ABSTRACT

Title of thesis: SLEEP DURATION IN ADOLESCENT GIRLS: CORRELATES AND ASSOCIATION WITH OBESITY RISK

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The present study aimed to identify demographic, behavioral, and school-related factors associated with week night sleep duration among an ethnically diverse sample of 582 adolescent girls from the Trial of Activity for Adolescent Girls (TAAG) 2. The distribution of sleep duration categories (<7 hours, 7-9 hours, and >9 hours) differed significantly among ethnic groups in bivariate analyses, but not in the final multivariate model. Additionally, sleep duration was negatively associated with distance to school from home, typical time spent on the computer, and school start time. In contrast to previous findings, shortened sleep duration was not associated with increased body mass index (BMI), body fat percentage, or quantity of moderate-to-vigorous physical activity (MVPA). Findings show support for delayed school start times. In addition, future research should examine whether interventions to reduce screen time activities among adolescents is effective in increasing their sleep duration.

SLEEP DURATION IN ADOLESCENT GIRLS: CORRELATES AND ASSOCIATION WITH OBESITY RISK

by

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Chapter 1: Introduction and Background

Adolescent development is accompanied by increases in responsibilities, demands, and independence. As a result, a substantial proportion of teenagers in the U.S. are not getting adequate sleep on a regular basis. Adequate sleep duration has been shown to have a protective effect on many different health outcomes, including cognitive performance, immunity, and metabolic processes (1-7). Therefore, research should elucidate which factors lead to sleep deprivation among adolescents in order to inform the design of policies and interventions to address these needs. In addition, knowledge about any disparities in sleep duration is useful so that public health initiatives can target those who are most vulnerable to the negative consequences of sleep deprivation.

Furthermore, sleep deprivation is a possible risk factor for obesity and overweight (8-16). Obesity increases risk for a number of conditions, including coronary heart disease, type 2 diabetes, certain cancers (endometrial, breast, and colon), hypertension, dyslipidemia, stroke, liver disease, gallbladder disease, sleep apnea, osteoarthritis, and infertility (17). Due to growing prevalence over the past few decades, obesity continues to be of major concern for public health: more than one-third of adults in the United States and almost 17% of youth are obese (18). A recent estimate totals the cost of obesity at about $147 billion per year across Medicare, Medicaid, and private insurers. (19) Obesity disproportionately affects minority and low income populations; with disparities present even among the youngest members of the population (20, 21). In addition to inactivity and unhealthy diet, differences in sleep duration between subpopulations may be contributing to these health disparities.

Study Aims

The purpose of this study was to contribute to knowledge on the predictors of sleep duration in adolescents, and examine whether sleep deprivation could be a risk factor for obesity and excess body fat among youth. The goals of this cross-sectional study were to:

1. Determine how social, environmental, and behavioral factors are correlated with weeknight sleep duration in a diverse sample of 11th grade girls.

    a. Examine whether ethnicity, family structure (single parent home status), and neighborhood socioeconomic status were associated with sleep duration.

    b. Determine whether obligations outside of school were related to sleep duration, including paid job, “screen time” activities, and participation in sports.

    c. Examine how two school-related factors, start time and distance from home, were associated with sleep duration.

    Hypothesis: socioeconomic status, minority status, part-time paid work, earlier school start time, and longer travel time to school would be negatively associated with sleep duration.

2. Determine whether sleep duration was significantly and inversely related to indicators of body mass.

    a. If such a correlation was found, examine whether physical activity mediated the relationship between sleep duration and body mass index (BMI: weight (kg)/weight (m^2)) and percent body fat.

Hypothesis: sleep duration would be negatively correlated with both BMI and body fat percentage.

Chapter 2: Literature Review

Sleep Duration and Health

One of the Healthy People objectives for 2020 is to increase the proportion of 9-12 graders who get “sufficient sleep”, defined as 8 hours or more on a school night. As of 2009, only 30.9% met these requirements according to data from Youth Risk Behavior Surveillance System (YRBSS) (22). However, some experts recommend 9 hours of sleep per night for adolescents (23). In a sample of high school students in the Midwest, the majority (91.9%) got less than 9 hours of sleep on most school nights and 10% reported fewer than 6 hours on *each* week night. Perceived effects of sleep deprivation included feeling tired during the day (93.7%), difficulty paying attention (83.6%), lower grades (60.8%), and increased stress (59.0%); some reported engaging in harmful behaviors such as taking sleeping pills (6.0%) or smoking a cigarette (5.7%) to help them sleep (24).

Research shows that along with pubertal development, teenagers experience increasing daytime sleepiness even when sleeping as much as younger adolescents. These findings suggest that older teens actually have increased need for sleep time as they progress through puberty (5). At the same time, changes in curfews and school schedules affect sleep patterns. For instance, most high schools have an earlier start time than local middle or elementary schools. Additionally, as teenagers mature they typically enjoy more independence from their parents, and are allowed to stay out and stay up later. As other responsibilities also increase, such as homework and part time jobs, adolescents are likely to be staying up later and waking up earlier (5).

Average sleep duration has been declining over the last century, for both adolescents and adults (25). For teenagers, this may be explained by increased distractions (internet, video games, smart phones) and by the increased pressure to prepare for college – via SAT courses, volunteering, internships or jobs, and pursuing extracurricular activities – much earlier than previous generations (5, 26).

Sleep deprivation is associated with a variety of negative outcomes. Physiologically, shorted sleep duration can negatively impact the immune system and lead to metabolic changes such as increased insulin resistance (27). Furthermore, sleep deprivation impairs cognition and thus compromises academic performance, as evidenced by several studies and reviews (4, 28-30). For instance, one study showed that teenage boys who get less than 8 hours of sleep per night score lower on tests of reasoning ability and overall cognitive performance, relative to those who sleep more than 8 hours. These results remained significant even when adjusted for age, socioeconomic status, and pubertal stage (30).

Correlates of Sleep Behaviors

Socio-demographic factors

Age

Literature consistently shows that over adolescence, sleep duration declines with age (5, 25, 29, 31-33).

Gender

In a multi-level analysis of sleep correlates, gender was not a significant predictor of weeknight sleep duration among 12-19 year olds (31). A Brazilian study of 14-21 found that females got more sleep (32). However, an Australian study of private school students aged 11-17 found that females reported less sleep by diary data, but there was no significant difference between genders by actigraphy (33); meanwhile a study of Japanese 15-18 year olds found females are more likely to have shorter sleep duration (34). In a study of middle school students, authors found that girls got significantly more sleep as 6th graders, but the decline in sleep over the course of 3 years was sharper among girls; authors suggested this result could be explained by earlier pubertal development and an increase in grooming habits among girls (35). In summary, differences in sleep habits between adolescent boys and girls remain ambiguous.

Ethnicity

Most studies show that minority children and adolescents get less sleep than White children and adolescents. In a study sampling adolescents (mean age 13.7) from the Cleveland TeenZzz Study, minority status was significantly associated with less sleep in a multivariate model (36). Similarly, in a multilevel study of 12-19 year olds, African-Americans had significantly shorter average sleep time on weeknights relative to Whites, holding constant other demographics and environmental factors; there was no difference between Whites and Asian or Hispanic individuals on sleep duration (31). In a sample of 6th graders, Whites obtained more sleep on weeknights relative to non-Whites (35). Results of these studies suggest that ethnicity and cultural factors play a role in determining sleep duration.

Socio-economic status (SES)

Previous adolescent studies have found a varied relationship between measures of SES and sleep duration. In a multilevel study, family income was negatively associated with sleep duration among 12-19 year olds, while "family economic strain" was not significantly related (31). In a study sampling middle school students, those eligible for free or reduced price lunch obtained more weeknight sleep, while mother's educational status was not significantly correlated (35). Another multilevel study, which sampled 7th graders in New England, found that SES (factor composed of family income, parental education, number of working adults, and percentage single family homes in neighborhoods) was associated with later school night sleep onset, fewer minutes of sleep, and greater inconsistency in sleep patterns (37). In the Cleveland TeenZzz Study sample, parent education and parent income were both associated with sleep in the univariate analyses, but not in the multivariate model (36).

Neighborhood and Family Environment:

Neighborhood

Neighborhood factors have been proposed to affect sleep quality via psychosocial stress, and thus may also affect sleep duration (38). It is also possible that neighborhoods of lower SES might impact sleep due to increased noise pollution (38). Only two studies have examined neighborhood-level factors as a predictor of sleep duration. In the Cleveland TeenZzz Study sample, neighborhood distress (census tract % poverty, % female headed households, % high school dropouts, and % males disengaged from workforce) was associated with less total sleep and more variability in sleep time. However, in the multivariate model with minority status as a predictor, neighborhood distress was no longer significant (36). In a sample of 7th graders, poorer neighborhood conditions were associated with a discrepancy in school night vs. weekend sleep time, but not with average school night sleep duration (37).

Family structure

Few studies have examined family-related factors as predictors of sleep. In one large study, sleep duration on weeknights was negatively associated with married couple status, and positively correlated to parental rules (31). In another study, "number of people in home" was the only variable related to family environment, and had no association with weeknight sleep duration or variability in sleep time (37).

School-related Factors

Start time

In a study of sophomores and juniors at two high schools in Wisconsin with different start times, researchers showed that students attending the 8:35 am school averaged 11.3 minutes more sleep per night than students at the 7:50 am school. While there were no significant difference in scores on Epworth sleepiness scale (ESS) between the two schools, the earlier school students average was in the clinical range of sleepiness scores, but later school students were not (39). Another study showed that high school seniors transitioning from summer vacation to school decrease their weeknight sleep duration from 8.7 hours to 7 hours on average, and begin to exhibit, on average, a 30 minute difference between weeknight and weekend sleep duration (40). Adam et. al. also found school start time to be a significant predictor of weeknight sleep duration in a multivariate model (31). Additionally, in a study on academic achievement among first year students at US Air Force Academy, participants who started the school day 50 minutes later had significantly better GPA, class rank, and SAT scores; these findings were attributed to increased sleep time (28).

Distance to school

Both studies that looked at school-level variables and sleep duration found a significant association with travel time. The Japanese study showed that a commuting time of more than two hours predicted shorter sleep duration (34). Similarly, a multilevel study showed that traveling time to school was negatively associated with sleep duration among 12-19 year olds (31).

Behavioral Factors

Paid work

Literature on part-time work and adolescent sleep duration is inconsistent. An early study showed that teenagers who work more than 20 hours per week for pay sleep less, have a later bed time, experience more daytime sleepiness, and consume more caffeine and alcohol (5). Adam's 2007 cross-sectional analysis did not find work to be a significant predictor of weeknight sleep duration, but their sample encompassed adolescents aged 12 to 19 and there may not have been enough workers among participants to detect a real association (31). In a study of students attending evening classes in Sao Paulo (aged 14-21), paid work actually predicated longer sleep duration as a binary variable (32). In the study of Japanese students, part time workers were not significantly more likely to have short sleep duration when adjusting for other variables (34).

Sport Participation

Only one study has looked at sport participation as a predictor of sleep duration in adolescents. Adam. et. al found no significant relationship between time spent playing sports on weekdays and weeknight sleep duration among a combined sample of children and adolescents; sports also did not predict weeknight sleep duration in the multivariate model for 12-19 year olds (31). As explained in part C of this literature review, moderate-vigorous physical activity (MVPA) might be another correlate with sleep duration, and is discussed in greater detail within the context of sleep duration and BMI.

Screen Time Activities

Findings regarding the effects of television on sleep time have been inconsistent. For example, television time on weekdays was a significant predictor of sleep among children, but not among adolescents, in Adam et. al. multilevel study of sleep duration (31). Similarly, a study of Icelandic teenagers found that late-night television watching was linked to a decrease of total sleep time among younger adolescents, but not 16-19 year olds (41). Another recent study showed that fifth graders with access to electronic entertainment and communication devices (including televisions, computers, and smartphones) had significantly shorter sleep duration (42). However, in the Adam et. al. study, computer/video game time had no significant relationship to weeknight sleep duration among children or adolescents (31). In a study of European teens, sleeping less than 8 hours per day was associated with more time watching TV (11). However, in an analysis of YRBSS data, students who watched TV at least 4 hours per day actually had higher odds of sufficient sleep than those who watched for 0 hours. In the same study, playing video or computer games or used a computer for something not school-related for at least 2 hours per day was associated with lower odds of sufficient sleep, relative to 0 hours per day (22).

Sleep Duration and Obesity

The link between sleep duration and BMI among pre-pubescent children is well-established in the literature (9, 13, 43-46). However, this association seems to decline with age: studies on adolescents and adults have not been consistent (10, 14, 16, 46-51).

Children and Adolescents: Sleep Duration and Obesity

Previous literature supports the link between sleep duration and BMI in children and adolescents. One review article showed that 11 out of 11 cross-sectional studies based on youth populations found a negative and statistically significant correlation between sleep duration and BMI. Furthermore, two prospective studies found the same correlation (46). Published more recently, an analysis of European teenagers aged 12-17 (based on data from HELENA study) found that lower sleep duration was associated with increased BMI and higher body fat (11). However, a different prospective study of American adolescents aged 12-18 found no association between obesity (defined as above the 95th percentile for children's BMI) and sleep deprivation (52). Similarly, in a cohort of teenagers (mean age = 14.7) followed for two years, baseline sleep duration was not statistically associated to BMI or percent body fat at the second time point, although the relationship percent body fat and sleep duration approached significance (47).

Adults and Young Adults: Sleep Duration and Obesity

While the strength of association between sleep duration and BMI seems to decrease with age, a review shows that the majority of adult population-based studies also confirm that the link exists, as found in 17 out of 23 cross-sectional studies and three out of three longitudinal studies (46). Recently, a cross-sectional analysis examined the association between sleep duration and BMI in a sample of young adults (mean age 25). While BMI, obesity, and overweight status were inversely associated with sleep duration among men, no significant associations were found among women (49). Another review pointed to methodological issues in research focusing on body mass and sleep duration, and concluded that generalizations are coming from studies with individuals receiving very little sleep (<5 hours), suggesting that only extreme sleep deprivation has clinical significance for weight gain (7). In summary, more research is needed to elucidate the relationship between sleep duration and body weight.

Sleep Duration in Relation to Physical Activity

Based on a model created by Patel and Hu, sleep deprivation can cause weight gain from two main pathways: increased energy intake and decreased expenditure (46). Sleep deprivation can lead to decreased energy expenditure through both biological and behavioral pathways: research has shown that sleep-deprived individuals can have altered thermoregulation and are less likely to become physically active during the day due to feeling fatigued (46). Several cross-sectional studies have found an association between sleep duration and physical activity in adolescents (11, 22, 32). An analysis of the 2009 Youth Risk Behavior Survey found that students who engaged in at least 60 minutes of physical activity daily had higher odds of sufficient sleep (22). In the large European study, adolescents who slept less than 8 hours per day were more sedentary and had significantly fewer minutes of moderate physical activity, relative to those who slept 8 hours or more (11). In addition, a study of Brazilian youth found that relative to active participants, those who only engaged in exercise irregularly or were sedentary had lower weeknight sleep duration (32). Findings suggest that sleep-deprived teenagers are less likely to be physically active, perhaps due to increased fatigue.

Gaps in Literature

As evidenced by this literature review, there are many inconsistencies in findings on predictors of sleep duration among adolescents, and this field would benefit from more analyses in different samples. Certain factors, including neighborhood distress, family structure, paid work, sports participation, and screen time, are especially understudied and thus require more attention in research. Furthermore, using the Trial of Activity for Adolescent Girls (TAAG) 2 data to assess correlates of sleep duration provides several advantages, such as an ethnically diverse sample, variation in school type and start times, and availability of neighborhood level data. Additionally, TAAG 2 was one of the few studies to include objective physical activity measures among adolescent girls.

Chapter 3: Methods

Data Source

The hypotheses were tested using a cross-sectional, secondary analysis of data collected in 2009 for the Maryland-based Trial of Activity for Adolescent Girls (TAAG2) study. TAAG 2 was a cross-sectional assessment of physical activity and other factors among 11th grade girls in the Washington, D.C./Baltimore area; girls had also participated in the original TAAG study in 2006 when they were in 8th grade. The original TAAG study randomized 36 middle schools across the country (6 in Maryland) into a school-based environmental intervention to promote physical activity (18 schools) or control group (18 schools) (53).

Participants

There were 589 11th grade girls who participated in TAAG 2. Of this sample, seven girls were excluded because they did not answer the sleep-related questions on the questionnaire, resulting in a total of 582 participants in this study.

Measures

TAAG 2 data were collected using self-reported questionnaires, objective assessments of body mass and physical activity, and geo-coded data.

Sleep duration. Sleep duration was based on self-reported estimates. The questionnaire asked four questions related to sleep patterns. Respondents were asked to write down a time for each of the following: "What time do you usually go to bed on weekdays?" "What time do you usually wake up on weekdays?" Answers were used to calculate mean weeknight sleep duration. For bivariate analyses, girls were categorizes as short sleepers

(<7 hours per night), typical sleepers (7-9 hours per night), and long sleepers (>9 hours per night). Several participants (n=5) were identified as outliers because their average sleep duration was less than 4 hours. They were grouped with "short sleepers" for categorical analyses, and excluded from the correlational analyses.

Demographic data. Demographic variables are based on the survey questions. Girls were asked to indicate their grade level as 10, 11, or 12. Ethnicity is determined by two questions. Girls answered either yes or no to, "Do you think of yourself as Latino or Hispanic or Mexican American or of Spanish origin?" and could check one or more to options (White, Black or African-American, Asian, Native Hawaiian or other Pacific Islander, American Indian or Alaska Native, and Other) under "Do you think of yourself as...?" Students who selected a category other than "White," "Black" or "Hispanic" were categorized as "Other." SES level was approximated by whether a participant received free or reduced price lunch at school. Participants could answer yes, no, or "don't know" to "Do you get free or low-cost lunches at school?" In the analyses, the variable was dichotomized as "yes" and "no"/"don't know."

Parents Living at Home. The participants were asked to check yes or no to "Does your father live at home?" and "Does your mother live at home?" The variable was dichotomized as "both parents" and "0 parents or single parent-home."

Time Unsupervised. The survey asked girls how many days a week (0, 1, 2, 3, 4, or 5 days a week) and how many hours on a typical day (0, 1, 2, 3, 4, or "5 or more") they took care of themselves after school without an adult being there. Similar to the methodology of a previous study using TAAG data, time unsupervised was analyzed as a binary variable, with a cutoff for longer time unsupervised of at least 2 hours per day on 2 or more days per week (54).

"Screen time" activities. Approximate amount of time spent on various sedentary "screen time" activities was determined through self-reports on the questionnaire. Girls were asked to indicate how many hours on an average school day they on the computer or internet, watching TV, DVD, or videos, and playing videogames, not including internet games. For each of these activities, participants could indicate 0, less than 1, 1, 2, 3, 4, 5, or 6 or more hours. Categorical variables for computer and television time were recoded as "Less than 1 hour," "1 hour," "2 hours," and "3 hours or more." Because few girls played videogames, the videogame variable was recoded as "Less than 1 hour," and "1 hour or more."

Paid Job and Hours Working for Pay. The survey asked "Do you have a job for which you earn money?" to which participants could answer yes or no. Those who answered yes were also asked how many hours per week they currently worked for pay, during the school year and not during summer break. Participants could choose 1-9 hours, 10-19 hours, 20-29 hours, 30-39 hours, 40 hours, or more than 40 hours. The variable was recoded as 0 hours (those who did not have a paid job), 1-9 hours, 10-19 hours, and 20 or more hours.

Sports Participation. In the survey, girls were asked to indicate which sports teams they had been on during the past year at school and outside of school. The list included baseball or softball, basketball, field hockey, frisbee, cheerleading/dance team, golf, gymnastics, ice hockey, lacrosse, soccer, swimming, tennis track and field, and volleyball. Participants could also write in another sport. Participants who indicated any sport team membership were placed into the “sport participation” category. If a girl did not check off any boxes for this question or checked the box for “I didn’t participate in any sports teams,” she was classified as, “no sport participation.”

Geographical Data

Neighborhood SES. Participants’ home addresses were geocoded and ArcGIS was used to examine neighborhood factors at the census block-group level. Neighborhood SES was approximated by the percentage households with an annual income below $24,999 within the census block as measured in the year 2000. Similar methodology has previously been applied in studies with TAAG data (55).

Distance to school. Distance to school was also calculated in ArcGIS as the radial distance in miles from each participant’s home residence to her school address. Girls who were homeschooled or not attending school had a distance to school of “0.” For categorical analyses, distance to school was categorized as less than 1 mile, 1-5 miles, and over 5 miles.

School start time. Participants were recruited from a total of 95 high schools. A research assistant was responsible for contacting the appropriate individual for each school, and recorded the school start time according to the bell schedule. Girls who were homeschooled or were not attending school (n=15) were excluded from these analyses. For categorical analyses, school start time was dichotomized as “7:30 am or earlier” and “after 7:30 am.”

Anthropometry

Height, weight and triceps skinfold were assessed by trained researchers. Height was measured without shoes using a portable stadiometer (Shorr Productions) to the nearest 0.1 cm; body weight was assessed using a digital scale (Seca 880) and measured to the nearest 0.1 kg while the girl was dressed in light clothing without shoes. Triceps skinfold thickness was measured three times on the right side of the body using a Lange Skinfold caliper to the nearest millimeter.

Body Mass Index (BMI) and Weight Status. Body Mass Index (BMI - weight(kg)/height(m)^2) was calculated for each participant. Weight status is described by "normal/underweight," or "overweight," by comparing height, weight, and age at measurement time with the United States Centers for Disease Control (CDC) growth charts (56). Participants above the 85th percentile were classified as overweight.

Percent body fat was also estimated from physical measures (height, weight, triceps skinfold) using an equation that was developed for use in girls in this age range; this method is highly correlated with percent body fat measured by Dual-energy X-ray absorptiometry (DEXA) method. Investigators used the following equation (57):

Percent fat = −23.393 + 2.269(BMI) + 1.943(triceps skinfold) −2.955 (Black = 1; 0 = Other) −0.524 (age) −0.058 (BMI*triceps skinfold)

Physical Activity

Moderate to Vigorous Physical activity (MVPA). Each participant wore a Computer Sciences and Applications (CSA) accelerometer over their right hip for 7 days, except during sleep and water activities. The CSA accelerometer collected activity counts every 30 seconds. Moderate-vigorous physical activity (MVPA) is defined as activity exceeding 1500 counts per 30-second time point, which translates to 4.6 metabolic equivalents (METS) (58). Average daily minutes of MVPA was calculated for each participant. Additionally, girls were categorized as meeting or not meeting the recommended MVPA minimum of 30 minutes per day.

Statistical Methods

Data was analyzed using SAS 9.3 (SAS Institute Inc, Cary, NC). First, bivariate relationships between sleep duration category and potential correlates were examined with Chi-Square or ANOVA tests for categorical and continuous variables, respectively. PROC CORR was then used to check for inter-correlations among all continuous and ordinal variables, with Pearson's r (continuous variables) or Spearman's ρ (ordinal variables) to inform the strength of each correlation. A threshold of $r > |0.3|$ was used to inform collinearity between two variables. Next, a multivariate linear regression model with average week night sleep duration as the dependent variable was constructed using PROC MIXED, with the school-level variable set as a random effect. For the second aim, correlation between average sleep duration and BMI was also evaluated with Pearson's r to inform the strength of the correlation. Similar analyses were repeated with body fat percentage and MVPA.

Human Subjects. The study design was reviewed and approved by University of Maryland's Institutional Review Board (IRB).

Chapter 4: Results

Sample Description

Of the 582 who completed the sleep-related portion of the questionnaire approximately half (49%) fell within the range of 7 to 9 hours on a typical school night, approximately one-third (31%) slept for less than 7 hours on a typical school night, and the remainder (21%) reported sleeping for over 9 hours on a typical school night. Compared to a "sufficient sleep" definition of 8 hours, less than a third of the sample (29%) met this minimum. On average, girls slept for 7.32 hours on weeknights (median = 7.33, mode = 7.00).

Descriptive characteristics of the sample are provided in Table 1. The sample was ethnically diverse; 47% of the girls identified as non-Hispanic White, 21% as Black, 13% as Hispanic, and 18% as "Other." Approximately 1 in 5 (21%) indicated that they received free or reduced price lunch at school. The majority (68%) lived with both parents, and 40% had a paid job. Among girls who attended high school, the average distance from home to school was 2.56 miles.

Bivariate Relationships with Sleep Duration

Chi-square tests revealed a difference in sleep duration distributions by ethnic group ($p<.0001$). Fewer non-Hispanic whites fell into the short sleep duration category (25%), compared to Blacks (37%), Hispanics (32%), and Other ethnicities (39%). Additionally, there were fewer whites (15%) than Blacks (29%) in the long sleep duration group. These differences are illustrated in Figure 1. Additionally, ANOVA tests revealed significant differences in average sleep duration among ethnic groups ($p = 0.0193$);

pairwise comparisons showed that girls who identified as “Other” had a significantly shorter sleep duration (7.04 hours) than non-Hispanic Whites (7.42 hours). With the exception of ethnic group, no other demographic variables revealed a statistically significant bivariate relationship with sleep duration.

There were no statistically significant differences in time unsupervised by an adult, hours working per pay, or sports participation by sleep duration category. However, one activity was significantly associated with sleep: average time spent on the computer for non-school purposes (p=0.0085). As illustrated in Figure 2, there was a gradient relationship between computer time and likelihood of getting adequate sleep. Of the girls who reported spending three or more hours on the computer on an average weekday, 44% fell into the short sleep duration category, compared to only 22% of girls who spent less than one hour on the computer. However, not all “screen time” activities were significantly related to sleep. Time spent watching TV or videos had no significant relationship to sleep duration. And while a small proportion of the sample (12%) reported playing videogames for at least 1 hour per day, these individuals were not more likely to fall into the short sleep duration category.

Distance to one’s own school was the only other individual-level variable to significantly correlate with sleep duration. Chi-square tests revealed a significant relationship (p = 0.007) between distance to school category and sleep duration. As shown as Figure 4, more girls who lived the farthest from their high school fell into the short sleep duration category and fewer were in the long sleep category compared to girls who lived 5 miles or less from their school.

School start time also made a difference with regards to sleep duration. Girls who attended a school where the first bell was scheduled for 7:30 am or earlier were more likely to be in the short sleep duration group than those whose first bell rang after 7:30.

Neighborhood-level SES, as approximated by the percentage of households with an annual income below $24,999, was not significantly related to sleep duration category or average weeknight sleep duration.

Multivariate Model Results

The multi-level model represented data from a total of 553 participants who attended a total of 67 schools. Girls who indicated typical sleep duration below 4 hours (n=5) and girls for whom physical activity data was missing (n=24) were excluded from these analyses. Videogame time and body fat percentage were not included in the final model given that they showed moderate or strong statistically significant correlations with at least one other predictor (Table 2). Results for the full multilevel model are provided in Table 3. Both computer time and distance to school remained significant predictors, regardless of other variables. Additionally, the full model showed that having both parents living at home was associated with shorter sleep duration when adjusting for other factors (p = 0.025).

Sleep Duration, Body Mass, and Physical Activity

Average week night sleep duration had no relationship with BMI, or body fat percentage, or physical activity in this sample.

Post-hoc Analyses

Given that ethnicity was no longer a significant predictor of sleep time in the multivariate model, post-hoc analyses were conducted to examine whether other factors were associated with both ethnicity and sleep duration. Chi-square tests revealed that school start time ($p < 0.001$), TV time ($p < 0.001$), and computer time ($p < 0.001$) distributions also varied by ethnic group (Figures 5-7). There were no significant differences in the distributions of distance to school.

Chapter 5: Discussion

The majority of participants in the sample (79%) did not meet the optimal sleep duration of 9 hours of sleep recommended for adolescents (23). Even compared to a less conservative recommendation of 8 hours of sleep, only 29% of participants in the sample would meet the criteria for sufficient sleep. Similarly, the prevalence of sufficient sleep among high school students was only 31%, as measured by a nationally representative survey in 2009 (22).

In this sample, there was no significant relationship between individual-level SES or neighborhood-level SES and week night sleep duration. Previous findings with regards to SES-related variables and association with sleep duration have been inconsistent. Other researchers used different parameters to estimate SES, such as family income or parental education level, which may be more sensitive measures than whether a student reports receiving discounted lunch (36, 37). The only other study which used similar methodology with regards to SES found that students who received free or reduce price lunch had a longer week night sleep duration, although this sample consisted of middle school students (35).

This study found that whites had significantly longer mean sleep duration than girls in the "Other" group, but there were no significant differences in mean sleep duration in relation to African American and Hispanic groups. The literature seems to show that minority status is associated with shorter sleep duration (35, 36). However, little research has examined individual ethnic groups in relation to sleep duration, and one study that did so found a significant difference between African-Americans and whites only, which is not consistent with the present findings (31). For this reason, future research into sleep duration should differentiate among specific ethnic groups rather than grouping all non-Whites together. Furthermore, as shown in Figure 1, girls in the “minority” groups appear less likely to reach 7 hours of sleep than whites, but also more likely to fall into the 9 hours or more category. Thus, the question of which ethnic group is least likely to reach “sufficient sleep” may depend on the definition of sufficient sleep duration.

Given that race/ethnicity is no longer significant in the multivariate model, it is likely that the relationship between race/ethnicity and sleep time can be explained by differences in other factors between ethnic groups such as typical school start time, distance to school, and time spent on the computer. Post-hoc analyses showed that a greater proportion of White participants attended a school which began after 7:30 am, compared to other ethnic groups, and there were significant differences in computer time among ethnic groups. Therefore, findings are inconclusive on whether there is a real contribution of cultural factors in determining the sleep duration of adolescents.

Having both parents living at home was associated with shorter sleep duration when adjusting for other factors. An earlier study similarly found that married couple status was associated with shorter sleep duration (31). However, in our study, being unsupervised by an adult, although associated with single-parent status, was not associated with sleep duration in bivariate analyses. This was an unexpected result, given that adolescent sleep duration was previously linked to “parental rules” (31). One likely explanation for this discrepancy is that parental control over bed time diminishes as adolescents get older. In this sample, the majority of girls were in 11^{th} grade, and less likely to have sleep schedules monitored or influenced by their parents than younger samples of adolescents.

Both having a paid job and total hours working for pay during the week was not associated with sleep duration. While it would be expected that teenagers with work responsibilities would be less likely to get adequate sleep, previous findings on this topic have also been inconsistent (5, 31, 32, 34), suggesting that teenagers who do not work are not compensating with more sleep and choosing to spend time on other activities and responsibilities instead. Another possible explanation is that some of the paid jobs require a higher level of physical exertion, so that these girls would require more sleep due to increased fatigue.

Like the previous study that examined sports participation among teenagers and weeknight sleep time (31), there was no association between sleep duration and sports participation in this sample. However, this study used a binary variable that only distinguished between girls who participated in any sports at all and those who did not. Varsity athletes and girls who play on intramural teams were grouped together, though they differ in the level of involvement, with girls playing for a varsity team having more substantial time commitments to their sport. Therefore, results do not rule out the possibility of a real negative or positive correlation between time spent practicing sports and sleep duration.

Computer time was the only "screen time" activity to show a significant negative relationship with sleep duration. Some previous research also supports the link between computer use and shorter sleep time in youth populations (59, 60). Preliminary research suggests that decreasing screen time among adolescents is an appropriate intervention target in an attempt to increase sleep time: a cross-sectional study which examined the "time budgets" of Australian teenagers found that "screen time" was a relatively elastic behavior in terms of time commitment, compared to social time and physical activities (61). Smartphones and tablets have become widespread in recent years, so that teenagers have more access to internet today than ever before. There is a need for future research to examine whether portable devices with internet access have a unique effect on sleep duration among teenagers. However, because this is an observational cross-sectional study, we cannot conclude that computer activities cause sleep deprivation directly. It is possible that girls who have trouble sleeping are simply choosing to spend time on the computer/internet when they stay up later.

While computer activities, such as internet browsing and social media, tend to be engaging, watching TV or videos might typically be a more passive activity. A review of the literature suggests that television has a significant effect on sleep duration among children and younger adolescents, but not among groups of older adolescents (11, 31, 41). Interestingly, a study conducted in Belgium showed that over a third (37%) of teenagers reported using television as a sleep aid, and some reported using computer games as a sleep aid. However, using both types of electronic media as a sleep aid was negatively correlated to bed on weekdays, total hours of sleep per week, and their self-reported levels of tiredness in this sample (60). While this study was conducted abroad, it is likely that using television and computers as a sleep aid is also a common practice among American teenagers (60). Null findings with regard to videogames are not surprising, given that the majority of the sample engaged in little or no videogaming, and among those who did, very few spent over 2 hours on a typical weekday on videogames.

Girls who lived further away from their high school were more likely to fall into the short sleep duration category. This is consistent with the findings of previous studies which showed that a longer commute to school is negatively associated with sleep duration among teenagers (31, 34). This relationship is likely to be explained by an earlier wake time for those who have longer to commute, without an earlier bed time to compensate for the difference. Previous studies have suggested that teenagers have a different circadian rhythm than adults, with a naturally later bedtime (62). Accordingly, it was not surprising that an earlier school start time was also significantly correlated with shorter sleep duration, as found by other researchers (28, 31, 39, 40). These findings thus show support for delayed school start time policies.

With regards to the second aim of this study, no relationship was identified between overweight status, BMI, or body fat percentage and sleep duration, even within ethnic group-specific strata. While these null findings were unexpected based on the literature review, there are several explanations for this result. For one, this sample of adolescents was relatively older than those analyzed in previous studies; other researchers have suggested that the strength of the relationship between sleep duration and BMI declines with age (46). Secondly, the sample was restricted to females, while a similar cross-sectional study among young adults found this correlation only to exist among men (49). Finally, the relationship between sleep duration and obesity risk may be more complex than a simple inverse linear association. For instance, a study of twin pairs (ages 10-20) conducted in China found that among female participants, both long (≥9 hours) and short

(<8 hours) sleepers tended to have higher adiposity measures than those in the medium sleep duration category (63).

Physical activity was not related to sleep duration in this sample. Other researchers have hypothesized that sleep deprivation causes fatigue and this makes exercise and physical exertion less feasible (46), but the cross-sectional design of this study did not allow for the temporal analysis of this relationship. Given that the link between reduced physical exertion and sleep deprivation is an emerging field of study, future research should continue to build upon several studies which have found some relationship between these two factors (11, 22, 32).

Strengths and Limitations

This was one of few studies to use objective physical activity data when looking at the relationship between sleep duration and BMI. Another advantage of using TAAG 2 data for this study was the ethnically diverse sample, compared to studies which took place in the Midwest region of the U.S. or in other countries. Having school-level data also allowed the study to examine the unique effect of school start time on sleep duration.

Because this study was cross-sectional, causal inferences cannot be made. Another important limitation was lack of objective sleep data, given that other studies have found differences in correlates of sleep duration when comparing diary data to actigraph data (33). Because participants were only asked to write down the typical time they went to bed and the typical time they "got up," the data may also not be accurately reflecting actual sleep duration. Finally, the study did not examine factors related to quality of sleep or the discrepancy between weeknight and weekend sleep duration, which may also play an important role in adolescent health and well-being.

Conclusion

This study provided further evidence that the majority of teenagers are not reaching optimal levels of sleep duration. Given that adequate sleep duration has benefits towards immune and metabolic functioning, as well as cognitive performance, the findings of this study are valuable in pointing out risk factors for short sleep: longer distance to school, earlier school start time, and time spent on the computer. Delaying school hours so that children and older teenagers have more time to sleep in on a daily basis might be a low-cost way to benefit health outcomes. Furthermore, if evidence continues to link electronic media use with short sleep time and poorer sleep quality, parents should be advised talk to their adolescents regarding the possible negative effect of screen time activities, and to discourage the use of such devices as sleep aids. Future research should also examine whether the use of devices such as smartphones and tablets, which have been gaining popularity among teenagers in recent years, has any impact on sleep duration. Finally, while sleep deprivation was not related to overweight status or body fat in this sample, findings do not eliminate the possibility that sleep deprivation may have contributed to overweight or increased body fat during earlier development.

Table 1. Sample characteristics and comparison of individual-level characteristics by week night sleep duration category.

	Total Sample (n=582)		<7 hours (n=181)		7-9 hours (n=279)		>9 hours (n=122)		*p*-value
	n	*% Sample*	*n*	*% Row*	*n*	*% Row*	*n*	*% Row*	
Free or reduced priced lunch									0.3096
No / Not sure	458	79%	147	32%	212	46%	99	22%	
Yes	124	21%	34	27%	67	54%	23	19%	
Race/Ethnicity									**<.0001**
Black	125	21%	46	37%	43	34%	36	29%	
Other	106	18%	41	39%	38	36%	27	25%	
Hispanic	75	13%	24	32%	33	44%	18	24%	
White	276	47%	70	25%	165	60%	41	15%	
Parents living at home									0.1722
Both parents	396	68%	123	31%	198	50%	75	19%	
None/single parent	186	32%	58	31%	81	44%	47	25%	
Have paid job	232	40%	63	27%	122	53%	47	20%	0.1526
Hours working per week									0.3061
0	350	60%	118	34%	157	45%	75	21%	
1-9 hours	92	16%	20	22%	50	54%	22	24%	
10-19 hours	83	14%	23	28%	44	53%	16	19%	
20 or more hours	57	10%	20	35%	28	49%	9	16%	
Unsupervised for more than 2 days / week & 2 hours / day	364	63%	120	33%	164	45%	80	22%	0.1966
Did not participate in team sports	228	39%	72	32%	112	49%	44	19%	0.7289
Computer time									**0.0085**
Less than 1 hour	156	27%	35	22%	82	53%	39	25%	
1 hour	115	20%	30	26%	61	53%	24	21%	
2 hours	157	27%	50	32%	75	48%	32	20%	
3 hours or more	154	26%	66	43%	61	40%	27	18%	
Television time									0.4878
Less than 1 hour	167	29%	61	37%	70	42%	36	22%	
1 hour	114	20%	34	30%	60	53%	20	18%	
2 hours	135	23%	36	27%	68	50%	31	23%	
3 hours or more	166	29%	50	30%	81	49%	35	21%	
Videogame time									0.5656
Less than 1 hour	515	88%	163	32%	247	48%	105	20%	
1 hour or more	67	12%	18	27%	32	48%	17	25%	
School start time									**<.0001**
7:30 am or earlier	223	39%	93	42%	86	39%	44	20%	
After 7:30 am	344	61%	86	25%	190	55%	68	20%	
Overweight (>85th percentile)	170	29%	53	31%	74	44%	43	25%	0.2097
Meet MVPA guidelines (≥30 min per day)	95	16%	29	31%	46	48%	20	21%	0.9911
Distance to school									**0.007**
< 1 mile	128	22%	32	25%	59	46%	37	29%	
1-5 miles	382	65%	116	30%	190	50%	76	20%	
> 5 miles	72	12%	33	46%	30	42%	9	13%	

Table 1 Continued. Sample characteristics and comparison of individual-level characteristics (mean, standard deviation) by week night sleep duration category.

	Total Sample (n=582)		**<7 hours (n=181)**		**7-9 hours (n=279)**		**>9 hours (n=122)**		**ANOVA *p*-value**
	M	**S.D.**	**M**	**S.D.**	**M**	**S.D.**	**M**	**S.D.**	
Distance to own school in miles	2.56	2.69	3.01	2.93	2.44	2.5	2.17	2.66	**0.0161**
Body fat percentage	31.06	6.93	31.19	6.86	31.06	6.97	30.87	6.99	0.9263
BMI	23.86	5.27	23.73	4.7	23.62	5.17	24.6	6.21	0.2134
Average daily minutes of MVPA	20.09	11.7	20.33	11.99	20.01	11.49	19.91	11.86	0.9459

Table 2. Correlation matrix for ordinal/continuous variables of interest (n=577).

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Sleep duration													
2. BMI	0.0026												
3. Body fat percentage	-0.0135	0.6691**											
4. Average daily MVPA	-0.0127	-0.1159**	-0.1011*										
5. SES (FRPL)	-0.0068	0.0159	-0.0016	0.0789									
6. Single parent home	0.0836	0.0969*	-0.0252	-0.0990*	-0.0082								
7. Time unsupervised	-0.0258	0.0737	-0.0267	0.0076	0.0022	0.1789**							
8. Sport participation	-0.0671	0.1147	0.0940	-0.2471	0.0211	0.1086**	-0.0408						
9. Hours working for pay	0.0145	0.0214	-0.0224	-0.0452	-0.0316	0.1085**	0.0940*	0.0780					
10. TV time	0.0672	0.1171**	0.0608	-0.0851*	0.1065*	0.1195**	0.0620	0.0902*	-0.0062				
11. Computer time	-0.2181**	0.0109	0.0211	-0.0124	0.0138	-0.0388	0.0243	0.0603	-0.0950*	0.0392			
12. Videogame time	0.0390	0.085*	-0.0007	-0.0379	0.3158**	0.0190	-0.0129	0.0430	-0.0409	0.1546**	0.0600		
13. Neighborhood SES	0.0221	0.0490	-0.0471	-0.0403	0.0112	0.1672**	0.0933	0.1572	0.1206**	0.1189**	-0.0487	0.0642	
14. Distance to school	-0.1499**	-0.0101	0.0498	-0.0284	-0.0026	0.0053	0.0067	-0.0462	0.0063	-0.0520	0.0311	-0.0591	-0.0116

Note: Binary and ordinal variables were coded as follows: SES (0=high, 1 = receives free or reduced priced lunch at school); single parent home (0=both parents, 1=single parents or no parents); time unsupervised (0=low, 1=at least 2 hours per day on 2 days per week or more); sport participation(0=some, 1=none); hours working for pay (0=none, 1=1-9 hours, 2=10-19 hours, 3=20 or more hours); TV time (0=less than 1 hour, 1 = 1 hour, 2 = 2 hours, 3 = 3 or more hours); computer time (0=less than 1 hour, 1 = 1 hour, 2 = 2 hours, 3 = 3 or more hours); videogame time(0=less than 1 hour, 1 = 1 hour or more). Neighborhood SES is estimated by percentage of households in census block-group with a household income less than $24,999.

*p <0.05.

**p <0.01.

Table 3. Multi-level linear model predicting average weeknight sleep duration.

	Coefficient	Standard Error	*P* value
Intercept	7.280	0.347	<.0001
Individual-level effects			
Race/ethnicity			0.216
Black	-0.105	0.133	
Other	-0.249	0.130	
Hispanic	0.027	0.152	
Ref = Non-Hispanic White			
BMI	-0.006	0.009	0.499
Average daily MVPA in minutes	0.000	0.004	0.994
SES - High	0.036	0.111	0.749
Ref = Free / reduced price lunch			
Parents - both	-0.230	0.102	**0.025**
Ref = 0-1 Parents at home			
Time Unsupervised - low	0.056	0.097	0.562
Ref = Unsupervised for at least 2 h per day, 2+ days per week			
Sports participation	0.114	0.097	0.242
Ref = none			
Hours working for pay per week			0.651
None	0.168	0.161	
1-9 hours	0.239	0.188	
10-19 hours	0.165	0.190	
Ref = 20 or more hours			
TV time on typical school day			0.145
Less than 1 hour	-0.060	0.124	
1 hour	-0.050	0.138	
2 hours	0.209	0.130	
Ref = 3 or more hours			
Computer time on typical school day			**0.001**
Less than 1 hour	0.509	0.129	
1 hour	0.343	0.137	
2 hours	0.207	0.126	
Ref = 3 or more hours			
Distance to school in miles	-0.055	0.017	**0.002**
Neighborhood SES	0.186	0.521	0.722
School-level effects			
	Covariance Parameter		
School start time (by school cluster)	0.08737		

Figure 1. Average week night sleep duration category by ethnicity (n=582).

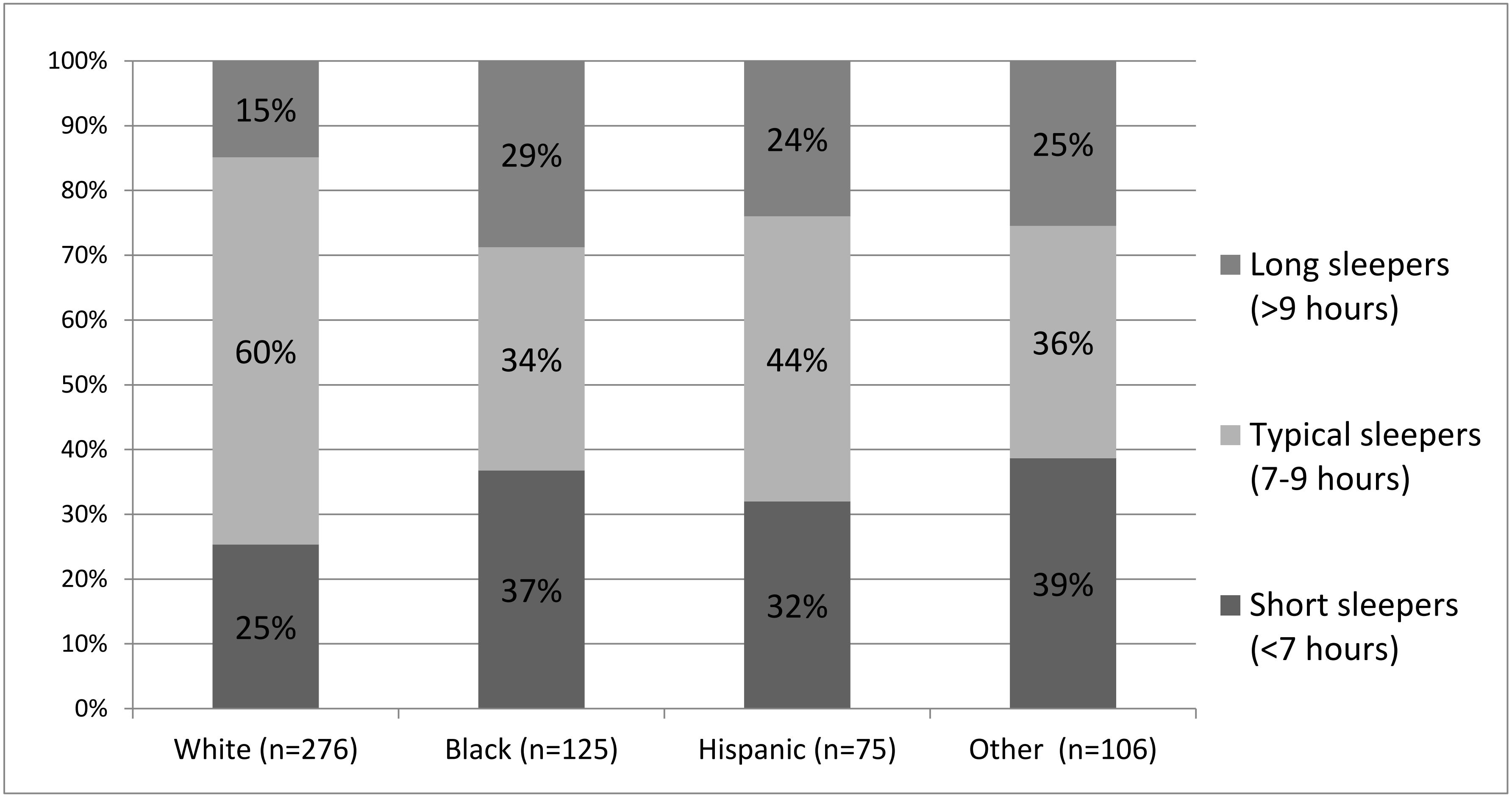


Figure 2. Average week night sleep duration by time spent on the computer (n=582).

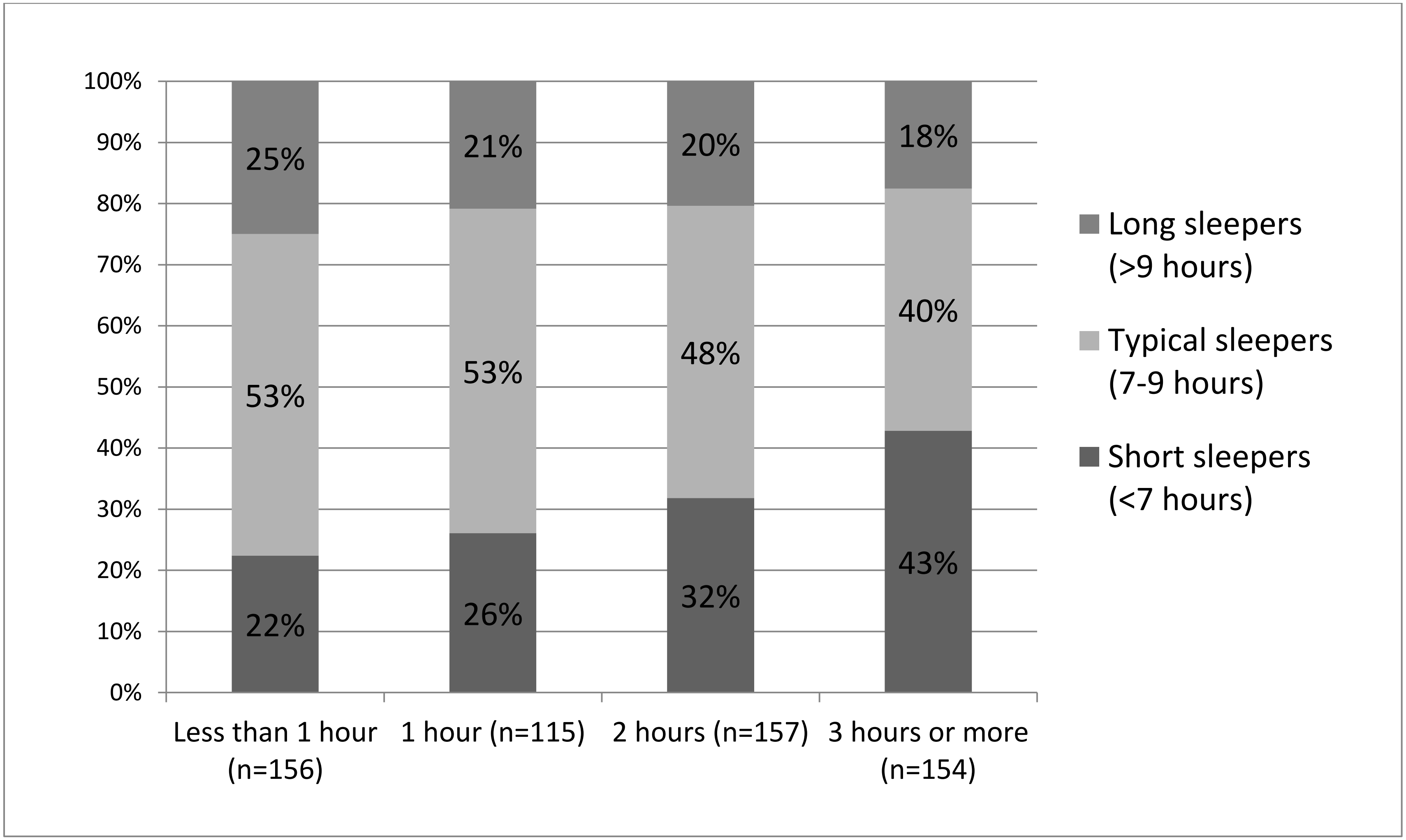


Figure 3. Average week night sleep duration by time spent watching television or videos (n=582).

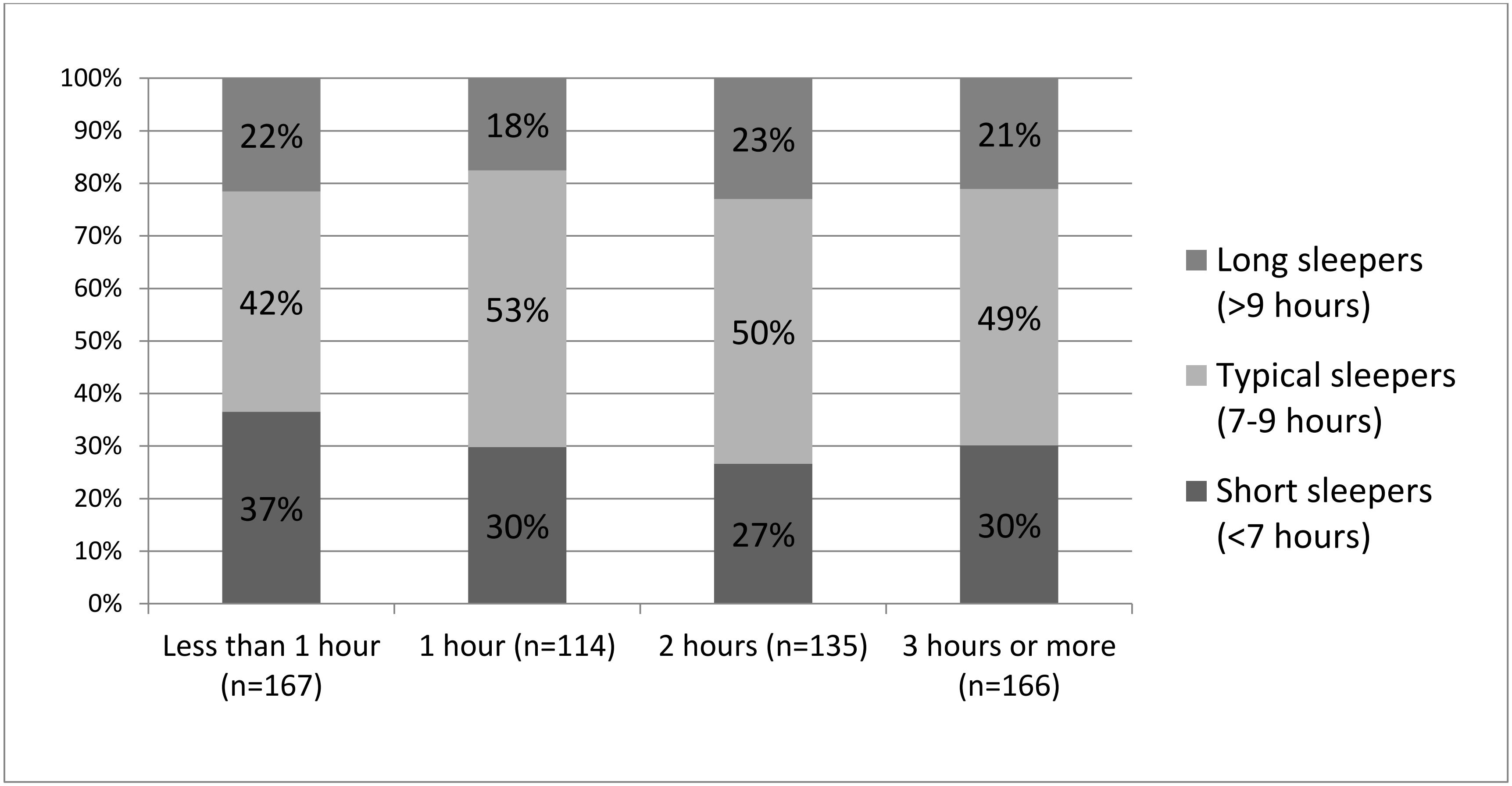


Figure 4. Average week night sleep duration by distance to school category (n=582).

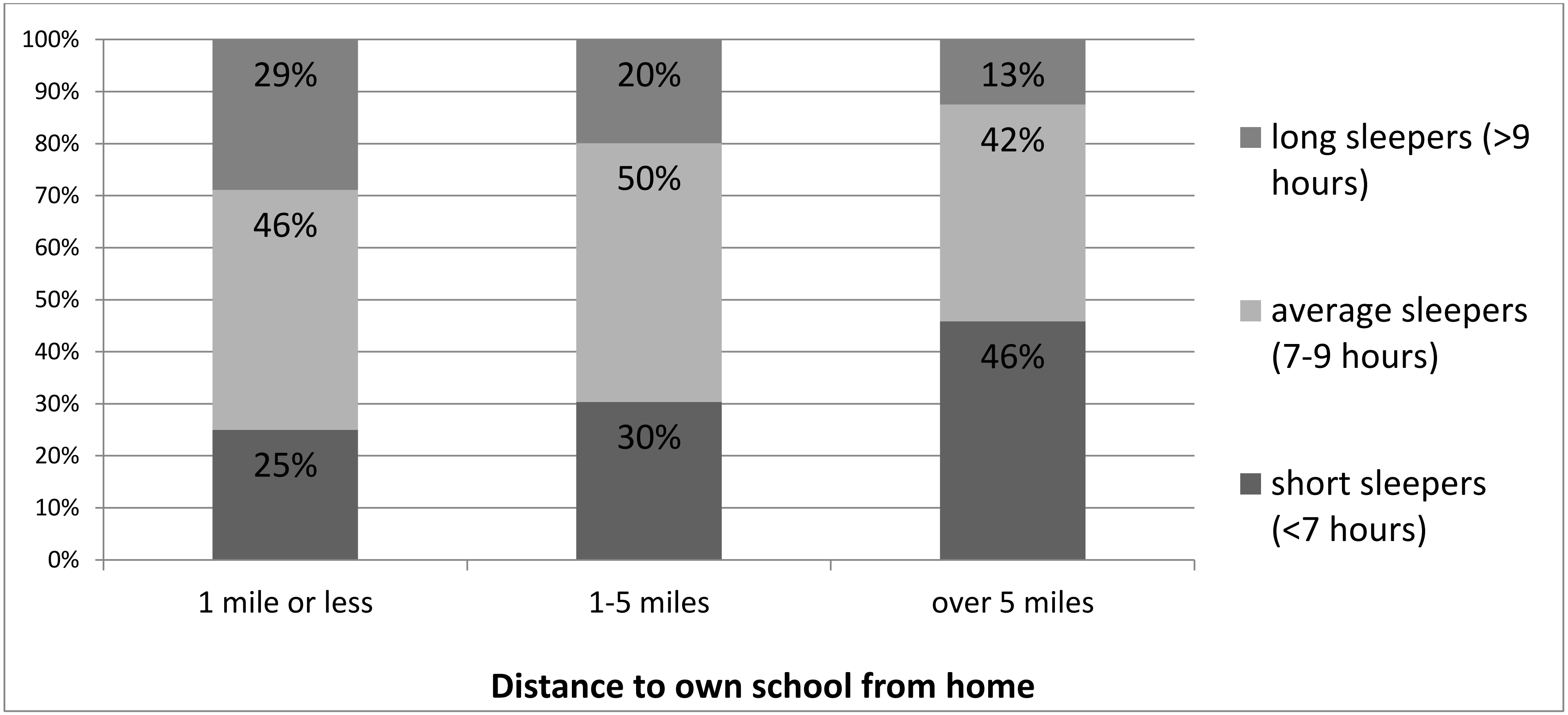


Figure 5. Distribution of computer time categories within ethnic groups ($p<0.001$).

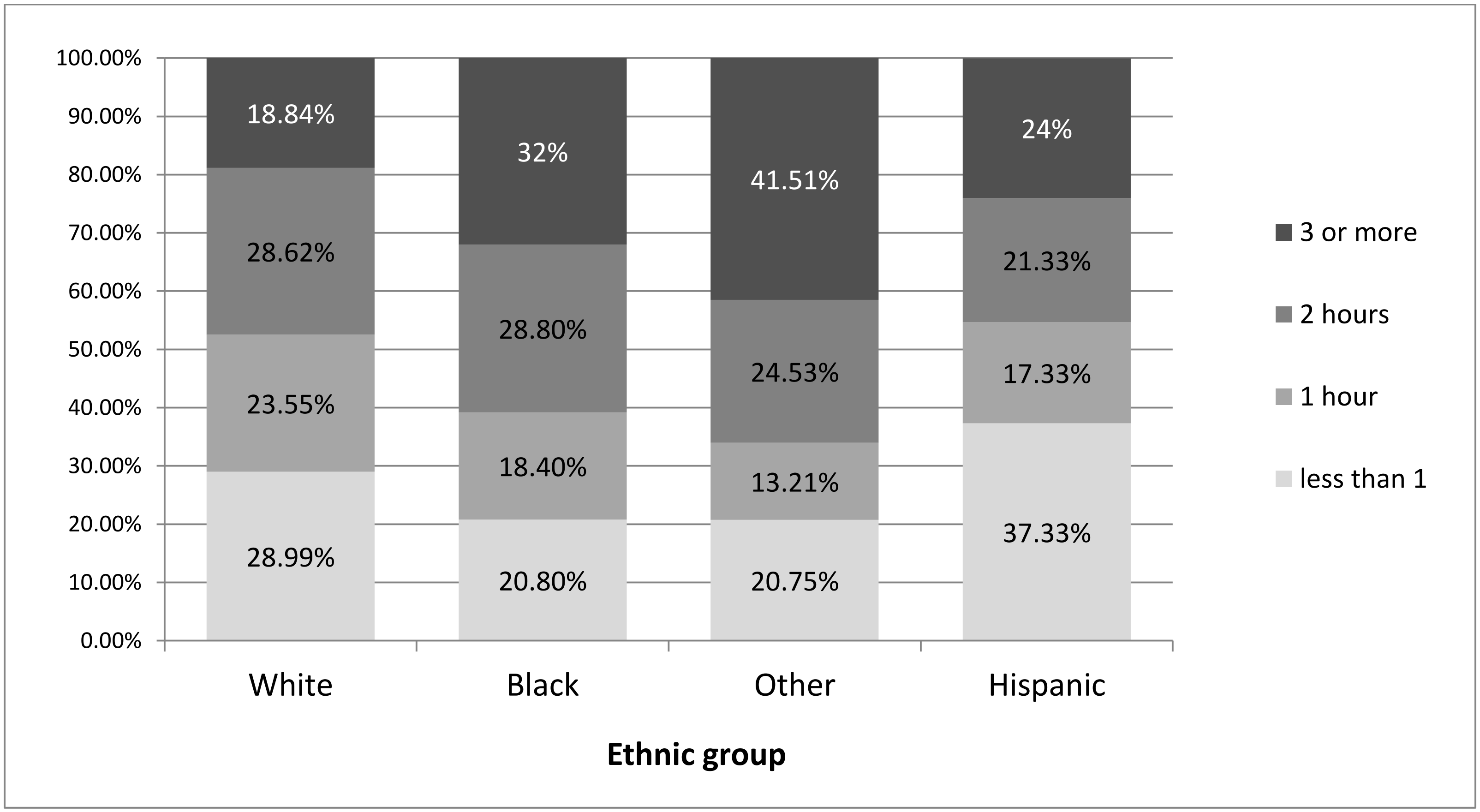


Figure 6. Distribution of television time categories within ethnic groups (p<0.0001).

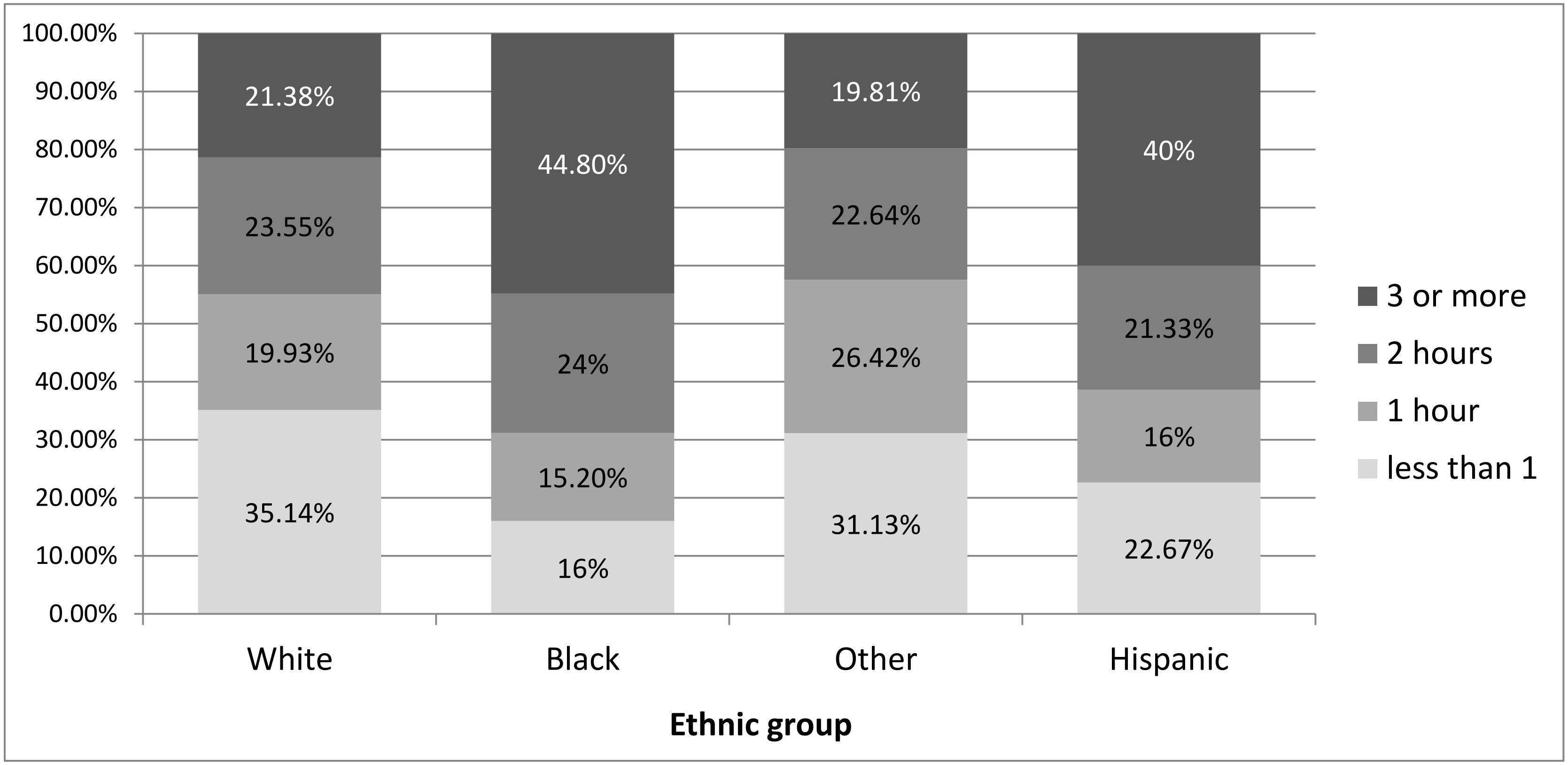
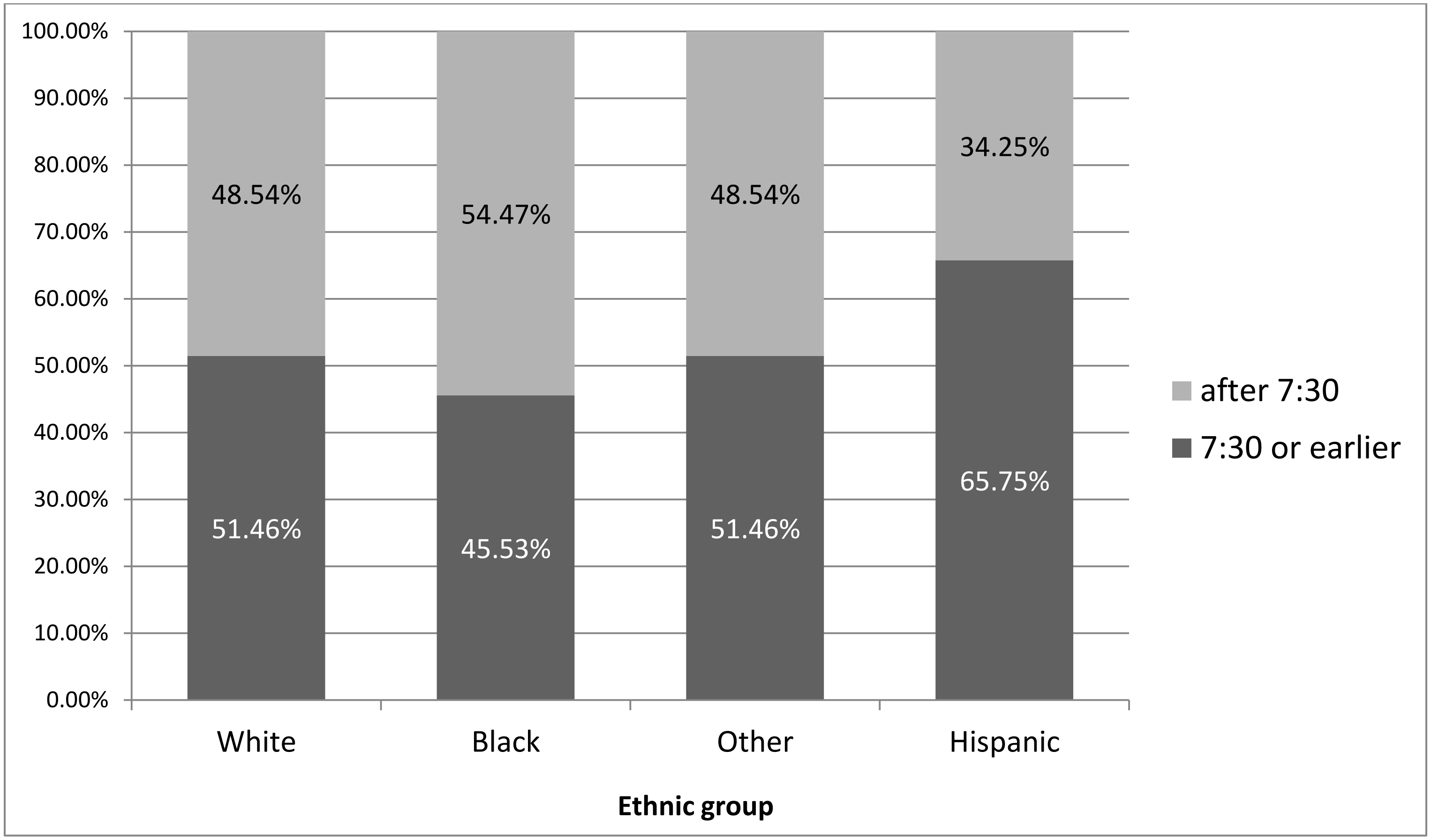


Figure 7. Distributions of school start-time categories within ethnic groups (p<0.0001).



References

1. Onyper SV, Thacher PV, Gilbert JW, Gradess SG. Class start times, sleep, and academic performance in college: A path analysis. Chronobiology International. 2012;29(3):318-35. doi: 10.3109/07420528.2012.655868. PubMed PMID: 2012-06289-009. PMID: 22390245.

2. Besedovsky L, Lange T, Born J. Sleep and immune function. European Journal Of Physiology. 2012;463(1):121-37. doi: 10.1007/s00424-011-1044-0. PubMed PMID: 22071480.

3. Sands-Lincoln M, Loucks EB, Lu B, Carskadon MA, Sharkey K, Stefanick ML, et al. Sleep Duration, Insomnia, and Coronary Heart Disease Among Postmenopausal Women in the Women's Health Initiative. Journal of Women's Health (15409996). 2013;22(6):477-86. doi: 10.1089/jwh.2012.3918. PubMed PMID: 2012145837.

4. Curcio G, Ferrara M, De Gennaro L. Sleep loss, learning capacity and academic performance. Sleep Medicine Reviews. 2006;10(5):323-37. PubMed PMID: 16564189. 5. Carskadon MA. Patterns of sleep and sleepiness in adolescents. Pediatrician. 1990;17(1):5-12. PubMed PMID: 1991-06922-001. PMID: 2315238.

6. Martinez-Gomez D, Eisenmann JC, Gomez-Martinez S, Hill EE, Zapatera B, Veiga OL, et al. Sleep duration and emerging cardiometabolic risk markers in adolescents. The AFINOS study. Sleep Medicine. 2011;12(10):997-1002. PubMed PMID: 2011428237.

7. Knutson KL. Does inadequate sleep play a role in vulnerability to obesity? American Journal of Human Biology. 2012;24(3):361-71. doi: 10.1002/ajhb.22219. PubMed PMID: 74105055.

8. Al-Hazzaa HM, Musaiger AO, Abahussain NA, Al-Sobayel HI, Qahwaji DM. Prevalence of short sleep duration and its association with obesity among adolescents 15- to 19-year olds: A cross-sectional study from three major cities in Saudi Arabia. Annals of Thoracic Medicine. 2012;7(3):133-9. doi: 10.4103/1817-1737.98845. PubMed PMID: 2011632597.

9. Bell JF, Zimmerman FJ. Shortened nighttime sleep duration in early life and subsequent childhood obesity. Archives Of Pediatrics & Adolescent Medicine. 2010;164(9):840-5. PubMed PMID: 20819966.

10. Eisenmann J, Ekkekakis P, Holmes M. Sleep duration and overweight among Australian children and adolescents. Acta Paediatrica. 2006;95(8):956-63. doi: 10.1080/08035250600731965. PubMed PMID: 21782287.

11. Garaulet M, Ortega FB, Ruiz JR, Rey-López JP, Béghin L, Manios Y, et al. Short sleep duration is associated with increased obesity markers in European adolescents: effect of physical activity and dietary habits. The HELENA study. International Journal of Obesity. 2011;35(10):1308-17. doi: 10.1038/ijo.2011.149. PubMed PMID: 66445221.

12. Hiscock H, Scalzo K, Canterford L, Wake M. Sleep duration and body mass index in 0-7-year olds. Archives of Disease in Childhood. 2011;96(8):735-9. doi: 10.1136/adc.2010.204925. PubMed PMID: 2011211782.

13. Kong AP, Wing Y-K, Choi KC, Li AM, Ko GTC, Ma RC, et al. Associations of sleep duration with obesity and serum lipid profile in children and adolescents. Sleep Medicine. 2011;12(7):659-65. doi: 10.1016/j.sleep.2010.12.015. PubMed PMID: 63190075.

14. Liu R, Liu X, Arguelles LM, Patwari PP, Zee PC, Chervin RD, et al. A Population-Based Twin Study on Sleep Duration and Body Composition. Obesity (19307381). 2012;20(1):192-9. PubMed PMID: 69919231.

15. Logue EE, Bourguet CC, Palmieri PA, Scott ED, Matthews BA, Dudley P, et al. The Better Weight-Better Sleep Study: A Pilot Intervention in Primary Care. American Journal of Health Behavior. 2012;36(3):319-34. doi: 10.5993/AJHB.36.3.4. PubMed PMID: 2011471734.

16. Magee C, Caputi P, Iverson D. Short sleep mediates the association between long work hours and increased body mass index. Journal of Behavioral Medicine. 2011;34(2):83-91. doi: 10.1007/s10865-010-9287-3. PubMed PMID: 58785487.

17. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report: US Department of Health and Human Services Public Health Service; 1998.

18. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity in the United States, 2009-2010. Hyattsville, MD.: National Center for Health Statistics; 2012. Available from: http://www.cdc.gov/nchs/data/databriefs/db82.pdf.

19. Finkelstein E, Trogdon, JG, Cohen, JW, and Dietz, W. Annual medical spending attributable to obesity: Payer- and service-specific estimates. Health Affairs. 2009:28(5): w822-w31.

20. Caprio S, Daniels SR, Drewnowski A, Kaufman FR, Palinkas LA, Rosenbloom AL, et al. Influence of race, ethnicity, and culture on childhood obesity: implications for prevention and treatment... a consensus statement of Shaping America's Health and the Obesity Society. Diabetes Care. 2008;31(11):2211-21. PubMed PMID: 2010123743.

21. Eaton DK, Kann L, Kinchen S, Shanklin S, Flint KH, Hawkins J, et al. Youth Risk Behavior Surveillance--United States, 2011. Morbidity and Mortality Weekly Report. Surveillance Summaries. Volume 61, Number 4. Centers for Disease Control and Prevention, 2012 1546-0738.

22. Foti KE, Eaton DK, Lowry R, McKnight-Ely LR. Sufficient Sleep, Physical Activity, and Sedentary Behaviors. American Journal of Preventive Medicine. 2011;41(6):596-602. doi: 10.1016/j.amepre.2011.08.009. PubMed PMID: 67345350.

23. Carskadon MA, Acebo C, Jenni OG. Regulation of adolescent sleep: implications for behavior. Annals Of The New York Academy Of Sciences. 2004;1021:276-91. PubMed PMID: 15251897.

24. Noland H, Price JH, Dake J, Telljohann SK. Adolescents' Sleep Behaviors and Perceptions of Sleep. Journal of School Health. 2009;79(5):224-30. PubMed PMID: 37208736.

25. Gradisar M, Gardner G, Dohnt H. Recent worldwide sleep patterns and problems during adolescence: A review and meta-analysis of age, region, and sleep. Sleep Medicine. 2011;12(2):110-8. doi: 10.1016/j.sleep.2010.11.008. PubMed PMID: 2010935561.

26. Carskadon MA. When Worlds Collide. (cover story). Phi Delta Kappan. 1999;80(5):348. PubMed PMID: 1423546.

27. Hitze B, Bosy-Westphal A, Bielfeldt F, Settler U, Plachta-Danielzik S, Pfeuffer M, et al. Determinants and impact of sleep duration in children and adolescents: data of the Kiel Obesity Prevention Study. European Journal of Clinical Nutrition. 2009;63(6):739-46. doi: 10.1038/ejcn.2008.41. PubMed PMID: 40831207.

28. Carrell SE, Maghakian T, West JE. A's from Zzzz's? The Causal Effect of School Start Time on the Academic Achievement of Adolescents. American Economic Journal: Economic Policy. 2011;3(3):62-81. PubMed PMID: 1242527.

29. Dewald JF, Meijer AM, Oort FJ, Kerkhof GA, Bögels SM. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. Sleep Medicine Reviews. 2010;14(3):179-89. doi: 10.1016/j.smrv.2009.10.004. PubMed PMID: 2010630269.

30. Ortega FB, Ruiz JR, Castillo R, Chillón P, Labayen I, Martínez-Gómez D, et al. Sleep duration and cognitive performance in adolescence. The AVENA study. Acta Paediatrica. 2010;99(3):454-6. doi: 10.1111/j.1651-2227.2009.01618.x. PubMed PMID: 47828527.

31. Adam EK, Snell EK, Pendry P. Sleep timing and quantity in ecological and family context: A nationally representative time-diary study. Journal of Family Psychology. 2007;21(1):4-19. doi: 10.1037/0893-3200.21.1.4. PubMed PMID: 2007-03149-002.

32. Fischer FM, Nagai R, Teixeira LR. Explaining Sleep Duration in Adolescents: The Impact of Socio-Demographic and Lifestyle Factors and Working Status. Chronobiology International: The Journal of Biological & Medical Rhythm Research. 2008;25(2/3):359-72. PubMed PMID: 32069537.

33. Tremaine RB, Dorrian J, Blunden S. Subjective and objective sleep in children and adolescents: Measurement, age, and gender differences. Sleep & Biological Rhythms. 2010;8(4):229-38. doi: 10.1111/j.1479-8425.2010.00452.x. PubMed PMID: 54397784.

34. Tagaya H, Uchiyama M, Ohida T, Kamei Y, Shibui K, Ozaki A, et al. Sleep habits and factors associated with short sleep duration among Japanese high-school students: A community study. Sleep & Biological Rhythms. 2004;2(1):57-64. doi: 10.1111/j.1479-8425.2003.00079.x. PubMed PMID: 12408134.

35. Fredriksen K, Rhodes J, Reddy R, Way N. Sleepless in Chicago: Tracking the Effects of Adolescent Sleep Loss During the Middle School Years. Child Development. 2004;75(1):84-95. PubMed PMID: EJ685526.

36. Moore M, Kirchner HL, Drotar D, Johnson N, Rosen C, Redline S. Correlates of adolescent sleep time and variability in sleep time: The role of individual and health related characteristics. Sleep Medicine. 2011;12(3):239-45. doi: 10.1016/j.sleep.2010.07.020. PubMed PMID: 2010969392.

37. Marco CA, Wolfson AR, Sparling M, Azuaje A. Family socioeconomic status and sleep patterns of young adolescents. Behavioral Sleep Medicine. 2011;10(1):70-80. doi: 10.1080/15402002.2012.636298. PubMed PMID: 2012-02105-009. PMID: 22250780.

38. Hill TD, Burdette AM, Hale L. Neighborhood disorder, sleep quality, and psychological distress: Testing a model of structural amplification. Health & Place. 2009;15(4):1006-13. doi: 10.1016/j.healthplace.2009.04.001. PubMed PMID: 2010387992.

39. Dexter D, Bijwadia J, Schilling D, Applebaugh G. Sleep, sleepiness and school start times: a preliminary study. WMJ: Official Publication Of The State Medical Society Of Wisconsin. 2003;102(1):44-6.

40. Hansen M, Janssen I, Schiff A, Zee PC, Dubocovich ML. The impact of school daily schedule on adolescent sleep. Pediatrics. 2005;115(6):1555-61. PubMed PMID: 2009019693.

41. Thorleifsdottir B, Björnsson JK, Benediktsdottir B, Gislason T, Kristbjarnarson H. Sleep and sleep habits from childhood to young adulthood over a 10-year period. Journal Of Psychosomatic Research. 2002;53(1):529-37. PubMed PMID: 12127168.

42. Chahal H, Fung C, Kuhle S, Veugelers PJ. Availability and night-time use of electronic entertainment and communication devices are associated with short sleep duration and obesity among Canadian children. Pediatric Obesity. 2013;8(1):42-51. PubMed PMID: 20133027064.

43. Padez C, Mourao I, Moreira P, Rosado V. Long sleep duration and childhood overweight/obesity and body fat. American Journal of Human Biology. 2009;21(3):371-6.

44. Ozturk A, Mazicioglu MM, Poyrazoglu S, Cicek B, Gunay O, Kurtoglu S. The relationship between sleep duration and obesity in Turkish children and adolescents. Acta Paediatrica. 2009;98(4):699-702. doi: 10.1111/j.1651-2227.2008.01169.x. PubMed PMID: 36840012.

45. Must A, Parisi SM. Sedentary behavior and sleep: paradoxical effects in association with childhood obesity. International Journal of Obesity. 2009;33:S82-S6. doi: 10.1038/ijo.2009.23. PubMed PMID: 37580471.

46. Patel SR, Hu FB. Short Sleep Duration and Weight Gain: A Systematic Review. Obesity (19307381). 2008;16(3):643-53. PubMed PMID: 31449202.

47. Lytle LA, Murray DM, Laska MN, Pasch KE, Anderson SE, Farbakhsh K. Examining the Longitudinal Relationship Between Change in Sleep and Obesity Risk in Adolescents. Health Education & Behavior. 2013;40(3):362-70. PubMed PMID: 87775087.

48. Wheaton AG, Perry GS, Chapman DP, McKnight-Eily LR, Presley-Cantrell LR, Croft JB. Relationship between body mass index and perceived insufficient sleep among U.S. adults: an analysis of 2008 BRFSS data. BMC Public Health. 2011;11(1):295-302. doi: 10.1186/1471-2458-11-295. PubMed PMID: 61027680.

49. Meyer KA, Wall MM, Larson NI, Laska MN, Neumark-Sztainer D. Sleep Duration and BMI in a Sample of Young Adults. Obesity (19307381). 2012;20(6):1279-87. PubMed PMID: 75913525.

50. Se Eun P, Hee Man K, Dae Hyun K, Jongoh K, Bong Soo C, Dae Jung K. The Association Between Sleep Duration and General and Abdominal Obesity in Koreans: Data From the Korean National Health and Nutrition Examination Survey, 2001 and 2005. Obesity (19307381). 2009;17(4):767-71. PubMed PMID: 37158281.

51. Storfer-Isser A, Patel SR, Babineau DC, Redline S. Relation between sleep duration and BMI varies by age and sex in youth age 8-19. Pediatric Obesity. 2012;7(1):53-64. doi: 10.1111/j.2047-6310.2011.00008.x. PubMed PMID: 2011626170.

52. Calamaro CJ, Park S, Mason TBA, Marcus CL, Weaver TE, Pack A, et al. Shortened sleep duration does not predict obesity in adolescents C. J. Calamaro et al. Sleep duration and obesity in adolescents. Journal of Sleep Research. 2010;19(4):559-66. doi: 10.1111/j.1365-2869.2010.00840.x. PubMed PMID: 54623670.

53. Webber LS, Catellier DJ, Lytle LA, Murray DM, Pratt CA, Young DR, et al. Promoting physical activity in middle school girls trial of activity for adolescent girls. American Journal of Preventive Medicine. 2008;34(3):173-84. doi: 10.1016/j.amepre.2007.11.018. PubMed PMID: 2008-01880-001. PMID: 18312804.

54. Rushovich BR, Voorhees CC, Davis CE, Neumark-Sztainer D, Pfeiffer KA, Elder JP, et al. The relationship between unsupervised time after school and physical activity in adolescent girls.

International Journal of Behavioral Nutrition & Physical Activity. 2006;3:20-9. doi: 10.1186/1479-5868-3-20. PubMed PMID: 28774079.

55. Voorhees CC, Catellier DJ, Ashwood JS, Cohen DA, Rung A, Lytle L, et al. Neighborhood Socioeconomic Status and Non School Physical Activity and Body Mass Index in Adolescent Girls. Journal of Physical Activity & Health. 2009;6(6):731-40. PubMed PMID: 44993700.

56. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC Growth Charts for the United States: methods and development. Vital And Health Statistics Series 11, Data From The National Health Survey. 2002(246):1-190. PubMed PMID: 12043359.

57. Pratt C, Webber LS, Baggett CD, Ward D, Pate RR, Murray D, et al. Sedentary Activity and Body Composition of Middle School Girls: The Trial of Activity for Adolescent Girls. Research Quarterly for Exercise and Sport. 2008;79(4):458-67. PubMed PMID: EJ840631.

58. Treuth MS, Schmitz K, Catellier DJ, McMurray RG, Murray DM, Almeida MJ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. Medicine & Science in Sports & Exercise. 2004;36(7):1259-66. PubMed PMID: 2005029653.

59. Cain N, Gradisar M. Electronic media use and sleep in school-aged children and adolescents: A review. Sleep Medicine. 2010;11(8):735-42. doi: 10.1016/j.sleep.2010.02.006. PubMed PMID: 53047955.

60. Eggermont S, Van den Bulck J. Nodding off or switching off? The use of popular media as a sleep aid in secondary-school children. Journal of Paediatrics & Child Health. 2006;42(7/8):428-33. doi: 10.1111/j.1440-1754.2006.00892.x. PubMed PMID: 21604034.

61. Olds T, Ferrar KE, Gomersall SR, Maher C, Walters JL. The Elasticity of Time: Associations Between Physical Activity and Use of Time in Adolescents. Health Education & Behavior. 2012;39(6):732-6. PubMed PMID: 84490121.

62. Carskadon MA, Wolfson AR, Acebo C, Tzischinsky O, Seifer R. Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. Sleep: Journal of Sleep Research & Sleep Medicine. 1998;21(8):871-81. PubMed PMID: 1999-00079-009.

63. Yu Y, Lu BS, Wang B, Wang H, Yang J, Li Z, et al. Short sleep duration and adiposity in Chinese adolescents. Sleep. 2007;30(12):1688-97. PubMed PMID: 18246978.