from weight in kg divided by height in meters, squared. In order to adjust the BMI for age and gender, a standardized z-score for BMI was computed using the 2000 Centers for Disease Control growth charts with the provided SAS software application.[16] Overweight was defined as ≥ 85th BMI percentile, and obesity as ≥ 95th BMI percentile.[4] Triceps skinfold thickness was measured according to procedures described in the Anthropometric Standardization Reference Manual,[17] using anthropometric tape and Lange calipers (Cambridge Scientific Instruments, Cambridge). The measures were performed 3 times by trained technicians, and the average of the 3 trials was used.

Data Analysis

Group differences on categorical variables were assessed using Student unpaired *t*-tests, and differences in proportions were determined using the binomial distribution and χ^2. Pearson correlation coefficients were calculated to determine whether directly reported child or parent-reported weekday TST was associated with caloric intake, dietary components, calculated energy expenditure, and child or parent-reported sleep time. Similarly, Pearson correlation coefficients were computed to determine whether child-reported, parent-reported, or PSG-recorded sleep time was associated with caloric intake, dietary components, and calculated energy expenditure. Analysis of covariance models were fitted to evaluate changes in standardized BMI z-scores and parent-reported TST in relation to factors found to be associated with these outcome variables on bivariate analyses. All statistical procedures were conducted using SPSS 17.0. A significance α level of 0.05 was used for all statistical tests. Data where appropriate are shown as mean ± SD.

Table 1—Demographic and anthropometric characteristics

	Boys	Girls	Total Cohort	p value[b]
Age (years ± SD)	13.3 ± 1.7	13.3 ± 1.8	13.3 ± 1.8	0.927
Gender (n [%])	165 [51.7]	154 [48.3]	319 [100]	0.576
Ethnicity				
Caucasian (n[%])	99 [49.3]	102 [50.7]	201 [63.0]	0.888
Hispanic (n [%])	66 [55.9]	52 [44.1]	118 [37.0]	0.231
Overweight				
Caucasian (n[%])	31 [31.3]	29 [28.4]	60 [29.9]	0.770
Hispanic (n[%])	31 [47.0][c]	23 [44.2][c]	54 [45.8][c]	0.912
Obese				
Caucasian (n,[%])	13 [13.1]	14 [13.7]	27 [13.4]	1.000
Hispanic (n,[%])	21 [31.8][c]	14 [26.9][c]	35 [29.7][c]	0.708
Standardized BMI[a]	0.526 ± 1.21	0.468 ± 1.10	0.498 ± 1.16	0.656
Triceps skinfold z-score	0.285 ± 0.743	0.0502 ± 0.634	0.172 ± 0.701	0.003
	Caucasians	**Hispanics**		
BMI z-score[a]	0.270 ± 1.18	0.885 ± 1.00		< 0.001
Triceps skinfold z-score	0.117 ± 0.669	0.265 ± 0.746		0.067

[a]See text for definition. [b]p values in this column represent comparisons between boys and girls. [c]p < 0.01-0.05 for comparisons between Caucasians and Hispanics.

Table 2—Analysis of covariance model of standardized BMI

Variable	Regression Coefficient	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	p value
Parent-reported total sleep time	−0.002	−0.005	0.000	< 0.001
Hispanic ethnicity	−0.578	−0.834	−0.323	0.016

RESULTS

Of the 505 children studied in the initial TuCASA examination, data were available from 319 children who participated in the follow-up examination. The remainder could not be located, refused participation, or were excluded due to implausible (4 subjects), missing dietary data (4 subjects), or missing sleep questionnaire data.

As shown in **Table 1**, the average age of the children was 13.3 ± 1.8 years. There were 51.7% boys and 48.3% girls; 63% were Caucasian and 37.0% were Hispanic. The standardized BMI was significantly higher in Hispanic children but was not different between boys and girls. In addition, a greater proportion of Hispanic children were obese or overweight. However, the triceps skinfold z-score was significantly greater in boys, and there was also a trend towards being significantly higher in Hispanic children.

Bivariate correlation found that parent-reported, but not child-reported or PSG recorded TST, was inversely associated with standardized BMI ($r = -0.160$, $p = 0.004$). However, there were no significant relationships between standardized BMI and any of the examined dietary components or estimated energy expenditure variables. Similar analyses using triceps skinfold z-scores did not demonstrate any significant correlations. As shown in **Table 2**, an analysis of covariance model incorporating parent-reported total sleep time and ethnicity indicates that standardized BMI increases with decreasing parent-reported TST and Hispanic ethnicity.

Significant bivariate correlations were observed between parent-reported TST and screen time ($r = -0.144$, $p = 0.011$), caffeine consumption ($r = -0.278$, $r < 0.001$), total caloric expenditure ($r = -0.220$, $p < 0.001$), recreational caloric expenditure ($r = -0.168$, $p = 0.003$), and age ($r = -0.518$, $p < 0.001$). No other dietary components were associated with total sleep time. These findings were not observed for child-reported or PSG recorded TSTs. Furthermore, parent-reported TST was higher among Caucasians than Hispanics (523 ± 60 vs. 509 ± 61 min, $p = 0.034$) but was lower among overweight children (508 ± 61 vs. 523 ± 60 min, $p = 0.027$), with an additional trend to be lower among obese children (505 ± 67 vs. 521 ± 59 min, $p = 0.055$). Parent-reported TST was not affected by the presence of obstructive sleep apnea. As shown in **Table 3**, an analysis of covariance including only those factors with significant bivariate relationships demonstrated that both increasing age and caffeine consumption were associated with decreasing parent-reported sleep time, with a similar trend noted with increasing screen time. Inasmuch as the impact of age in the model appeared to be quite large, a median split of the cohort was performed and the analyses were repeated within a younger (< 13.3 years) and an older (≥ 13.3 years) sub-cohort. As shown in **Table 3**, in the younger group, increasing screen time was associated with a decrease in TST, but caffeine consumption was

Table 3—Analysis of covariance models of parent-reported total sleep time

Variable	Regression Coefficient	95% Confidence Interval		p value
		Lower Bound	Upper Bound	
Entire Cohort				
Screen time	−2.9095	−7.431	1.620	0.207
Caffeine consumption	−0.270	-0.463	−0.077	0.006
Total caloric expenditure	−10.728	−39.597	18.141	0.465
Recreational caloric expenditure	4.52	−15.076	24.116	0.650
Age	−17.172	−20.969	−13.375	0.000
Hispanic ethnicity	3.6573	−16.427	23.742	0.358
Overweight	4.689	−15.155	24.534	0.642
Children < 13.3 Years				
Screen time	−6.511	−13.009	−0.013	0.050
Caffeine consumption	0.005	−0.379	0.389	0.979
Total caloric expenditure	−0.327	48.259	47.605	0.989
Recreational caloric expenditure	−11.569	−45.571	22.440	0.502
Hispanic ethnicity	6.424	−26.096	38.944	0.697
Overweight	21.257	−11.450	53.964	0.201
Children ≥ 13.3 Years				
Screen time	−918	−7.500	5.664	0.783
Caffeine consumption	−0.380	−0.611	−0.150	0.001
Total caloric expenditure	21.069	−67.219	5.700	0.098
Recreational caloric expenditure	21.069	3.295	45.432	0.090
Hispanic ethnicity	8.070	−18.802	39.941	0.554
Overweight	−5.918	−32.041	20.205	0.655

not. In contrast, the reverse was observed in the older group, with caffeine consumption associated with decreasing TST, and screen time not associated with TST.

DISCUSSION

In our cohort of 319 Caucasian and Hispanic adolescents, we found that a higher BMI z-score was associated with Hispanic ethnicity and decreased parent-reported sleep time. Parent-reported sleep time was significantly associated with age, self-reported caffeine intake, and screen time. In younger adolescents, having a decreased parent-reported sleep time was associated with greater amounts of screen time, but not caffeine intake. In contrast, in older adolescents, reduction of parent-reported sleep time was associated with more caffeine intake, but not screen time.

Our finding that BMI was inversely related to parent-reported total sleep time is consistent with many previous studies in adults, as well as some investigations in adolescents.[5] The mechanisms explaining this relationship have not yet completely determined, but may include leptin and ghrelin changes resulting in greater appetite and caloric intake.[7] However, we did not find caloric intake to be significant in predicting BMI or sleep time. Surprisingly, this finding is not uncommon. In fact, when trends in the National Dietary Intake Surveys (NHANES) are compared over several decades, changes in caloric intake fail to correspond with the increased prevalence of overweight.[18] This relationship has also been inconclusive in many epidemiological studies, and this may reflect the weakness of the food frequency methodology to accurately assess caloric intake in racially diverse samples or reporting bias by particular groups such as overweight individuals.[19] However, the YAQ is the most widely recommended food frequency tool for comparing dietary intakes of groups of adolescents.

Additionally, we did not see gender differences in the relationship between BMI and sleep time. This latter observation is in contrast the findings of Knutson and others who found that for every hour of sleep increase in children in grades 7-12, the risk of obesity declined 10%, but only in males.[20] However, our subjects were younger than those studied by Knutson et al., perhaps providing an explanation for the discordance in results. An alternative explanation for the relationship between reduced sleep times and higher BMI is that getting fewer hours of sleep may be a marker of having a less health-conscious lifestyle.[5]

We found that both higher amounts of screen time and caffeine use to be associated with a reduction in parent-reported total sleep time, and that these relationships were age dependent. Specifically, a comparison of two age groups (greater than or less than 13.3 years) revealed that screen time habits, but not caffeine consumption affected sleep times in the younger group, whereas the reverse was true in the older group. These differences may be due to age-related preferences for type of screen habits (e.g., television viewing is more common in younger age groups versus internet use, and thus may impact sleep differently) as well as puberty-related changes in sleep patterns in the older adolescents. The latter may be exacerbated by caffeine intake. Younger adolescents may not ingest as much caffeine due to more parental control over food and beverage choices and possibly less motivation to use it. Older adolescents may use caffeine to compensate for daytime fatigue, possibly compounded by effects of insufficient sleep due to factors such as earlier wake and later bed times, busier schedules of social activities, employment, and school. Additionally, despite sleeping less, adolescents are believed to have relatively high sleep requirements associated with puberty.[19]

Our study was similar to others that found higher use of electronic media was associated with shorter sleep duration.[10,22] In our study, we chose to use a combined screen time variable rather than inquiring about the different types of screen media separately. Our rationale was that a combined variable might provide more relevant data compared to studies that focus exclusively on television or video game use, and exclude newer forms of electronic media, such as the Internet. Screen time in our study averaged 4 hours per day, which is similar to amounts reported in other studies and exceeds the American Academy of Pediatrics recommendations by 2 hours.[23]

We found that parent-reported sleep times, but not child- or PSG-reported sleep times were related to BMI z-scores, caffeine intake, or screen time. There are several possible explanations for this discordance. As proposed by Patel et al., we believe that parent-reported sleep durations capture a more "meaningful dimension of sleep" compared to the research environment of a PSG sleep study. Additionally, we feel that the sleep habits of our younger adolescents (mean age 13 years) are likely to remain under more parental influence, and therefore their responses regarding sleep duration have face validity.[24] Furthermore, the research environment of in-home PSG might have distorted the usual sleep environment and thus masked any of the associations we found with parent-reported sleep times.

We found that Hispanic children were significantly more likely to be overweight and obese compared to Caucasians. This finding is consistent with previous reports. The 1999-2002 National Health and Nutrition Examination Survey (NHANES) reported a greater prevalence of overweight and obesity in Hispanic adolescents compared to their Caucasian peers. They reported 28% of 455 Caucasian adolescents 12-19 years old were overweight (BMI ≥ 85th percentile), compared to 41% of 720 Hispanic adolescents. Obesity, defined as BMI ≥ 95th percentile, was found in 23% of Hispanic adolescents and 14% of their Caucasian counterparts.[25] A larger study, the National Survey of Children's Health, found similar results in 45,000 subjects, with 19% of Hispanic youth having a BMI ≥ 95th percentile compared to 12% for Caucasian youth.[26] The rate of obesity increase has also been found to be higher in Hispanic children. From 1986 to 1998 the increase in obesity rate was 120% for Hispanic children, compared to 50% for Caucasian children.[27] Thus, our findings provide additional data highlighting the disparity in obesity prevalence in Hispanic children with its potential for significant public health consequences.

In contrast to our findings demonstrating the association between BMI z-score and lower parent-reported TST, we did not find triceps skinfold measures to have this relationship. This differs from other reports, which found that higher skinfold measures were associated with reduced sleep times in adolescents[28] and higher electronic screen time hours.[29] It is unclear why we did not have similar findings in our cohort. It is possible that our subjects had more abdominal rather than subcutaneous body fat. However, we cannot confirm this, as we did not measure abdominal fat. Nevertheless, our finding that higher triceps skin fold measures were found in boys and Hispanics is consistent with previous reports.[30]

A limitation of our study includes the cross sectional design, which precludes the ability to draw conclusions on the causality of the relationship between sleep duration, obesity, and the environmental factors studied. Additionally, the study relied on self- and parent-report data to accurately report usual sleep times, eating habits, exercise patterns, and electronic screen habits. Finally, the use of weekday sleep and wake times may not represent overall sleep, but were felt to be better surrogates for any sleep deficiency that might be present.

Despite the aforementioned limitations, key strengths of our study include a large sample size with ethnic diversity and use of validated methodology while addressing several factors implicated in the relationship of obesity to sleep habits and other lifestyle habits. Further strengths of our study include the use of measured height and weight using standardized procedures and equipment rather than using self-reported data. In addition, exercise assessments were based on thorough, validated activity questionnaire data, rather than limited to 1-2 questions, which although frequently reported, may not accurately classify the amount of usual physical activity.

In conclusion, Hispanic ethnicity and reduced parent reports of total sleep time were found to be associated with a higher BMI z-score. Total sleep time was inversely related to screen time and caffeine consumption. Therefore, parents should be apprised that screen time and caffeine use could lead to insufficient sleep and predispose adolescents to increased risk of obesity.

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