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Olivia Shafer Date

A Cross-Sectional Examination of Sleep and Obesity in Children and Adolescents Aged 10-17 Across the United States

By

Olivia Shafer
Master of Public Health

Hubert Department of Global Health

Solveig A. Cunningham, PhD MSc
Committee Chair

Johnathan A. Edwards, MSPH
Committee Member

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By

Olivia Shafer

Bachelor of Science
American University
2017

Thesis Committee Chair: Solveig A. Cunningham, PhD MSc

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Abstract

A Cross-Sectional Examination of Sleep and Obesity in Children and Adolescents Aged 10-17 Across the United States
By Olivia Shafer

Background. Childhood and adolescent obesity is a primary health concern in the United States. Obesity has multiple health sequelae including diabetes, high blood pressure, sleep apnea, among others. Sleep has been suggested as lying on the pathway to obesity. Most of the research done to date has focused on adults, rather than children and adolescents. This paper will examine the relationship between sleep and obesity in a younger population, with a representative sample that allows for generalizability to children and adolescents within the United States between the ages of ten and seventeen who are not institutionalized.

Objectives. To examine the relationship between sleep and obesity in a cross-sectional manner in non-institutionalized children and adolescents between ten and seventeen years old in the United States.

Methods. Data are from the National Survey of Children's Health (2016-2017) and were used to explore the relationship between hours of sleep children and adolescents get and BMI class. The sample size was 30,790. Descriptive statistics, ANOVA, chi-square, logistic regression, and multinomial regression were performed to explore this relationship.

Results. For each additional hour of sleep there is a 15.2% lower odds of obesity for children and adolescents between ten and seventeen years of age. Children and adolescents were 0.733x more likely to remain obese if they had one more hour of sleep compared to those who are of normal weight holding all other variables constant.

Conclusion. The results suggest that the amount of sleep children and adolescents get is associated with BMI category, and obesity. Further research in the area should look to establish the causal pathway between this relationship, and if there is a point where intervention could be useful.

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Introduction

Childhood and adolescent obesity, a body mass index at or above the 95th percentile of sex-specific BMI for age growth charts (Centers for Disease Control and Prevention 2019), is a major health concern in the United States. Adolescents between the ages of twelve and nineteen have the highest prevalence of obesity at 20.6% followed by 18.4% for children aged six to eleven. Obesity in children is a health concern because it is associated with insulin resistance, type 2 diabetes, high blood pressure, asthma, high cholesterol, and sleep apnea among other conditions (Centers for Disease Control and Prevention). In addition to these physical health sequalae, obesity has been associated with mental health outcomes including anxiety, depression, low self-esteem, and bullying (Centers for Disease Control and Prevention).

Several papers have reported a relationship between sleep and obesity in children or adolescents. A paper by Firouzi et al. reported that children in Malaysia between the ages of six and twelve with inadequate sleep were at a higher risk of being overweight (Firouzi, Poh et al. 2014). Another study randomly assigned children to either spend an extra hour and a half in bed or spend an hour and a half less in bed and found that those who spent more time in bed reported decreased food consumption in comparison to the group who spent less time in bed (Hart, Carskadon et al. 2013). A paper by Duraccio et al. summarizes the possible mechanisms behind the relationship between sleep and obesity. One of the potential mechanisms involves the activation of the brain's reward center. Another mechanism is the increased caloric intake associated with mood regulation. Potential changes in metabolic hormones like leptin, ghrelin, and insulin sensitivity could have something to do with the link between sleep and obesity as well (Kara M. Duraccio 2019). While the specific mechanism for the relationship between sleep and obesity in children and adolescents is unknown, this paper will examine the link between

sleep, diet, activity, and obesity in a cross-sectional manner. This paper will also examine the role that potential confounding variables may play including nutrition, physical activity, socioeconomic status and neighborhood level factors.

This paper aims to examine how sleep and obesity are related in a cross-sectional manner for children aged ten to seventeen across the United States. This paper will look at the role of confounding variables like socioeconomic status, time spent doing physical activities and sedentary activities, and diet. The data used in this paper were taken from the 2016 and 2017 National Survey of Children's Health, a representative sample of children and adolescents across the United States. This thesis will add to the growing body of research on sleep and obesity, focusing on adding to the information about children and adolescents within the United States after controlling for physical activity, screen time, socioeconomic status and diet.

Literature Review

Prevalence of Obesity in the United States

The prevalence of childhood obesity is high in the United States. Childhood obesity is defined as a body mass index (BMI) at or higher than the 95th percentile of sex-specific BMI for age growth charts (Centers for Disease Control and Prevention 2019). According to the Centers for Disease Control and Prevention (CDC), children aged six to eleven, the prevalence was at 18.4% and was even higher for adolescents between the ages of twelve and nineteen at 20.6% (Centers for Disease Control and Prevention 2019).

Additionally, the prevalence differed across populations. Non-Hispanic whites had a prevalence of 14.1%, non-Hispanic blacks at 22%, non-Hispanic Asians at 11%, and Hispanics at 25.8% for children and adolescents aged two to nineteen (Centers for Disease Control and Prevention 2019). According to the CDC, children who are obese have a higher risk of insulin resistance, type 2 diabetes, asthma, sleep apnea, high blood pressure and cholesterol, gallstones, fatty liver disease, heartburn, and joint problems (Centers for Disease Control and Prevention). Mental health outcomes, such as anxiety and depression, low self-esteem, and bullying, are also associated with childhood obesity (Centers for Disease Control and Prevention). Children who are obese are more likely to be obese as adults, and the risk factors they experience in adulthood may increase in severity as they age (Centers for Disease Control and Prevention).

A study done by Carey et al. using the National Survey of Children's Health data from 2011 and 2012 on children and adolescents aged ten to seventeen in the United States found that BMI was significantly associated with more school absences and problems after controlling

for sociodemographic and healthcare variables (FR Carey 2015). They suggest a relationship between weight status and worse educational outcomes in children (FR Carey 2015).

Sleep

According to the National Sleep Foundation, sleep is important for a myriad of reasons in both children and adolescents (National Sleep Foundation). If children and adolescents do not have adequate sleep, they may have trouble learning in school, may exhibit poor behavior, and may have trouble with their mood and emotions (National Sleep Foundation). Inadequate sleep may also be linked to drowsy driving, substance use, and suicidal behaviors in adolescents (National Sleep Foundation). Fredriksen et al. found that by middle school, both males and females were getting less sleep than is recommended, in a study done on children aged eleven to fourteen (Katia Fredriksen 2004). Additionally, those who were not getting adequate sleep also experienced decreased grades and self-esteem, as well as more depressive symptoms (Katia Fredriksen 2004).

Sleep Guidelines and Recommendations for Children Aged 10-17

Babies, children, and adolescents require different amounts of sleep and obtain their sleep in in various patterns such as small naps or sleeping through the night (National Sleep Foundation). The National Sleep Foundation provides the following recommendations for sleep time for children aged ten to seventeen. Children aged six to thirteen should have between 9 and 11 hours of sleep, no less than 7 hours, and no more than 12 hours (National Sleep Foundation). Children in this age range may be more interested in watching television before bed, which can impact their sleep and cause difficulty falling asleep (National Sleep Foundation). Adolescents between the ages of fourteen and seventeen require 8 to 10 hours of

sleep per night, and should not get less than 7 hours or more than 11 hours (National Sleep Foundation).

Sleep Patterns

A meta-analysis of studies by Galland et al. examined sleep time in children and adolescents to create an estimate of sleep patterns using actigraphy data (Barbara C. Galland 2018). Children between nine and eleven had sleep time means between 7.30 and 9.30 hours, with a pooled mean of 8.07 hours (Barbara C. Galland 2018). Adolescents between twelve and fourteen had sleep time means between 6.00 and 8.70 hours and pooled mean of 7.15 hours (Barbara C. Galland 2018). Lastly, adolescents aged fifteen to eighteen had mean sleep times ranging between 6.40 and 7.53 hours, with a pooled mean of 7.02 hours (Barbara C. Galland 2018). All of these estimates fall below the recommendations by the National Sleep Foundation for hours of sleep per night. This indicates that children and adolescents are not getting enough sleep.

Sleep and Obesity

According to a study in Adolescent Health, Medicine, and Therapeutics by Duraccio et al. adolescents with inadequate sleep appear to experience more neural activation in the regions of the brain related to food reward (Kara M. Duraccio 2019). However, they note that this increase in brain activity may not lead to adolescents seeking out food (Kara M. Duraccio 2019). Duraccio et al. also note that adolescents with poor sleep may increase their food intake as a way to compensate for negative emotional experiences, but that the studies examining this have produced mixed results (Kara M. Duraccio 2019). Another potential mechanism is metabolic changes associated with poor sleep (Kara M. Duraccio 2019). Leptin and ghrelin are two hormones that regulate hunger, with leptin suppressing hunger and ghrelin increasing

hunger (Kara M. Duraccio 2019). Duraccio et al. note that while studies suggesting a link between poor sleep and hormonal changes have been done in adults, the results of these studies do not necessarily generalize to adolescents or children (Kara M. Duraccio 2019). While leptin and ghrelin hormonal shifts appear to be inconclusive in adolescents, insulin sensitivity could be another mechanism in the pathway between sleep and obesity (Kara M. Duraccio 2019). A study done by Dorenbos et al. on adolescents found that sleep should be an intervention for insulin resistance in early puberty, as insulin resistance is known to be associated with body composition and BMI (E. Dorenbos 2015). Despite these initial findings, Duraccio et al. concluded that the mechanisms for how poor sleep is related to the increased risk of obesity remain unclear (Kara M. Duraccio 2019).

Additional studies not reviewed by Durracio et al. have found possible correlations between sleep and BMI, but have also not proven causality. A study by Laurson et al. found that children aged seven to twelve in the Midwest meeting the recommendations for screen time, physical activity, and sleep were less likely to be obese than their counterparts who met none of them, one of them, or two of them (Kelly R. Laurson 2014). A study in Malaysian children found that children aged six to twelve who had inadequate sleep and had higher carbohydrate intake were at a higher risk of being overweight or obese (Firouzi, Poh et al. 2014). In a study by Hart et al. on children aged eight to eleven years, children were randomized to either spend an hour and a half less in bed or an hour and a half more in bed for one week (Hart, Carskadon et al. 2013). The children had their leptin levels measured, and filled out a food diary (Hart, Carskadon et al. 2013). The children who had more sleep had lower leptin levels, lower weight, and reported decreased food consumption compared to the children who were randomized to

sleep less (Hart, Carskadon et al. 2013). This indicates that there may be a relationship between sleep and weight, with leptin potentially playing a role.

Based on the literature, there appears to be a relationship between sleep and obesity. The potential causal pathways for this link are laid out below. To the author's knowledge, an analysis with this large of sample size has not been done examining the relationship between sleep and obesity in children and adolescents in the United States.

Potentially Confounding Variables

Nutrition

Americans should eat a variety of foods, including vegetables, fruits, grains, dairy, protein, and oils (US Department of Health and Human Services). The vegetables consumed should include legumes, dark green, starchy, and red and orange vegetables, and should aim to have 2.5 cups of vegetables a day (US Department of Health and Human Services). People should avoid adding butter, other creamy sauces, and salt to their vegetables, and should alternate the vegetables they regularly consume (US Department of Health and Human Services). Whole fruits, including canned, fresh, dried, and frozen fruits, are another component of a healthy diet (US Department of Health and Human Services). People should aim to have 2 cups of fruit a day (US Department of Health and Human Services). Whole grains and limited amounts of refined grains are also components in healthy eating patterns (US Department of Health and Human Services). Whole grains have the whole kernel and are foods like oats, brown rice, and quinoa (US Department of Health and Human Services). Refined grains have lower fiber and iron content due to having part of the kernel removed (US Department of Health and Human Services). The daily recommended amount of grains is 6 ounces, with at least 3 ounces of whole grains (US Department of Health and Human Services).

Fat-free and low-fat dairy is another aspect of a healthy diet. Adolescents aged nine to eighteen should have 3 cups of dairy a day (US Department of Health and Human Services). Nutrient-dense forms of protein, including animal and plant proteins, should be included in a healthy eating pattern (US Department of Health and Human Services). People should aim to have 5.5 ounces of protein a day, from a variety of sources, including nuts, meat, eggs, seafood, legumes, seeds, poultry, and soy products(US Department of Health and Human Services). Oils are another component of a healthy diet, as they provide necessary fatty acids (US Department of Health and Human Services). Oils from corn, olives, peanuts, canola, soybean, safflower, and sunflowers are a good source of fatty acids (US Department of Health and Human Services). It should be noted that the fats from palm oil, coconut oil, and palm kernel oil are not included in this category, as they are higher in saturated fats compared to the other oils listed above (US Department of Health and Human Services). Healthy diets reduce the intake of sodium, saturated fats, trans fats, and added sugars (US Department of Health and Human Services).

In general, the typical American diet does not meet the guidelines outlined above. Close to 75% percent of the population has a diet low in fruits, oils, dairy, and vegetables (US Department of Health and Human Services). Over 50% of the population meets or exceeds the total protein and grain guidelines (US Department of Health and Human Services). Most of the population consumes more than the recommended amounts of saturated fat, sodium, and added sugars (US Department of Health and Human Services). A study in China on children aged six to seventeen found that children who consumed a Westernized diet, higher in snacks, red meat, cakes, and beverages with added sugar, had an increased risk of obesity (Dan Liu 2018). A review paper by St-Onge et al. reported there may be a link between nutrition and sleep in

adults. Specifically citing evidence that a high carbohydrate diet has been linked to shorter sleep onset latency times and slow wave sleep (St-Onge, Mikic et al. 2016). Additionally, there is evidence supporting the association between high fat diets and reduced sleep efficiency and REM sleep, along with an increase in arousals and slow wave sleep (St-Onge, Mikic et al. 2016).

Activity Recommendations

According to the World Health Organization (WHO), people between the ages of five and seventeen should have 60 minutes of moderate to vigorous physical activity daily (World Health Organization). It is acceptable to split physical activity into segments to meet the cumulative 60-minute goal (World Health Organization). The WHO also recommends that children and adolescents who are not currently physically active can work their way up to 60 minutes daily (World Health Organization). Any physical activity, even less than the recommended amount, is an improvement from no physical activity (World Health Organization). Physical activity is essential for children and adolescents because it helps them weigh a healthy amount and develop healthy muscles, bones, joints, lungs, and heart function (World Health Organization).

Children and adolescents above the age of six should have a consistent amount of screen time per day that does not interfere with physical activity, sleep, or study time (American Academy of Pediatrics).

<u>Activity and Obesity</u>

A systematic review by Janssen et al. reported that physical activity is associated with health benefits in children. These benefits include a reduction in risk for obesity and high blood pressure (Janssen and Leblanc 2010). Additionally, there appears to be a dose-response relationship. Higher amounts of physical activity yielded more benefits, and aerobic activities

yielded the most health benefits (Janssen and Leblanc 2010). This led them to recommend that children and adolescents aged five to seventeen should have a total of 60 minutes of moderate physical activity daily (Janssen and Leblanc 2010). Mitchell et al. found that for each hour increase in sedentary activity the odds of obesity also increased in twelve year old children in the United Kingdom after controlling for confounding variables such as age, sex, parental sociodemographic variables, maternal obesity, smoking, television habits, early life sleep, pubertal development, height, and height squared (Mitchell, Mattocks et al. 2009). These studies suggest that activity type should be examined when answering the research question.

Activity and Sleep

A study by Pesonen et al. reported a link between physical activity in eight year old children in Finland and sleep (Pesonen, Sjöstén et al. 2011). The study used actigraphy to track daytime and evening physical activity of the children along with their sleep. They found that children who had higher levels of physical activity had poorer sleep efficiency, shorter sleep durations, and more arousals and awakenings during the night compared to those with less physical activity (Pesonen, Sjöstén et al. 2011). These results are in contrast to other epidemiological studies that rely on self-reported measures on sleep and physical activity.

Socioeconomic Status

Socioeconomic Status and Nutrition

Socioeconomic status may impact several of these factors including nutrition. Darmon and Drewnowski found that there was a relationship between socioeconomic status and dietary patterns after reviewing studies from around the world in both children and adults (Darmon and Drewnowski 2008). They reported that generally, poorer dietary patterns were seen in those of lower socioeconomic status, compared to higher-quality dietary patterns in those with higher socioeconomic status (Darmon and Drewnowski 2008). The relationship was observed at

the household level and individual level, as well as across age and sex (Darmon and Drewnowski 2008).

Socioeconomic Status and Activity

Socioeconomic status may impact physical activity. Drenowatz et al. reported that children aged eight to eleven with lower socioeconomic status had more sedentary behavior than children who were not of a low socioeconomic background (Drenowatz, Eisenmann et al. 2010). They did not find a significant relationship between socioeconomic status and physical activity after controlling for BMI (Drenowatz, Eisenmann et al. 2010).

Socioeconomic Status and Sleep

Socioeconomic status was found to be related to sleep patterns on both weekend nights and school nights, but in different ways, according to a study done with seventh graders in New England by Marco et al. (Marco, Wolfson et al. 2011). For weekend nights, sleep hygiene, neighborhood conditions, and socioeconomic status had an association with later and inconsistent sleep habits (Marco, Wolfson et al. 2011). For school nights, sleep hygiene habits and socioeconomic status were associated with inconsistent, shorter, and later sleep practices (Marco, Wolfson et al. 2011). Another study by Grandner et al. in adults across the United States concluded that people with a lower socioeconomic background were more likely to have sleep complaints related to duration and quality (Michael A. Grandner 2010). These studies support the hypothesis that socioeconomic status may influence sleep.

Socioeconomic Status and Obesity

Obesity prevalence had an inverse relationship in non-Hispanic white children and adolescents in the United States, as income decreases, the prevalence of obesity increased, according to an NCHS data brief (Cynthia L. Ogden 2010). The authors also found that most children with obesity are not low-income; at 130% of the poverty level (Cynthia L. Ogden 2010).

Additionally, those with lower incomes may experience barriers to maintaining their weight and getting adequate sleep, such as work schedules for parents, which can make bedtime routines challenging, according to a study examining preschoolers' bedtime routines (Hale L).

Environmental Factors and Obesity

Household-level Factors and Obesity and Sleep

Household-level factors may also play a role in childhood and adolescent obesity. According to a paper by Young Jo, households with obese children were more likely to have parents who were obese, less educated, not married, and limited financially (Young Jo 2017). The author also reported that households with obese children tended to live in areas of food deserts, where access to healthy foods is limited, based on data from a nationally representative sample (Young Jo 2017). A paper by Spilsbury et al. found that parenting style impacted sleep in children between the ages of eight and eleven in Ohio (James C. Spilsbury 2005). Specifically, parenting styles that encouraged maturity in the children were associated with a longer sleep time on average (James C. Spilsbury 2005). While there is limited research in this area, these findings suggest a possible link between the home environment and sleep.

Neighborhood Level Factors and Obesity and Sleep

The neighborhood and built environment children and adolescents grow in may influence their weight. A paper by Singh et al., using data on children aged ten to seventeen in the United States, found that children who lived in neighborhoods with unfavorable conditions (garbage and litter in the neighborhood, the neighborhood is not safe, poor housing, and vandalism) were more likely to spend more than two hours a day watching television, not be physically active, and use the computer for more than two hours a day compared to children who lived in neighborhoods with favorable conditions (Gopal K. Singh 2010). Additionally, they reported that approximately 20% of children living in neighborhoods with unfavorable

conditions were obese, compared to nearly 15% in the neighborhoods with favorable conditions (Gopal K. Singh 2010). A study by Troxel et al. in middle schoolers in the United States found that adolescents who lived in neighborhoods with lower cohesion was associated with an increased risk of sleep troubles (Troxel, Shih et al. 2017). This suggests that neighborhood level factors and sleep could have a relationship.

Conceptual Framework

Children are getting less sleep than the 8-11 hours of sleep recommended by the National Sleep Foundation by the time they are in middle school, with a more pronounced decrease in sleep times from the beginning of sixth grade to the end of eighth grade in females compared to males (National Sleep Foundation , Katia Fredriksen 2004). While the mechanism for a relationship between sleep and obesity is unknown, especially in children and adolescents, Duraccio et al. present some theories.

One potential hypothesis is food reward processes. In this pathway, the reward centers of the brain would be impacted by having less sleep, and studies have shown that these regions have increased activity in adolescents who got less sleep compared to when they had healthy sleep (Kara M. Duraccio 2019). Additionally, when adolescents had less sleep, they ranked desserts or sweet foods higher in terms of how appetizing they were compared to when they had an adequate amount of sleep (Kara M. Duraccio 2019)

Another potential pathway is related to mood regulation. Eating may be a way to moderate negative emotions that are associated with poor sleep habits; however, the evidence is mixed, and further research is needed to examine this relationship (Kara M. Duraccio 2019).

Metabolic changes have been found in adults with shortened sleep (Kara M. Duraccio 2019). Notably, related to leptin and ghrelin, hormones that suppress and stimulate hunger, respectively (Kara M. Duraccio 2019). However, this research is limited in adolescents and children, and more is needed to determine whether shortened sleep impacts these hormones in children and adolescents. Shortened sleep may also impact insulin resistance (Kara M. Duraccio 2019). Puberty alone increases the risk of insulin resistance, and studies have shown that adolescents who did not have adequate sleep had higher insulin resistance than peers who

had enough sleep (Kara M. Duraccio 2019). A study by Hart et al. found changes in fasting leptin levels after randomizing children to either spend an hour and half more or less in bed. The children who were randomized to spend an hour and a half more in bed had lower levels of leptin, reported less food intake, and weighed less than those who were randomized to spend an hour and a half less in bed (Hart, Carskadon et al. 2013).

Another potential pathway could be the higher intake in sugary foods and beverages. Several studies have shown that short sleep duration is associated with an increase in high-glycemic foods and drinks (Kara M. Duraccio 2019). This increase can contribute to problems with glucose regulation, as well as increased caloric intake, as these high glycemic foods and drinks are often higher in calories (Kara M. Duraccio 2019). An increase in caloric intake could also be due to adolescents skipping breakfast and consuming more calories later on in the day to make up for it (Kara M. Duraccio 2019).

Sedentary activity has been linked, in a correlational manner, to inadequate sleep (Kara M. Duraccio 2019). Sedentary activity is lying or sitting down, and encompasses sitting or lying to watch TV or play video games, working at a desk while sitting, driving, etc (The Department of Health 2019). A meta-analysis by Carter et al. reported an association between inadequate sleep, in quality and quantity, and the use of a media device in children and adolescents aged six to nineteen (Carter B 2016).

While studies have looked at the pathways of mood regulation, hormonal changes, increased intake of high glycemic foods, activation of the brain's reward centers, and increased sedentary behaviors, as well as screen time on the pathway below from inadequate sleep to childhood and adolescent obesity, they do not do so together. Poor sleep may be related to

obesity through a combination of these various pathways. For example, a child or adolescent may have shorter sleep duration, leading them to consume more calories the following day. This increase in caloric intake could be due to an attempt to regulate moods, consuming high glycemic foods, and or activation in the brain's reward area. Over time, the children or adolescents could develop insulin resistance, or experience changes in leptin and ghrelin, altering their dietary patterns as well. Children and adolescents may also spend more time on sedentary activities and or screen time, which could create a feedback loop where they, in turn, have an increase in inadequate sleep and continue to increase sedentary behavior and screen time. Over time, all of these factors could contribute to childhood and adolescent obesity. The pathway highlighted in blue in the conceptual framework shows the mechanisms that will be examined in this paper.

Figure One: Conceptual Framework for Sleep and Obesity in Children and Adolescents.

Data

The data for this project were from the National Survey of Children's Health (NSCH) (National Survey of Children's Health 2016-2017). NSCH funding primarily comes from the Health Resources and Services Administration's Maternal and Child Health Bureau (HRSA MCHB), with other funding coming from the CDC, the United States Department of Agriculture, and the United States Environmental Protection Agency (Data Resource Center for Child & Adolescent Health). The United States Census Bureau, Associate Director for Demographic Programs, performed the NSCH for the HRSA MCHB (Data Resource Center for Child & Adolescent Health). The survey is intended to be representative of children between the ages of zero and seventeen in the United States who are not institutionalized (The National Survey of Children's Health). The goal of the survey is to provide data on child health including, both physical and mental health, insurance coverage, access to healthcare, the family, schooling, and neighborhood for children aged zero to seventeen across the United States, in a cross-sectional manner (Data Resource Center for Child & Adolescent Health). The sampling frame for the survey is civilian, non-institutional household addresses across the United States (US Census Bureau 2018). The households were randomly selected to participate, and one child within each household was identified to participate. Children between the ages of zero and five, and children with special healthcare needs were more likely to be selected (Data Resource Center for Child & Adolescent Health). The dataset combined the information collected from 2016 and 2017 and has approximately 1,400 surveys per state, and a total of 71,811 surveys were conducted (US Census Bureau 2018, US Census Bureau 2018). Data were weighted to be representative of non-institutionalized children aged zero to seventeen of the United States (Data Resource Center for Child & Adolescent Health).

Eligibility

Households were eligible if at least one child resided there, and the parent who responded to the survey spoke English or Spanish, as the surveys were offered in those two languages. A screening questionnaire was used to determine eligibility and asked whether or not children between the ages of zero and seventeen lived there, and what language was primarily spoken. Questions were also asked about the child's race, the child's age and sex, whether or not they had any health concerns, including a developmental delay, and utilization of services such as physical therapy, occupational therapy, speech therapy, in order to determine if the child had special healthcare needs for sampling purposes.

2016

The addresses were randomly sampled across the 50 states and Washington DC using the Census Master Address File data, and each state had about the same number of households selected (US Census Bureau 2018). Households were flagged as being more likely to have children, and put into stratum one, and then those households not flagged as being more likely to have children were put into stratum two. Houses that were flagged had a child identifier from The Census Bureau's Center for Administrative Records Research and Applications (CARRA). Households were randomly assigned to one of three groups: one-third of the sample received no cash incentive, one-third received a $2 cash incentive, and the last third received a $5 cash incentive (US Census Bureau 2018). Households selected were mailed instructions to fill out the screener questionnaire but were able to fill out a paper screener and questionnaire through non-response follow-up(US Census Bureau 2018). Everyone initially received instructions for the web forms, but if they did not respond, or filled out a paper screening questionnaire, they were later on mailed a topical questionnaire to complete. Families that

were predicted based on census block group web past data collection efforts to use paper were mailed a paper screener and questionnaire earlier on in follow-up (US Census Bureau 2018). The surveys were organized by topic, and a toll-free phone number and website were available to help answer any questions in order to maximize response rates. In order to select which child was sampled from a household with more than one eligible child, it was first determined if they had any special healthcare needs. The children were sorted and assigned a roster number, with kids who had special healthcare needs being first, and then the roster sorted by age (US Census Bureau 2018). In households with four or more eligible children, they were sorted first with special healthcare needs, then name, and then age (US Census Bureau 2018). Children with special healthcare needs were oversampled 80% in households having children with and without special healthcare needs (US Census Bureau 2018). Additionally, children aged zero to five were oversampled 60% in those households where all of or zero of the children had special healthcare needs (US Census Bureau 2018).

364,150 households were selected to participate across the United States in 2016. Of those households, 138,009 households filled out the screening questionnaire to determine eligibility, with households being eligible if children resided there. Of those households, 67,047 were eligible to fill out the survey. 50,212 households completed the survey (US Census Bureau 2018).

2017

Households across all 50 states and Washington DC were randomly selected to participate. However, instead of selecting a roughly equal number of households per state, the households were sampled so they yielded roughly the same number of participants (US Census Bureau 2018). A total of 170,726 households were selected across the 50 states and

Washington DC. Of those households, 58,510 households filled out screener forms, and 29,343 households were eligible. Of the eligible households, 21,599 participated in the survey (US Census Bureau 2018). To maximize response rates, 90% of the households were mailed a $2 cash incentive to participate, surveys were offered in both English and Spanish, and a toll-free number and website were available to help participants with any questions they had along the way (US Census Bureau 2018). As in 2016, children between the ages of zero and five, and children with special healthcare needs were oversampled, and people had the opportunity to fill out the paper survey through follow-up efforts as they did in 2016.

Survey Questions

The questions relevant to this project were the same in both 2016 and 2017. Questions related to BMI were "*What is this child's current height?"*. Parents were able to enter the child's height in either feet and inches or meters and centimeters. For the question "*How much does this child currently weigh?*", parents could enter the child's weight in pounds and ounces or kilograms and grams. They also ask, *"How much did he or she weigh when born?",* and the parents could answer in pounds and ounces or kilograms and grams. For the question *"Are you concerned about this child's weight?",* parents could choose from three options: "*yes, it's too high", "yes, it's too low",* or *"no, I am not concerned*. The surveys also ask about sleep; *"How often does this child go to bed at about the same time on weeknights?",* with the answer options being: *"0 days", "1-3 days", "4-6 days",* and *"every day"*. The survey asked *"During the past week, how many hours of sleep did this child get during an average day?* The surveys for children aged six to eleven and twelve to seventeen had the same answer options. These included: "*less than 6 hours", "6 hours", "7 hours", "8 hours", "9 hours", "10 hours",* and *"11 hours or more"* (CAHMI 2019).

Methods

Variables

The variables in this project came pre-coded as categorical variables, with the exception of age. The levels for the variables came coded as integers, such as 0, 1, 2, etc, but were re-labeled for easier interpretation as detailed below.

BMI

Obesity was measured with a BMI category variable. The variable was categorical, with 4 levels, Underweight, Normal, Overweight, and Obese. Underweight children were in the 5th percentile for BMI. Normal BMI and was somewhere between the 5th and 84th percentile for their BMI. Overweight children were between the 85th to 94th percentile for BMI. Children with a BMI at or above the 95th percentile were coded as Obese. BMI was calculated for children between the ages of ten to seventeen, and used parent reported height and weight data to calculate it. BMI was then classified into the above categories using CDC BMI-for-Age Growth Charts.

Sleep

There were three variables related to sleep. One was whether or not children get the recommended amount of sleep. The data were coded into two categories- the child sleeps the recommended number of hours, or the child sleeps less than the recommended number of hours. This variable was not included in the models, as hours of sleep provides more information and it can be determined whether or not a child is sleeping a sufficient amount from that variable.

Whether or not the child has a consistent bedtime was a second sleep-related variable. Parents were asked how often their child goes to bed at the about the same time on weeknights. The responses are coded as follows: the child always goes to bed at about the

same time on weeknights, the child usually goes to bed at about the same time on weeknights, the child sometimes goes to bed about the same time on weeknights, and the child rarely or never goes to bed about the same time on weeknights.

Hours of sleep was the third sleep variable. The data came coded as a categorical variable with seven levels including: less than 6 hours, 6 hours, 7 hours, 8 hours, 9 hours, 10 hours, and 11 or more hours. It was re-coded to be a linear variable. Less than 6 hours of sleep and 6 hours of sleep were coded as 6. 7, 8, 9, and 10 -hours were re-coded as their respective integers. 11 or more hours was re-coded as 11 hours. The variable was made linear using the as.numeric command in R.

Control Variables

Activity

Physical activity was categorized into 4 levels, for the number of days children were physically active for at least 60 minutes a day. The levels are: 0 days a week for 60 minutes, 1 to 3 days a week, 4 to 6 days a week, and every day. Television watching was coded as a categorical variable as well, with 5 categories; the child does not watch television, the child watches less than an hour of television a day, the child watches 1 hour of television a day, the child watches 2 to 3 hours of television a day, and the child watches 4 or more hours of television a day. Screen time with a computer or other electronic device was coded in the same manner as television watching, with 5 levels; does not use electronic devices, less than 1 hour a day, 1 hour per day, 2 to 3 hours per day, and 4 or more hours of electronic device use per day.

Food and Socioeconomic Status

Food and SES questions overlapped in many cases. One variable was on food insufficiency, and was coded with 4 levels; we could always afford to eat good nutritious meals, we could always afford enough to eat but not always the kinds of foods we should eat,

sometimes we could not afford enough to eat, and often we could not afford enough to eat. Another question was on whether or not someone in the family received free or reduced meals at school within the past 12 months. This variable had two levels; yes and no. Income level of the child's family was categorical with 4 levels; 0% to 99% of the Federal Poverty Line (FPL), 100% to 199% FPL, 200% to 399% of the FPL, and 400% FPL or above. Whether or not the respondents feel the neighborhood is safe is another variable, with three levels. The levels include definitely agree, somewhat agree, and somewhat or definitely disagree. Another question asked whether or not the neighborhood has sidewalks, and was coded as yes or no. Whether or not the neighborhood has a park was another variable, coded as yes or no.

One of the questions asked whether or not families could afford nutritious meals. The variable is coded as a categorical variable with 4 levels. 1 indicates the family could always afford to eat good nutritious meals. 2 indicates they could always afford enough food to eat, but that it was not always the kind of food they should eat. 3 indicates they could sometimes not afford enough to eat. 4 indicates they could often not afford enough to eat.

Income level was also asked of the parents. In 2016 there were 18.56% missing values, and 16.03% in 2017 (Child and Adolescent Health Measurement Initiative (CAHMI) 2019). The missing values were imputed by Census in the survey years (Child and Adolescent Health Measurement Initiative (CAHMI) 2019). Using the SCHIP groupings, there are 4 levels of this categorical variable. 1 indicates the child's family is between 0 and 199% of the federal poverty level. 2 indicates the child's family is at 200 and 299% of the federal poverty level. 3 indicates the child's family is between 300 and 399% of the federal poverty level. 4 indicates the child's family is 400% of the federal poverty level or higher.

Demographic

Age was left as linear data years of age as the unit. Sex was dichotomous, with male or female being the options.

Missing

Missing values were coded as "Missing" and included for Table One and Table Two. Missing values were removed when running the models by R. 41,021 values were dropped because they were missing the outcome variable of BMI category. This was due in large part to the outcome variable not being reported in the dataset for anyone under the age of ten in the sample. This means that results are only generalizable to children and adolescents between the ages of ten and seventeen.

Statistical Analysis

All statistical analysis, tables and graphs were produced using RStudio version 1.2.5001 (R Core Team 2013). Survey weights were applied prior to analysis. While the focus of the project is children and adolescents aged ten to seventeen, the sample was not subset to avoid errors with standard error after the survey weights had been applied. Mean and standard error was calculated for age and hours of sleep, and percentages were calculated for the remaining variables, as they were all categorical. To examine the relationship between BMI category and variables of interest, a chi-square test for association was performed. Chi-square tests for association were calculated in R using the svytable and svychisq commands from the Survey package.

Two logistic regression models were created to further examine the relationship between BMI category and the variables of interest. The first model has a dichotomous outcome of obese, or not obese. Not obese included people who were underweight, normal weight, or overweight. The only variable in this model was hours of sleep.

The second model was the final model with obese or not obese as the outcome. The variables included hours of sleep, age, sex, child goes to bed at the same time, food insufficiency, income level, days of physical activity, time spent with electronic devices, and time spent watching TV. The variables included in this model were chosen based on a review of the literature.

The fourth model was a multinomial logistic regression. This model had 4 outcome options- underweight, normal weight, overweight, and obese. The model contained the primary variable of interest, hours of sleep, as well as age, sex, child goes to bed at the same time, food insufficiency, income level, days of physical activity, time spent with electronic devices, and time spent watching TV, the same variables as the final model above. The reference category for this model was “Normal” weight.

Results

Descriptive Results

BMI Category

Table One shows survey adjusted descriptive statistics for children and teens aged 0-17 in the United States. 2.6% of the population are underweight. 26.2% of the children are normal weight. 6.3% of the children are overweight and, 6.6% of the children are obese. A large number of missing data because BMI data were not reported for children under the age of ten in the sample, so BMI data is only representative of those aged 10-17. Figure Two shows the BMI distribution for children between the ages of ten and seventeen in the sample. The vast majority of the children who had BMI information reported were normal weight.

Figure Two: BMI Category Distribution for Children Aged 10-17.

Sleep

62.8% of children sleep the recommended number of hours for their age, and 33.8% sleep less than the recommended number of hours for their age group. Figure Three displays the average number of hours of sleep children get on average per night by BMI category. All of the groups were significantly different from one another, with the exception of normal weight and overweight using a Bonferroni correction. Children and adolescents get an average of 8.51 hours of sleep per night. 34.4% of children always go to bed at the same time on weeknights. 53.0% of the children usually go to bed at the same time on weeknights. 7.9% of children sometimes go to bed at the same time on weeknights. 3.4% of children rarely or never go to bed at the time on weeknights.

Figure Three: Mean Hours of Sleep by BMI Category.

Confounding Variables

The majority of children and adolescents (65.5%) live in families that have enough money to eat good nutritious meals, according to the parents. Additionally, most children are

not using any SNAP or Food Stamps or using free or reduced lunches at school. Most of the children live in households where the household income is 400% of the federal poverty line or higher. This suggests the majority of households likely do not have trouble accessing food for their families, which could play a role in whether or not their children are overweight or obese. Again, the vast majority of the children live in neighborhoods that their parents deem to be safe, have sidewalks, and have parks, suggesting the children and adolescents have the opportunity to exercise and be active in their neighborhoods, which could impact their BMI category. Children have varying levels of physical activity, with 60 minutes of physical activity 1-3 days a week being the most common at 25.9% of the population. Many children watch TV or used electronic devices for 2-3 hours per day.

Demographic

The average age of children in the United States is 9.41 years old. 51.1% are male, and 48.9% are female.

Table One: Descriptive Statistics of Children and Teenagers in the United States Aged 0-17

Table Five, in the appendix shows the raw, unadjusted descriptive statistics of the sample.

Analytic Results

Table Two displays the analysis of variance (ANOVA) results with chi-square associations between BMI category and the variables of interest with survey adjusted data to examine whether or not there were any significant differences between the BMI categories for each variable. There was a statistically significant difference between the BMI categories and whether or not children and adolescents were meeting the recommended hours of sleep for their age. The largest difference in the percentage of the population came between underweight children and obese children with, 68% of underweight children meeting

recommendations and 54.5% of obese children meeting recommendations. For those who did not meet sleep recommendations, the largest difference occurred between underweight and obese children, with only 29.1% of underweight children not meeting recommendations and 43.8% of obese children not meeting recommendations. Again, there was a statistically significant difference in the BMI categories for the number of hours of sleep children got. Underweight children had an average of 8.48 hours of sleep, normal weight children had an average of 8.22 hours of sleep, overweight children had an average of 8.29 hours of sleep and obese children had an average of 8.06 hours of sleep. Another result of interest is related to whether or not the child goes to bed at the same time during the week. For those who sometimes go to bed at the same time during the week, 12.5% of obese children fall in this category, while only 9.4% of underweight children and 9.5% of normal and overweight children fall in this category. There were lower percentages of overweight and obese children who usually go to bed at the same time compared to underweight and normal weight children. These significant differences between groups indicate that sleep habits and patterns may be different among children who are obese compared to children who fall in the other BMI categories.

Table Two: ANOVA Between BMI Categories.

Logistic Regression

Table Three displays the survey adjusted results from the logistic regression. The outcome variable was whether or not a child or adolescent was obese. The first model has only hours of sleep as a predictor of whether or not a child is obese. For each additional hour of sleep the odds of obesity were 15.8% lower.

The final model controls for age, sex, food insufficiency, the income level for the family, physical activity, and screen time. After controlling for all of these factors, there is a statistically significant relationship between hours of sleep and the odds of obesity. For each additional hour of sleep, there were 15.2% lower odds of obesity among children and adolescents aged ten to seventeen. For example, a child who sleeps 9 hours compared to a child who sleeps 8 hours has 15.2% lower odds of obesity after controlling for the factors above. This indicates that children who have more hours of sleep have lower odds of obesity and that sleep could potentially be a place for intervention. It is unknown whether or not children have lower odds of obesity because they sleep more, or if they sleep more because they are not obese, and further research to establish which comes first is needed. This, however, is a good starting place for establishing the link between sleep and obesity in children and adolescents in the United States. Of interest, whether or not the child goes to bed at the same time produced varied results for the outcome variable. When compared to those who always went to bed at the same time, children and adolescents who usually went to bed around the same time on weeknights had 24.7% lower odds of obesity. For those who only sometimes had the same bedtime during the week, the odds of obesity were 16.4% lower than those who always had the same bedtime. Lastly, for those who rarely or never went to bed at the same time on weeknights, the odds of obesity were 16.8% lower than those who always did. Results with respect to confounding variables such as physical activity and screen time were as expected. Children who got less physical activity had higher odds of obesity than those who had more physical activity, and those who spent more time watching TV or on electronic devices also had higher odds of obesity than those who had less screen time.

Table Three: Odds of Obesity from Logistic Regression.

Multinomial Regression

Table Four displays the relative risk of remaining underweight, overweight, or obese for each factor when compared to a child of normal weight. For each additional hour of sleep, the relative risk of remaining obese is 26.7% lower. When looking at the relative risk of remaining overweight, the relative risk is still lower, but not as low as the risk of remaining obese, at 14.9%. The relative risk of remaining underweight is 10% lower for each additional hour of sleep. Again, in this model, the results associated with a consistent bedtime were interesting. Children who usually go to bed at the same time had a 17.1% lower risk of remaining obese when compared to those of normal weight who always go to bed at the same time. This pattern was the same for those who sometimes, and rarely or never went to bed at the same time during the week. This finding suggests that having a regular bedtime may not be as important of a predictor of weight status as actual hours of sleep. As for overweight children, the consistent bedtime results varied. Those who usually went to bed at the same time had a 3.2% lower risk of remaining overweight compared to those who always go to bed at the same time and are of normal weight. The children and adolescents who sometimes went to bed at the same time had a 4.5% higher risk of remaining overweight than their normal weight counterparts who always went to bed at the same time. Lastly, those who rarely or never went to bed at the same time had a 25.2% lower risk of remaining overweight compared to those who went to bed consistently and were of normal weight. These results present a potential area of future research to look at the role of consistent bedtime versus the quality and amount of sleep children get.

Table Four: Relative Risk of Remaining Underweight, Overweight, or Obese.

Discussion and Implications

This thesis examined the relationship between sleep and obesity in a cross-sectional manner for children and adolescents in the United States between the ages of ten and seventeen. The main question was how the amount of sleep children and adolescents got was related to their BMI category. The results establish there is an association between the hours of sleep children and adolescents get and whether or not they are obese. Those who had higher levels of sleep had lower odds and relative risk of obesity than those who had lower levels of sleep. These results suggest that getting more sleep will lower the risk of being at an unhealthy weight, on both sides of the spectrum. At this point, it is still unclear whether or not children are obese because they are sleeping less, or if they are sleeping less because they are obese, but this presents an interesting point for further research to establish which comes first, and ultimately if there is a point of intervention. Another area of interest was how bedtime related to obesity. Here the results were somewhat varied between BMI categories, but consistent for those who were obese. Those who had some level of variation in their bedtime, either usually, sometimes, or rarely or never going to bed at the same time had lower odds and relative risk of obesity compared to those who always went to bed at the same time. This finding could be due to a variety of things, but one interesting idea is whether or not those who always go to bed at the same time happened to have a very late bedtime. They may be consistently going to bed late and waking up early for school, which is not surprising for adolescents who undergo a shift in their circadian rhythms by a few hours (UCLA Health). Teens and adolescents going through puberty may have their bedtime shifted back by a few hours, preventing them from getting enough sleep as they still need to be up early for school.

The findings on sleep duration and odds of obesity are consistent with those done in adults. A meta-analysis of studies in adults showed a consistent reporting between sleep duration and BMI (Cappuccio, Taggart et al. 2008). Cappuccio et al. wrote that studies consistently showed higher odds of short sleep duration for those who are obese in both children and adults (Cappuccio, Taggart et al. 2008). However, the various measures for obesity and BMI in children presented a challenge in comparing the results of the various studies they reviewed.

The limitations of the research include the cross-sectional manner of the data. The cross-sectional nature of the data means that while there is an association between hours of sleep and obesity, it cannot be determined from this data which comes first, and how exactly sleep plays a role in obesity. Another limitation of this project is the lack of BMI data for children under the age of ten. Height and weight were collected for all children in the sample; the BMI data were only reported for those ten years old and above. This reduced the generalizability of the information gained from this otherwise representative sample. Another limitation was the fact that objective measures were not used to collect BMI and sleep data. The survey relied on parents to report the amount of sleep their children get, bedtimes, and their weight and height. Parents may be unaware of how long their children are sleeping or if they fall asleep when they go to bed for the night. A strength of this project is the representative sample, making the results generalizable to those who fall within the ages of ten and seventeen across the United States. Another strength is the large variety of information collected in the survey, as it allows us to control for confounding variables in the model.

As this paper established the association between obesity and hours of sleep in children and teens between the ages of ten and seventeen, further research could be done to establish whether or not this link exists in those under the age of ten and at what age does this association begin. Further research could also use objective measures, such as actigraphy and height and weight measurement. Using objective measures could be helpful in examining the relationship between consistent bedtime and obesity as well. Another area of further research could rely on establishing the exact causal pathway between sleep duration and obesity. Knowing exactly how this relationship works could provide an area of intervention to address obesity in children and teens. Future public health campaigns focusing on promoting the importance of quality sleep, especially sleep duration in children and teens, should highlight the association between sleep and obesity.

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Tables and Figures:

Figure One: Conceptual Framework for Sleep and Obesity in Children and Adolescents

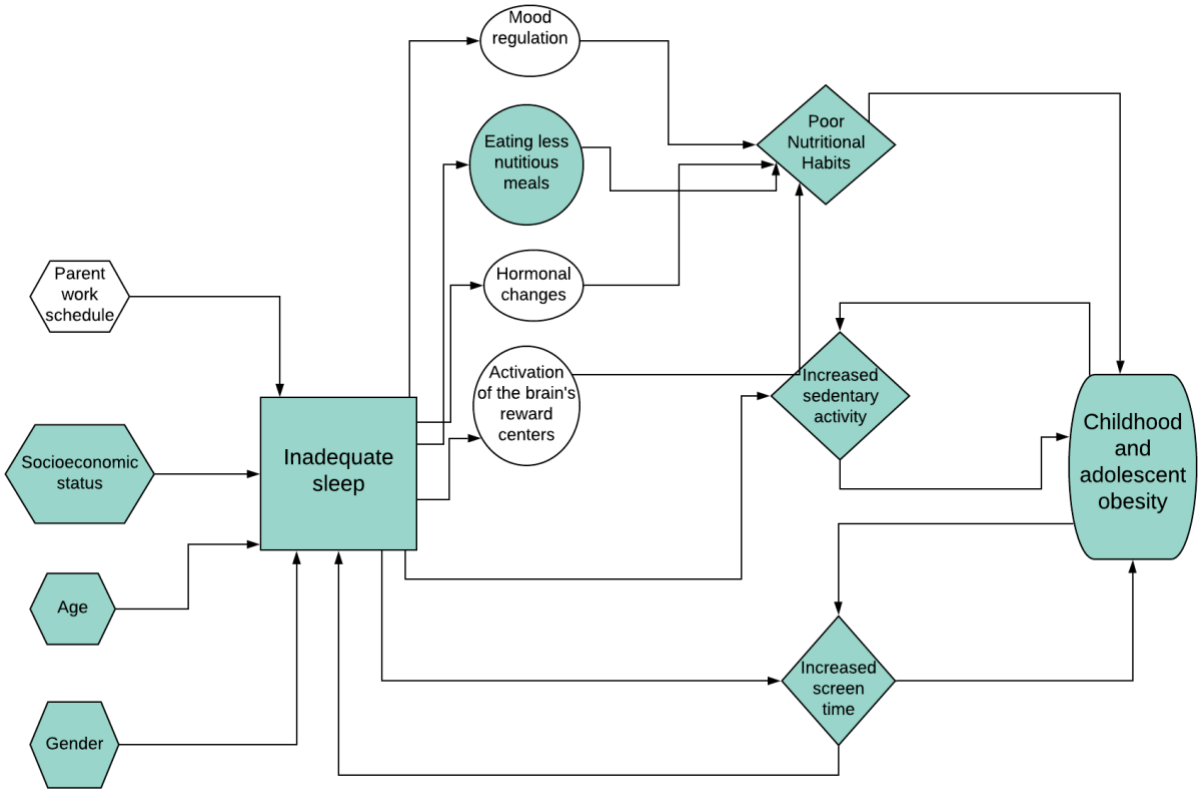
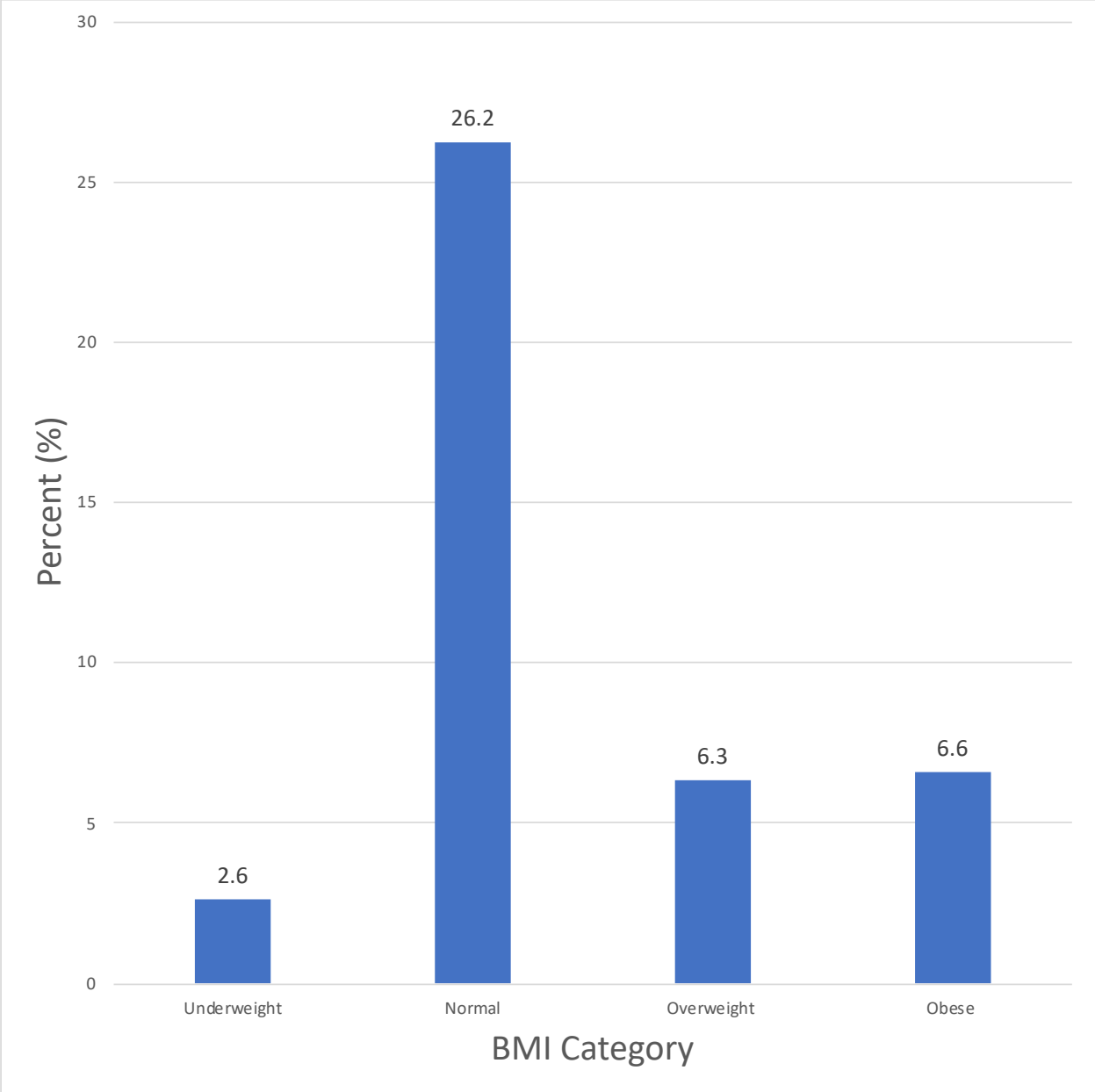
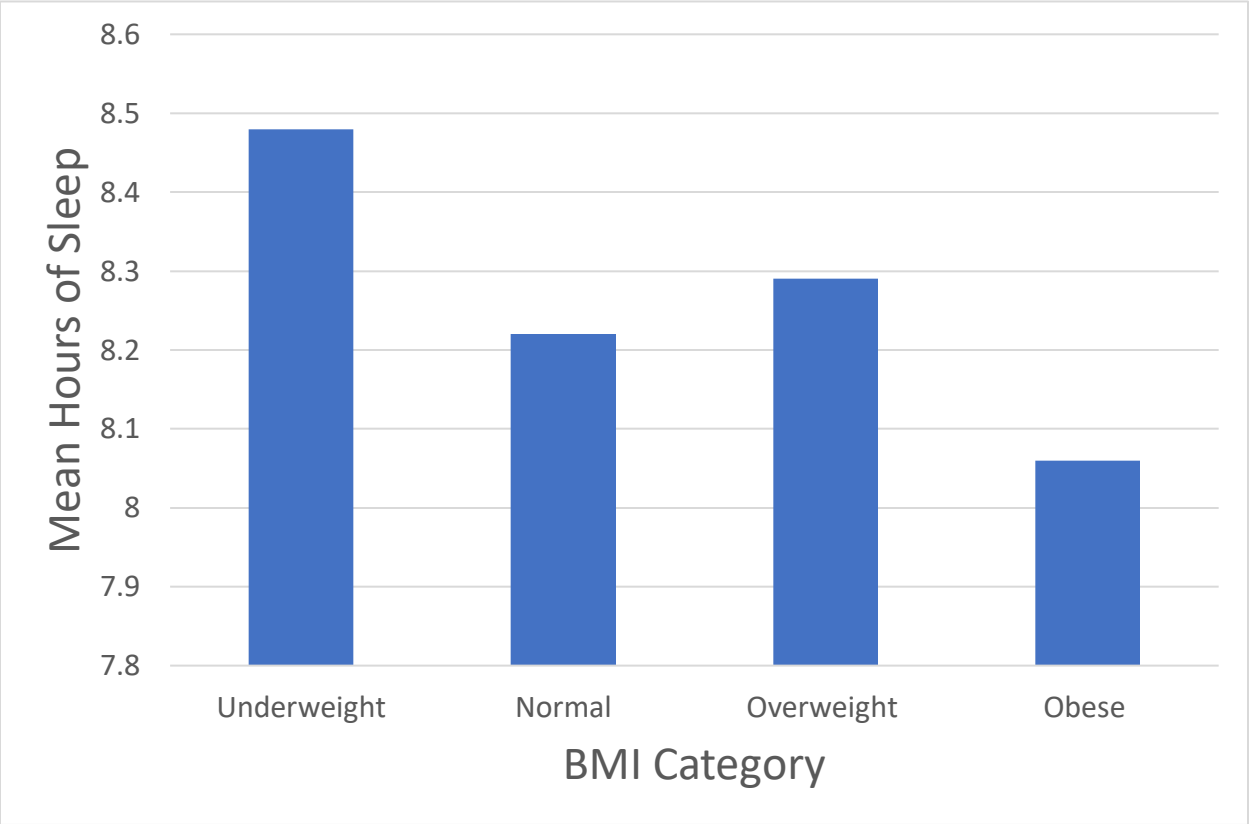


Figure Two: BMI Category Distribution for Children Aged 10-17



Source: The National Survey of Children's Health 2016-2017. Data are survey adjusted.

Figure Three: Mean Hours of Sleep by BMI Category



Source: National Survey of Children's Health 2016-2017. Data are survey adjusted. There was a significant difference between all groups with the exception of normal and overweight at the .001 level using a Bonferroni's correction.

Table One: Descriptive Statistics for Children and Teens Aged 0-17 in the United States

Variable	(Percent)
Age	
Mean (SD)	9.41 (5.16)
Median (Min, Max)	10.0 (0.00, 17)
Sex	
Male	(51.1%)
Female	(48.9%)
BMI	
Underweight	(2.6%)
Normal Weight	(26.2%)
Overweight	(6.3%)
Obese	(6.6%)
Missing	(58.2%)
Sleep Categories	
Child Sleeps Recommended Amount	(62.8.%)
Child Sleeps Less Than Recommended Amount	(33.8%)
Missing	(3.3%)
Hours of Sleep	
Mean (SD)	8.51 (1.12)
Median (Min, Max)	8.00 (6.00, 11.00)
Child Goes to Bed at The Same Time	
Always	(34.4%)
Usually	(53.0%)
Sometimes	(7.9%)
Rarely/Never	(3.4%)
Missing	(1.1%)
Food Insufficiency	
We Could Always Afford to Eat Good Nutritious Meals	(65.5%)
We Could Always Afford Enough to Eat but Not Always the Kinds of Foods We Should Eat	(25.4%)
Sometimes We Could Not Afford Enough to Eat	(5.34%)
Often We Could Not Afford Enough to Eat	(1.1%)
Missing	(2.66%)
Someone in the Family Received Food Stamps or Supplemental Nutrition Assistance Program Benefits within the Last 12 Months	
Yes	(19.4%)
No	(77.4%)
Missing	(3.2%)
Someone Received Free or Reduced Meals at School in the Last 12 Months	
Yes	(32.7%)
No	(64.0%)
Missing	(3.3%)
Income Level of Child Household	
0% to 99% FPL	(21.2%)
100% to 199% FPL	(21.7%)
200% to 399% FPL	(27.0%)
400% FPL or Above	(30.0%)
Safe Neighborhood	
Definitely Agree	(62.8%)
Somewhat Agree	(29%)
Somewhat or Definitely Disagree	(5.4%)
Missing	(2.9%)
Neighborhood Has Sidewalks	
Yes	(73.1%)
No	(24.4%)
Missing	(2.5%)

Neighborhood Has a Park	
Yes	(74.0%)
No	(23.3%)
Missing	(2.7%)
Days of Physical Activity	
0 Days	(6.1%)
1 to 3 Days	(25.9%)
4 to 6 Days	(19.0%)
Everyday	(15.3%)
Missing	(33.7%)
Time Spent with Electronic Devices	
Do Not Use Electronic Devices	(17.0%)
<1 Hour Per Day	(19.3%)
1 Hour Per Day	(20.7%)
2 to 3 Hours Per Day	(30.7%)
4 or More Hours Per Day	(11.0%)
Missing	(1.3%)
Time Spent Watching TV	
Do Not Watch TV	(8.6%)
<1 Hour Per Day	(17.8%)
1 Hour Per Day	(25.2%)
2 to 3 Hours Per Day	(39.0%)
4 or More Hours Per Day	(8.0%)
Missing	(1.4%)

Source: Data from The National Survey of Children's Health 2016 and 2017 reported from the child's parents or primary caregiver. Reported as percentages unless otherwise noted for the continuous variables of sleep and age. Data are survey adjusted. Percentages may not sum to 100 due to rounding.

Table Two: ANOVA Between BMI Categories

	Underweight	Normal	Overweight	Obese	Missing	Significance
n	**1,909,348**	**19,263,015**	**4,656,690**	**4,834,108**	**42,724,053**	
Age (mean (SD))	12.97 (0.11)	13.68 (0.12)	13.25 (0.14)	13.42 (0.15)	5.08 (0.12)	<0.05
Sex = Female	40.9%	51.0%	50.9%	41.6%	48.9%	<0.001
Sleep Categories						<0.001
Child Sleeps Recommended Amount	68.0%	64.2%	61.8%	54.5%	63.0%	
Child Sleeps Less Than Recommended Amount	29.1%	33.9%	36.1%	43.8%	32.7%	
Missing	2.9%	1.9%	2.1%	1.7%	4.3%	
Hours of Sleep (mean (SD))	8.48 (0.06)	8.22 (0.06)	8.29 (0.07)	8.06 (0.07)	8.94 (0.06)	<0.01
Child Goes to Bed at the Same Time						<0.001
Always	29.2%	27.2%	30.5%	31.2%	38.7%	
Usually	57.5%	58.2%	53.1%	49.5%	50.9%	
Sometimes	9.4%	9.5%	9.5%	12.5%	6.6%	
Rarely/Never	2.8%	4.2%	5.2%	6.5%	2.6%	
Missing	1.2%	0.8%	1.7%	0.4%	1.2%	
Food Insufficiency						<0.001
We Could Always Afford to Eat Good Nutritious Meals	69.1%	69.2%	60.6%	52.5%	65.7%	
We Could Always Afford Enough to Eat but Not Always the Kinds of Foods We Should Eat	23.7%	23.1%	30.6%	34.0%	25.0%	
Sometimes We Could Not Afford Enough to Eat	4.6%	5.2%	5.0%	8.8%	5.1%	
Often We Could Not Afford Enough to Eat	0.8%	1.0%	1.5%	2.4%	1.0%	
Missing	1.8%	1.6%	2.3%	2.3%	3.3%	
Someone in the Family Received Food Stamps or Supplemental Nutrition Assistance Program Benefits in the Last 12 Months						<0.001
Yes	16.3%	14.2%	20.2%	25.7%	21.2%	
No	82.1%	83.8%	77.2%	71.4%	75.0%	
Missing	1.6%	2.0%	2.7%	2.9%	3.9%	
Someone Received Free or Reduced Meals at School in the last 12 months						<0.001
Yes	31.6%	31.5%	40.8%	53.9%	30.1%	
No	65.3%	66.6%	56.2%	44.1%	65.9%	
Missing	3.1%	2.0%	3.0%	2.0%	4.0%	
Income Level of Child Household						<0.001
0% to 99% FPL	21.0%	16.8%	20.7%	28.3%	22.5%	
100% to 199% FPL	19.1%	19.5%	22.4%	25.3%	22.4%	
200% to 399% FPL	24.7%	27.2%	28.1%	27.3%	26.8%	
400% FPL or Above	35.2%	36.5%	28.7%	19.1%	28.3%	
Safe Neighborhood						<0.001
Definitely Agree	64.6%	67.3%	60.1%	62.3%	61.0%	
Somewhat Agree	29.6%	26.5%	31.6%	29.4%	29.7%	
Somewhat or Definitely Disagree	4.1%	4.6%	5.9%	6.1%	5.6%	
Missing	1.7%	1.6%	2.4%	2.2%	3.7%	
Neighborhood Has Sidewalks						<0.001
Yes	73.1%	73.5%	68.8%	70.8%	73.6%	
No	25.5%	25.1%	29.2%	27.4%	23.2%	
Missing	1.4%	1.4%	2.0%	1.8%	3.2%	
Neighborhood Has a Park						<0.001
Yes	75.5%	74.1%	68.4%	69.6%	75.1%	
No	23.0%	24.1%	29.3%	28.8%	21.6%	
Missing	1.5%	1.8%	2.3%	1.7%	3.4%	

Days of Physical Activity						<0.001
0 Days	10.8%	8.8%	11.2%	17.8%	2.8%	
1 to 3 Days	43.4%	36.8%	42.9%	43.6%	16.4%	
4 to 6 Days	26.5%	31.7%	27.7%	22.2%	11.6%	
Everyday	17.1%	21.0%	16.1%	14.5%	12.7%	
Missing	2.3%	1.8%	2.2%	1.8%	56.5%	
Time Spent with Electronic Devices						<0.001
Do Not Use Electronic Devices	2.5%	2.8%	2.7%	3.6%	27.2%	
Use Less Than 1 Hour Per Day	13.5%	11.3%	10.2%	7.4%	25.5%	
Use 1 Hour Per Day	24.6%	21.7%	18.5%	17.3%	20.7%	
Use 2 to 3 Hours Per Day	42.5%	44.6%	45.0%	44.6%	20.7%	
Use 4 or More Hours Per Day	15.8%	18.4%	22.0%	26.2%	4.5%	
Missing	1.1%	1.2%	1.6%	0.8%	1.3%	
Time Spent Watching TV						<0.001
Do Not Watch TV	4.3%	5.4%	3.3%	3.0%	11.4%	
Less Than 1 Hour Per Day	15.7%	17.2%	13.5%	9.5%	19.6%	
1 Hour Per Day	25.4%	27.0%	20.0%	19.7%	25.6%	
2 to 3 Hours Per Day	43.9%	40.5%	48.0%	49.3%	36.1%	
4 or More Hours Per Day	9.6%	8.7%	13.5%	17.7%	5.9%	
Missing	1.0%	1.2%	1.7%	0.8%	1.5%	

Source: Data from The National Survey of Children's Health 2016 and 2017 reported from the child's parents or primary caregiver. N=71811. Note: Estimates here are survey adjusted, and significance was calculated with chi-square tests. Due to rounding percentages may not sum to exactly 100.

Table Three: Odds of Obesity from Logistic Regression

	Simple Model	Final Model	Significance
Independent Variable	**Odds of Obesity**	**Odds of Obesity**	
Hours of Sleep	0.842	0.848	<0.01
Age		0.932	<0.01
Sex (Female)		0.659	<0.01
Child Goes to Bed at the Same Time:			
Usually		0.753	<0.01
Sometimes		0.836	
Rarely/Never		0.832	
Missing		0.2	<0.01
Food Insufficiency:			
We Could Always Afford Enough to Eat but Not Always the Kinds of Foods We Should Eat		1.418	<0.01
Sometimes We Could Not Afford Enough to Eat		1.48	<0.05
Often We Could Not Afford Enough to Eat		1.676	<0.1
Missing		2.025	<0.1
Income Level:			
100% to 199% FPL		0.902	
200% to 399% FPL		0.802	<0.1
400% FPL or Above		0.501	<0.01
Days of Physical Activity (60 or more minutes):			
1 to 3 days		0.665	<0.01
4 to 6 days		0.473	<0.01
Everyday		0.357	<0.01
Missing		0.96	
Time Spent with Electronic Devices:			
<1 Hour Per Day		0.561	
1 Hour Per Day		0.595	
2 to 3 Hours Per Day		0.665	
4 or More Hours Per Day		0.746	
Missing		0.412	
Time Spent Watching TV:			
<1 Hour Per Day		1.086	
1 Hour Per Day		1.339	
2 to 3 Hours Per Day		1.695	<0.05
4 or More Hours Per Day		1.992	<0.01
Missing		1.564	
Constant		5.16	<0.01
Observations: 30,790			

Source: Data from The National Survey of Children's Health 2016 and 2017 reported from the child's parents or primary caregiver. 30,790 Observations. Note: Estimates here are survey adjusted.

Table Four: Relative Risk of Remaining Underweight, Overweight or Obese

Independent Variable	Underweight	Overweight	Obese
Hours of Sleep	0.900 ***	0.851***	0.733***
Age	1.119***	1.007	1.018**
Sex (Female)	1.526***	1.276***	0.884***
Child Goes to Bed at the Same Time:			
Usually	1.065***	0.968	0.829***
Sometimes	1.128***	1.045***	0.877***
Rarely/Never	0.872***	0.748***	0.716***
Missing	0.804***	1.038***	0.342***
Food Insufficiency:			
We Could Always Afford Enough to Eat but Not Always the Kinds of Foods We Should Eat	01.001	1.356***	1.735***
Sometimes We Could Not Afford Enough to Eat	0.971***	1.214**	1.897***
Often We Could Not Afford Enough to Eat	0.942***	1.617***	2.279***
Missing	0.992***	1.084***	1.158***
Income Level:			
100% to 199% FPL	1.016	1.011	0.917**
200% to 399% FPL	1.190***	1.047**	0.966*
400% FPL or Above	1.171***	0.935***	0.622***

Days of Physical Activity (60 or more minutes):			
1 to 3 days	1.302***	1.135***	0.922***
4 to 6 days	1.602***	1.088***	0.669***
Everyday	1.739***	1.047***	0.589***
Missing	1.458***	1.525***	0.927***
Time Spent with Electronic Devices:			
<1 Hour Per Day	1.149***	1,257***	1.234***
1 Hour Per Day	1.208***	1.344***	1.365***
2 to 3 Hours Per Day	1.226***	1469***	1.444***
4 or More Hours Per Day	1.283***	1.640***	1.744***
Missing	0.792***	0.665***	0.892***
Time Spent Watching TV:			
<1 Hour Per Day	1.002	1.117***	1.203***
1 Hour Per Day	1.011	1.150***	1.456***
2 to 3 Hours Per Day	0.967**	1.290***	1.812***
4 or More Hours Per Day	0.845***	1.963***	3.939***
Missing	1.495***	1.963***	3.939***
Weight Variable	1.000	1.000	1.000
Constant	2.279***	3.652***	9.077***

Source: Data from The National Survey of Children's Health 2016 and 2017 reported from the child's parents or primary caregiver. 30,790 Observations. Note: Estimates here are not survey adjusted, but the weighting variable has been included in the analysis. Reference category was Normal Weight.

Appendix:
Table Five Unadjusted Raw Descriptive Statistics

Variable	Count (Percent)
Age	
Mean (SD)	9.41 (5.27)
Median (Min, Max)	10.0 (0.00, 17)
Sex	
Male	36800 (51.2%)
Female	35011(48.8%)
BMI	
Underweight	2188 (3.0%)
Normal Weight	23413 (32.7%)
Overweight	5007 (7.0%)
Obese	4536 (6.3%)
Missing	36567 (50.9%)
Sleep Categories	
Child Sleeps Recommended Amount	48822 (68.0%)
Child Sleeps Less Than Recommended Amount	21050 (29.3%)
Missing	1939 (2.7%)
Hours of Sleep	
Mean (SD)	8.51 (1.11)
Median (Min, Max)	8.00 (6.00, 11.00)
Missing	2286 (30.9%)
Child Goes to Bed at The Same Time	
Always	22582 (31.4%)
Usually	41349 (57.6%)
Sometimes	5337 (7.4%)
Rarely/Never	1890 (2.6%)
Missing	653 (0.9%)
Food Insufficiency	
We Could Always Afford to Eat Good Nutritious Meals	52202 (72.7%)
We Could Always Afford Enough to Eat but Not Always the Kinds of Foods We Should Eat	15161 (21.1%)
Sometimes We Could Not Afford Enough to Eat	2467 (3.4%)
Often We Could Not Afford Enough to Eat	534 (0.7%)
Missing	1447 (2.0%)
Someone in the Family Received Food Stamps or Supplemental Nutrition Assistance Program Benefits within the Last 12 Months	
Yes	7153 (10.0%)
No	62954 (87.7%)
Missing	1704 (2.4%)
Someone Received Free or Reduced Meals at School in the Last 12 Months	
Yes	13401 (18.7%)
No	56697 (79.0%)
Missing	1713 (2.4%)
Income Level of Child Household	
0% to 99% FPL	7651 (10.7%)
100% to 199% FPL	11253 (15.7%)
200% to 399% FPL	22073 (30.7%)
400% FPL or Above	30834 (42.9%)
Safe Neighborhood	
Definitely Agree	49323 (68.7%)
Somewhat Agree	1862 (26.0%)
Somewhat or Definitely Disagree	2284 (3.2%)
Missing	1542 (2.1%)
Neighborhood Has Sidewalks	
Yes	51132 (71.2%)
No	19384 (27.0%)
Missing	1295 (1.8%)

Neighborhood Has a Park	
Yes	53076 (73.9%)
No	17227 (24.0%)
Missing	1508 (2.1%)
Days of Physical Activity	
0 Days	4186 (5.8%)
1 to 3 Days	19086 (26.6%)
4 to 6 Days	16318 (22.7%)
Everyday	10601 (14.8%)
Missing	21620 (30.1%)
Time Spent with Electronic Devices	
Do Not Use Electronic Devices	10428 (14.5%)
<1 Hour Per Day	14311 (19.9%)
1 Hour Per Day	15374 (21.4%)
2 to 3 Hours Per Day	22648 (31.5%)
4 or More Hours Per Day	8341 (11.6%)
Missing	709 (1.0%)
Time Spent Watching TV	
Do Not Watch TV	5541 (7.7%)
<1 Hour Per Day	13799 (19.2%)
1 Hour Per Day	19269 (26.8%)
2 to 3 Hours Per Day	27303 (38.0%)
4 or More Hours Per Day	5151 (7.2%)
Missing	748 (1.0%)

Source: Data from The National Survey of Children's Health 2016 and 2017 reported from the child's parents or primary caregiver. N=71811. Reported as counts followed by percent unless otherwise noted for the continuous variables of sleep and age.