DOES CHRONOTYPE MODIFY THE RELATIONSHIP BETWEEN SLEEP DURATION AND BODY MASS INDEX IN ADOLESCENTS?

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Dedication

To Conor, Ellen, Sean, Brianna, and Kelsey, my pride and joy.

To Mark, my every-day, ordinary super hero.

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ABSTRACT

DOES CHRONOTYPE MODIFY THE RELATIONSHIP BETWEEN SLEEP DURATION AND BODY MASS INDEX IN ADOLESCENTS?

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Support for an association between sleep duration and body mass index exists. However, not all short sleepers are overweight/obese. The complex interplay between circadian and metabolic processes has become a recent focus in sleep and obesity research and may explain this perplexing observation. Chronotype (as a marker for circadian misalignment) may be able to predict who is at greatest risk for obesity onset when exposed to short sleep duration. The goal of this study was to examine sleep duration and chronotype in racially/ethnically diverse adolescents and to determine whether chronotype modified the association between sleep duration and body mass index. A cross-sectional study design was used to examine these relationships using self-reported sleep data from 115 9th and 10th grade students and actigraphy-estimated sleep data from 69 of these participants. Participants were recruited from a Northeast coastal city high school in NJ. Socio-demographic and behavioral predictors of sleep duration and chronotype were estimated using general linear models. School night and free night sleep duration, chronotype preference, chronotype, and social jet lag were the independent variables of interest for predicting BMI. The moderating effect of chronotype and social jet lag on sleep duration and BMI was also estimated. General linear models were used to estimate these associations while controlling for selected socio-demographic and behavioral characteristics. Black adolescents had shorter free night sleep than Hispanic adolescents.

Adolescents with later chronotypes drank more soda, were less physically active, and napped more frequently than adolescents with earlier chronotypes. Longer school night sleep and greater social jet lag predicted higher BMI z scores. Associations between social jet lag and BMI, as well as chronotype and health-related behaviors, suggest that chronobiological approaches to preventing obesity may be warranted. The overall goal of these approaches should be to align daily schedules with individual biological rhythms. Additional approaches to improve the regularity of sleep-wake timing may be needed. Shorter free night sleep duration in Black adolescents indicate that this group may be at greatest risk for the negative consequences of short sleep and irregular sleep-wake timing.

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CHAPTER 1

Tripling obesity rates in adolescents (12-19 years old) over the past 30 years (Ogden, Carroll, Kit, & Flegal, 2012) have had a profound impact on health care costs and the quality of life for many adolescents. Childhood obesity-related outpatient service annual direct costs exceed 14.1 billion dollars (e.g. emergency department visits) and Medicaid childhood obesity-related hospitalization costs increased 120% from 2001 to 2005 (Trasande & Chatterjee, 2009; Trasande, Liu, Fryer, & Weitzman, 2009). Additionally, increased school absenteeism (Geier et al., 2007), poor academic outcomes (Taras & Potts-Datema, 2005), and a quality of life in obese adolescents that is similar to adolescents diagnosed with cancer have been reported (Schwimmer, Burwinkle, & Varni, 2003). The isolation, peer anxiety, low self-confidence, and body dissatisfaction reported by obese children and adolescents exemplify the disquieting psycho-social impact of obesity (Lachal et al., 2012). Furthermore, poor cardio-metabolic profiles have led to the onset of chronic diseases previously diagnosed in adulthood (e.g. type 2 diabetes) (American Diabetes Association, 2000; Caprio, 2012; Fain, 2006; Pi-Sunyer, 2006). Obese adolescents become obese adults underscoring the intractability of obesity once established (Gordon-Larsen, The, & Adair, 2010; Whitaker, Wright, Pepe, Seidel, & Dietz, 1997). These data highlight the need to better understand the causes and risk factors associated with obesity in adolescents so that prevention efforts and weight management strategies can be appropriately targeted.

Prevention efforts have primarily focused on diet and physical activity in youth, but the results have been disappointing (Foster et al., 2010). A possible explanation for the limited success of these efforts is that the narrow focus on diet and physical activity overlooks the multi-factorial etiology of obesity. Recent attention has focused on the relationship between sleep and obesity, but findings are inconsistent (Guidolin & Gradisar, 2012). This suggests a nuanced relationship between sleep and obesity that has not been explored. In particular, very little emphasis has been placed on the importance of sleep-wake timing. Differences in sleep-wake timing, or chronotype (Roenneberg, Allebrandt, Merrow, & Vetter, 2012) may explain the disparate findings between short sleep (less than eight hours) (National Sleep Foundation, 2006) and obesity in adolescents (Guidolin & Gradisar, 2012) and the perplexing observation that all short sleepers are not overweight/obese.

Chronotypes range on a continuum from early (early bedtime-early wake time) to late (late bedtime-late wake time) (Roenneberg, Kuehnle, et al., 2007a) and may be a useful marker to identify individuals most susceptible to the metabolically deleterious effects of short sleep (e.g. unhealthy eating habits). This is plausible because of the relationship between chronotype and circadian alignment. Circadian alignment is the synchrony between endogenous biological rhythms (e.g. the secretion of hormones), exogenous rhythms (e.g. light-dark cycles of the 24-hour day), and behavioral rhythms (e.g. the sleep-wake cycle of individuals). When these rhythms are aligned, the body functions efficiently because hormones associated with routine functions prime the body for the anticipated behavior (Bray & Young, 2007). For example, the hunger hormone, ghrelin (Kirsz & Zieba, 2011), rises at typical meal times priming the body for anticipated food intake (Natalucci, Riedl, Gleiss, Zidek, & Frisch, 2005). Similarly, the sleep-inducing hormone (melatonin), rises during darkness priming the body for anticipated sleep onset (Arendt, 2006). When these rhythms are misaligned, hormones known to increase energy intake and alter body composition are disrupted. For example, the satiety hormone, leptin (Chin-Chance, Polonsky, & Schoeller, 2000), is reduced (Nguyen & Wright, 2010; Scheer, Hilton, Mantzoros, & Shea, 2009) and cortisol secretion is altered (Scheer et al., 2009). In adults, circadian misalignment is associated with cardio-metabolic disease and obesity (Manenschijn, van Kruysbergen, de Jong, Koper, & van Rossum, 2011; Scheer et al., 2009).

Adolescents are an appropriate population to study because there is shift towards a later chronotype during puberty that is characterized by later sleep onsets (M. A. Carskadon, Acebo, & Jenni, 2004; M. A. Carskadon, Vieira, & Acebo, 1993; M. A. Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). These later sleep onsets are at odds with the early waking required by high school start times. Consequently, on school-days, adolescents with late chronotypes go to bed late but rise early (National Sleep Foundation, 2006). In contrast on non-school days, adolescents with late chronotypes go to bed late and rise late. In fact, forty four percent of high school students report greater than two hour differences in sleep-wake timing between school days and non-school days (National Sleep Foundation, 2006). These chronic weekly shifts in sleep-wake timing (coined social jetlag) (Wittmann, Dinich, Merrow, & Roenneberg, 2006) alter circadian alignment and are greatest in individuals with later chronotypes (Roenneberg et al., 2012). Furthermore, these weekly shifts resemble the larger shifts in the sleep-wake timing of adult shift workers, a group known to suffer disproportionately from cardio-metabolic disease and obesity (Knutsson, Akerstedt, Jonsson, & Orth-Gomer, 1986; Suwazono, Dochi, Sakata, Okubo, Oishi, Tanaka, Kobayashi, Kido, et al., 2008;

Suwazono, Dochi, Sakata, Okubo, Oishi, Tanaka, Kobayashi, & Nogawa, 2008; Suwazono et al., 2006).

Having an early chronotype during adolescence may predict tolerance to early wake times. Adolescents with early chronotypes have reported more positive physical health and better school functioning than adolescents with late chronotypes (Randler, 2011c). In contrast, adolescents with late chronotypes have reported a reduced health-related quality of life (Delgado Prieto, Diaz-Morales, Escribano, Collado Mateo, & Randler, 2012), and are at higher risk for negative affect (Dagys et al., 2012). Additionally, individuals with late chronotypes have lower physical activity levels, greater fast food and soft drink consumption, greater tobacco use and alcohol consumption, and more behavioral/emotional problems (Baron, Reid, Kern, & Zee, 2011; Fleig & Randler, 2009; S. S. Gau et al., 2007; Kanerva et al., 2012; Schaal, Peter, & Randler, 2010; Schubert & Randler, 2008; Wittmann et al., 2006) suggesting potential pathways through which chronotype can impact obesity.

Statement of the Problem

The convergence of observations and experimental evidence over the past two decades has fueled interest in sleep and obesity research and garnered enthusiasm for sleep as a potentially modifiable risk factor for obesity (Cappuccio et al., 2008; Patel & Hu, 2008; Spiegel, Leproult, et al., 2004; Spiegel, Leproult, & Van Cauter, 1999). However, several factors indicate that the relationship between sleep and obesity may be more complex than initially considered. The directionality of the relationship between sleep and obesity remains undetermined. A recent systematic review limited to longitudinal studies found inconsistent evidence for a positive association between short sleep and subsequent weight gain in adults, but sufficient support for a positive association between short sleep and subsequent weight gain in children (Magee & Hale, 2012). In addition, few adolescent sleep and obesity studies have been reported (less than 20) and findings from these studies are inconsistent (Guidolin & Gradisar, 2012). Furthermore, evidence of a complex interplay between circadian and metabolic processes suggests that obesity may be a chronobiological disorder (Garaulet et al., 2012), but previous research has failed to account for important chronobiological factors (e.g. chronotype, circadian misalignment). To date, chronotype, is omitted from most studies. This study seeks to elucidate the relationship between sleep and overweight/obesity through body mass index measurements (BMI) in adolescents by incorporating the relatively unexplored variable of chronotype.

Purpose of the study

The purpose of this study is to examine variations in chronotype among racially/ethnically diverse 9th and 10th grade students and to investigate whether chronotype modifies the association between sleep duration and BMI. The following aims were identified:

1. To describe sleep duration and chronotype in 9th and 10th grade students and to examine whether variations in sleep duration and chronotype exist by race/ethnicity, sex, and /or pubertal category.
2. To determine if there is a relationship between sleep duration and BMI z scores in 9th and 10th grade students.

   Hypothesis: Short sleep duration will be associated with a higher BMI z score.
3. To determine if chronotype modifies the relationship between sleep duration and

BMI z scores in 9th and 10th grade students.

Hypothesis: The association between short sleep duration and a higher BMI z score will be stronger in individuals with later chronotypes.

4. To assess the concurrent validity of the Morningness Eveningness Questionnaire, the Munich Chronotype Timing Questionnaire, and actigraphy measurements for estimating chronotype in 9th and 10th grade students.

   Hypothesis: The Morningness Eveningness Questionnaire, the Munich Chronotype Timing Questionaire, and actigraphy data will be highly correlated.

Significance of the Study

This study is significant because it is exploring new factors related to the epidemic of obesity in youth. Conflicting evidence of an association between adolescent sleep and obesity (Guidolin & Gradisar, 2012) and the perplexing observation that all short sleepers are not overweight/obese intimate a nuanced relationship between sleep and BMI that has not yet been fully investigated. By including chronotype, this study will extend our current understanding of sleep duration and BMI in adolescents. If chronotype modifies the association between sleep duration and BMI, future studies that frame obesity as a chronobiological disorder may yield findings that can accelerate progress towards reducing obesity rates. Additionally, this study improves upon previous work by considering the etiology of obesity from a multi-factorial perspective, expanding sleep and obesity research in the adolescent population, and improving sleep measurement strategies by using valid and reliable instruments (Chaput et al., 2010; Guidolin & Gradisar, 2012; McAllister et al., 2009; Spruyt & Gozal, 2011).

The importance of finding markers to be able to measure, predict, and explain who is at greatest risk for obesity is clinically significant and is increasingly important for stemming obesity rates. If chronotype modifies the association between sleep duration and obesity, then chronotype can be used as a marker for identifying individuals at greatest risk for obesity through simple chronotype screening interventions in primary care settings. If chronotype modifies the association between sleep and obesity, future research leading to chronotype-specifc weight management strategies will be informed (Garaulet et al., 2012). Additionally, if chronotype modifies the association between sleep and obesity, urban planning and development polices to reduce light at night exposure (e.g. street lighting, signage) and to increase access to daytime light in outdoor spaces will help strengthen environmental cues critical to preventing further shifts towards later chronotypes (Roenneberg et al., 2012). Finally, if chronotype modifies the association between sleep duration and obesity, technological product development to mitigate short wave length light emitted from electronic devices will lead to improved chronotype profiles (Brainard et al., 2008). Accelerating progress in preventing obesity hinges on identifying adolescents at greatest risk and testing interventions to mitigate potentially modifiable risk factors such as sleep-wake timing.

Definition of Terms

Table 1

Definitions of Terms

Term	Conceptual Definition
Adolescence	A period of transition from childhood to adulthood with the onset of physical maturation marking the beginning and adult identity marking the end ("Age limits and adolescents," 2003). This typically coincides with the chronological ages of 10-19 (World Health Organization, World Bank Special Programme of Research, Development of Research Training in Human Reproduction, 2003).
Body Mass Index	A measure of body mass defined as the ratio of weight divided by height squared (weight (kg) / height (m) squared) (Keys, Fidanza, Karvonen, Kimura, & Taylor, 1972).
Chronobiology	The duration and timing of biological rhythms necessary for essential biological processes.
Chronotype	Individual differences in sleep-wake timing (Roenneberg et al., 2012). Chronotypes range from early (early bedtimes-early wake times) to late (late bedtimes-late wake times) relative to one's age and sex specific cohort (Roenneberg et al., 2004).
Circadian alignment	Synchrony between endogenous biological rhythms (e.g. the secretion of hormones), exogenous rhythms (e.g. light-dark cycles of the 24-hour day), and behavioral rhythms (e.g. the sleep-wake cycle of individuals).
Circadian misalignment	Lack of synchrony between endogenous biological rhythms (e.g. the secretion of hormones), exogenous rhythms (e.g. light-dark cycles of the 24-hour day), and behavioral rhythms (e.g. the sleep-wake cycle of individuals).
Eating habits	Refers to the type and the timing of food eaten.
Entrainment	The process of aligning endogenous rhythms to external environmental cues or internal neuro-hormonal cues.
Free nights	Friday and Saturday nights.
Obesity	Excess fat mass that is commonly defined as a BMI greater than or equal to the 95th percentile for age and sex (Ogden & Flegal, 2010).
Overweight	Excess weight relative to a set standard. Commonly defined as a BMI between the 85^{th} and less than the 95^{th} percentile for age and sex (Ogden & Flegal, 2010).
Physical activity	Physical activity is any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen, Powell, & Christenson, 1985). It may be subdivided into light, moderate, or vigorous intensity (Caspersen et al., 1985).
Puberty	The stage of transitioning to reproductive maturity (Ellison, 2002). The most commonly used scale to describe puberty through the assessment of secondary sexual development (e.g. breast development, genitalia development) is the Tanner Scale (Cameron, 2002). This scale ranges from Tanner Stage 1 (prepubertal) to Tanner Stage 5 (maturation).
Race/ethnicity	Socially constructed categories to which individuals self identify.
School nights	Sunday through Thursday nights.
Sex	Male or female categories to which individuals self identify.

Short sleep	In this study short sleep will be defined as less than eight hours (National Sleep Foundation, 2006).
Sleep	A natural, periodically occurring state of unconsciousness that is immediately reversible and is characterized by changes in the electrical activity of the brain (Dement & Vaughan, 1999).
Sleep duration	The amount of time between sleep onset and sleep offset (Gupta, Mueller, Chan, & Meininger, 2002), including any daytime sleep.
Social jet lag	Differences in sleep-wake timing on school nights and free nights.
Poverty	A family income between 130% and 185% of the poverty level (US Department of Agriculture Food and Nutrition Services, 2012).
Waist circumference	A proxy measure of central fat accumulation (Ashwell, Cole, & Dixon, 1996).
Waist to height ratio	A proxy measure of central fat accumulation that accounts for the effect of height (i.e. taller people may have larger waists) (Ashwell et al., 1996).

Conceptual Model

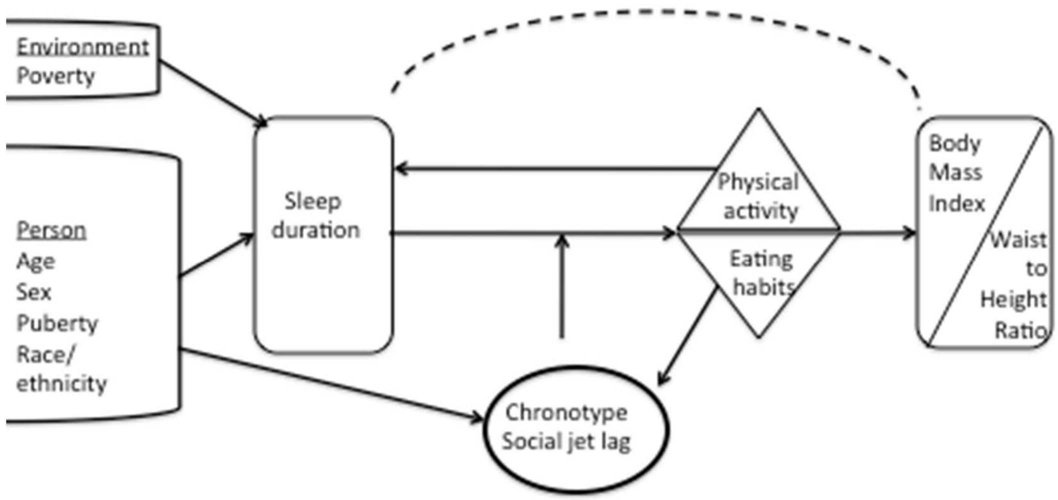
The conceptual model underpinning this study is adapted from models by Taheri and Patel & Hu, indicating that sleep duration alters bio-behavioral pathways associated with increased energy intake and decreased energy expenditure (Patel & Hu, 2008; Taheri, 2006). Persistent imbalances between energy intake and energy expenditure impact BMI (K. D. Hall et al., 2011; Ledikwe et al., 2006; Ledoux et al., 2011). Eating habits and physical activity are components of energy intake and energy expenditure respectively. An overconsumption of energy dense foods in relation to energy expended through physical activity creates an imbalance between energy intake and energy expenditure that, over time, contributes to increases in BMI (Drewnowski, Almiron-Roig, Marmonier, & Lluch, 2004; World Health Organization, 2003).

This study extends this model by indicating that sleep duration also directly influences BMI through hormones associated with subsequent increases in fat mass and that chronotype moderates sleep duration’s influence on behaviors associated with BMI (e.g. eating habits, physical activity) (Adam et al., 2009; Baron et al., 2011; Bennett, 2000; Buxton et al., 2010; Cavagnini, Croci, Putignano, Petroni, & Invitti, 2000; Holmbeck, 1997; Javaheri, Storfer-Isser, Rosen, & Redline, 2011; Schaal et al., 2010; Scheer et al., 2009). In sum, having a late chronotype as an adolescent will strengthen the association between short sleep duration and increases in BMI, whereas, having an early chronotype as an adolescent will lessen the association between short sleep duration and increases in BMI. Additionally, the influences of BMI and physical activity on sleep duration (e.g. sleep-disordered breathing) and the influence of eating habits on chronotype are identified (Beebe et al., 2007; Froy & Miskin, 2010). Finally, variables (person and environment) known to influence sleep duration and chronotype are identified (M. A. Carskadon et al., 1993; Lehnkering & Siegmund, 2007; Marco, Wolfson, Sparling, & Azuaje, 2011; M. Moore et al., 2011; Nolan & Parsons, 2009; Roenneberg, Kumar, & Merrow, 2007a; Stamatakis, Kaplan, & Roberts, 2007).

In this proposed study the dependent variable, BMI; the independent variables, chronotype and sleep duration; and the confounding variables, age sex, puberty, race/ethnicity, eating habits, physical activity, and poverty will be measured. See Figure 1: Sleep Duration, Chronotype, and Body Mass Index.

Figure 1

Sleep Duration, Chronotype, and Body Mass Index



CHAPTER 2

This chapter reviews the literature pertinent to this study, specifically obesity, sleep (sleep duration and chronotype), the relationship between sleep and obesity, correlates and determinants of sleep duration and chronotype, and the assessment of body fat and sleep. The final section discusses current gaps in adolescent sleep and obesity research and how this cross-sectional study advances our knowledge of the relationship between sleep duration, chronotype, and BMI in 9th and 10th grade students.

Overview of Obesity

Over the past few decades, rising obesity rates in adolescents and concomitant health consequences have drawn global attention to overweight (weight in excess of a set standard) and obesity (excess fat mass) (Ogden & Flegal, 2010). In the short term, obesity is associated with alterations in substances secreted by adipose tissue (fat mass) that influence energy intake, metabolism, and cardio-metabolic health, including leptin, adiponectin, tumor necrosis factor alpha, interleukin-6, and plasminogen activator inhibitor-1 (Bacha, Saad, Gungor, & Arslanian, 2004; Fain, 2006; Fay, 2004; Hutley & Prins, 2005; Iwashima et al., 2004; Lyon, Law, & Hsueh, 2003; Madeira et al., 2009; Mitrou et al., 2011; Otto & Lane, 2005; Papoutsakis, Yannakoulia, Ntalla, & Dedoussis, 2012; Rabe, Lehrke, Parhofer, & Broedl, 2008; Skurk & Hauner, 2004; Spranger et al., 2003; R. Weiss et al., 2004). Overweight and obese adolescents are two times more likely to be diagnosed with pre-diabetes (impaired fasting glucose or impaired glucose tolerance) and have more cardio-metabolic risk factors (e.g. elevated triglycerides, elevated systolic and/or diastolic blood pressure) than normal weight adolescents (Freedman, Mei, Srinivasan, Berenson, & Dietz, 2007; Li, Ford, Zhao, & Mokdad, 2009).

Additionally, obese adolescents experience a more rapid deterioration in glucose homeostasis than overweight/obese adults (Caprio, 2012; Zeitler et al., 2012). In the long term, the recalcitrance of obesity once onset occurs means that obese youth will likely become obese adults, thus, at risk for adult onset obesity related health consequences. Eighty four percent to 90% of obese youth become obese adults, regardless of parental obesity status (Freedman et al., 2007; Gordon-Larsen et al., 2010; Whitaker et al., 1997). In contrast 5% of youth with BMI less than the 50th percentile become obese adults (Freedman et al., 2007). However, overweight/obese youth who become non-obese as adults have no greater cardio-vascular disease risk than their consistently normal weight counterparts (Juonala et al., 2011). Since obesity (excess fat mass) is implicitly associated with current and future health in youth, understanding normal developmental changes in body composition and methods for measuring and monitoring body composition, particularly fat mass, are important.

Obesity Prevalence and Trends

Based on BMI definitions of obesity (greater than or equal to the 95th percentile for age and sex), 19.6% of 12-19 year old males, and 17.1% of 12-19 year old females were obese in 2009-2010 representing a three fold increase since 1980 (Ogden et al., 2012). Placing this current trajectory of rising obesity prevalence rates into a historical context is difficult because of the scarcity of obesity data collected prior to the 1960s. For children and adolescents, obesity prevalence rates had been steadily increasing since 1963, but there was an accelerated increase during the 1980s and 1990s (Fryar, Carroll, & Ogden, 2012). Reports for 2007-2010 indicate that childhood obesity prevalence rates plateaued in numerous countries around the world, including the US (Ogden et al., 2012;

T. Olds et al., 2011). However, these overall statistics and trends obfuscate significant disparities between socio-economic and racial/ethnic groups. Using the poverty income ratio as a marker for socio-economic status, obesity prevalence rates in youth ranged from 12% (high income females and males) to 19% and 21% (low income females and males, respectively) (Ogden, Lamb, Carroll, & Flegal, 2010). Further, obesity prevalence rates in adolescent males ranged from 17.5% to 28.9% (non-Hispanic White and Mexican Americans, respectively) and obesity prevalence rates in adolescent females ranged from 14.7% to 24.8% (non-Hispanic White and non-Hispanic Black, respectively) (Fryar et al., 2012). Together, these data indicate that obesity rates remain unacceptably high in adolescents, particularly adolescents from lower socio-economic and racial/ethnic minority groups. Furthermore, trends in obesity prevalence rates for specific subgroups of 6 to 19 year olds have continued to increase despite an overall plateau (e.g. White females, White males, and Black males) (Freedman, 2011).

Causes of Obesity

Imbalances between energy intake and energy expenditure are the most commonly considered causes of obesity. When energy intake exceeds energy expenditure, there is a hypertrophy (increase in size) and a hyperplasia (increase in number) of adipocytes (fat cells) (Otto & Lane, 2005). Many hormones (e.g. insulin, insulin like growth factor, glucocorticoids) contribute to adipocyte hyperplasia by prompting pre-adipocytes to become adipocytes (Otto & Lane, 2005). Consequently, obesity prevention strategies have largely focused on diet (energy intake) and physical activity (one component of energy expenditure), often not considering other potentially influential factors.

To challenge the privileged role of diet and physical activity in obesity prevention strategies, Chaput compared the ability of a high fat diet and non-participation in vigorous physical activity to short sleep, dis-inhibited eating, and low calcium intake to predict overweight/obesity development in adults (Chaput et al., 2010). This analysis of cross-sectional data from the Quebec Family Study indicated that short sleep, dis-inhibited eating, and low calcium intake were better predictors of overweight/obesity than a high fat diet and non-participation in physical activity. Furthermore, the analysis of longitudinal data from this same study indicated that individuals with short sleep, dis-inhibited eating, and low calcium intake gained twice as much weight as those with a high fat diet and non-participation in vigorous physical activity (Chaput et al., 2010). These findings highlight a more nuanced view of the many factors contributing to obesity and underscore the need to view obesity prevention from a constellation of potential mechanisms.

Overview of Sleep

People sleep for different durations and at different times. Unraveling the relationship between sleep duration and sleep-wake timing (chronotype) is challenging because later bedtimes are often associated with shorter sleep. Nonetheless, epidemiological evidence indicates that short and long sleep durations exist in individuals with early and late chronotypes and that sleep duration and chronotype are independent traits (Roenneberg, Kuehnle, et al., 2007a). In other words, there are no significant differences in sleep duration between individuals with early, intermediate, and late chronotypes (Horne & Ostberg, 1976). Therefore, sleep duration and chronotype may have independent and/or interacting effects on health.

Sleep Duration

Sleep duration declines as children progress through adolescence (Iglowstein, Jenni, Molinari, & Largo, 2003; Wolfson & Carskadon, 1998). However, Mary Carskadon's seminal work in adolescent sleep concluded that as children mature, biological sleep needs do not decline (M. A. Carskadon et al., 1980). This suggests that declines in sleep duration typically reported throughout adolescence reflect insufficient sleep during this developmental period. Several sources support these findings and indicate that, if given the opportunity, adolescents will sleep approximately nine hours (M. A. Carskadon et al., 1980; National Sleep Foundation, 2006; Terman & Hocking, 1913). However, only 3% to 17% of high school students report nine hours of sleep on school nights and the majority of high school students report less than eight hours of sleep on school nights (National Sleep Foundation, 2006; Wolfson & Carskadon, 1998).

Although defining nine hours of nocturnal sleep duration as optimal for adolescence remains controversial and wide inter-individual variability is recognized, adolescent sleep duration has declined significantly over the past century (Grandner, 2012; Matricciani, Olds, & Petkov, 2012). This decline has been estimated to be 0.75 minutes per year resulting in adolescents sleeping 75 minutes less per night today than 100 years ago (Matricciani et al., 2012). The implications of this decline and of short sleep duration continue to be investigated and range from depressed moods to poor academic and behavioral outcomes (Wolfson & Carskadon, 1998). Interest in an association between short sleep duration and overweight/obesity has grown over the past decade.

Chronotype

Chronotype refers to the typical timing of the sleep-wake cycle within the 24-hour day (Roenneberg, Kumar, & Merrow, 2007b). Chronotypes are classified as early (early bed times-early wake time), intermediate, or late (late bed times-late wake times) based on individual differences in sleep-wake timing (Baehr, Revelle, & Eastman, 2000). The majority of the population has an intermediate chronotype (Roenneberg, Kuehnle, et al., 2007a). It is not clear whether individuals retain their chronotype throughout life or whether individuals can shift chronotypes. For example, if an individual has a late chronotype during adolescence relative to his/her peers, can that individual shift to an early chronotype during young adulthood (relative to his/her peers)? The lack of longitudinal studies on chronotypes prevents definitive answers, however, a large epidemiological study of adults indicated that present chronotype was highly correlated with a retrospective self-assessment of chronotype as a child and teenager in relation to their age and sex peer group (Roenneberg et al., 2004).

While sleep-wake timing represents behavioral markers that differentiate chronotypes, there are also biological markers (or endogenous rhythms) that differentiate chronotypes, such as melatonin and core body temperature. An early chronotype reflects an earlier phasing of the endogenous rhythm to the 24-hour day and is characterized by earlier maximum melatonin levels (Duffy, Dijk, Hall, & Czeisler, 1999), earlier minimum core body temperatures (e.g. 3.50 am) (Baehr et al., 2000; Duffy et al., 1999), earlier bed times, and earlier wake times. Conversely, a late chronotype reflects a later phasing of the endogenous rhythm to the 24-hour day and is characterized by later maximum melatonin levels (Duffy et al., 1999), later minimum core body temperatures (e.g. 6.01 am) (Baehr et al., 2000; Duffy et al., 1999), later bed times, and later wake times.

Two opposing processes regulate sleep-wake timing: the circadian process (promoting wake) and the homeostatic process (promoting sleep) (Borbely, 1982). As night approaches the pressure to stay awake (circadian process) diminishes and the pressure to fall asleep (homeostatic process) increases resulting in sleep onset. Differences in circadian and homeostatic processes regulating sleep-wake timing contribute to differences in chronotype between individuals.

***The circadian process*.** The sleep-wake cycle is a circadian rhythm because sleeping occurs about once a day ("circa" about, "dia" day). Circadian rhythms are orchestrated by a central clock contained in approximately 20,000 neurons in the suprachiasmatic nuclei (SCN) (Reppert & Weaver, 2002). The strategic location of the SCN above the optic chiasm in the anterior hypothalamus (Lack & Wright, 2007) with projections to numerous regulatory centers in the hypothalamus suggests that the SCN play critical roles in synchronizing external environmental rhythms (e.g. light-dark cycles of the 24 hour day) with endogenous rhythms, such as those of the metabolic processes (Buijs et al., 2006). However, the central clock in the SCN has an intrinsic period that is slightly longer than the 24-hour day (Czeisler et al., 1999; Sack, Brandes, Kendall, & Lewy, 2000). Left unrestrained, this slightly-longer-than-24-hour period will cause a gradual shift in biological and behavioral rhythms towards later onsets, including later sleep-wake timing. This contributes to misalignment between biological rhythms (e.g. melatonin, the sleep-inducing hormone), behaviors (e.g. sleep-wake timing), and environmental cues (e.g. light-dark cycle). When these patterns are misaligned, endocrine functioning is perturbed (Nguyen & Wright, 2010). Nonetheless, the central clock is sensitive to environmental cues (e.g. light-dark) and aligns endogenous rhythms to the light/dark cycle of the 24-hour day. This prevents an ongoing shift towards later sleeping and waking times.

It is not clear if there are developmental changes in the length of the intrinsic period (M. A. Carskadon et al., 2004). For example, the average intrinsic period found during adolescence (24.27 hours) was longer than the average intrinsic period found during adulthood (24.12 hours). If the intrinsic period of the central clock does lengthen (M. A. Carskadon et al., 2004; M. A. Carskadon, Labyak, Acebo, & Seifer, 1999), the more the light–dark cue has to advance the clock to align the circadian rhythm to the 24 hour day (Roenneberg, Wirz-Justice, & Merrow, 2003a). However, these findings remain tentative and others report that the intrinsic period of the central clock does not change with age (Czeisler et al., 1999; Dijk, Duffy, & Czeisler, 2000).

Entrainment. The process of aligning endogenous rhythms to external environmental cues and/or internal neuro-hormonal cues is known as entrainment. The light-dark cycle is the dominant environmental cue for entraining biological rhythms associated with sleep-wake timing. Operating through circadian oscillators in the SCN, light and dark entrain the secretion of melatonin (the sleep inducing hormone) from the pineal gland to a 24-hour day. This process begins when light sensitive ganglion cells in the eye (melanopsin cells) transmit light cues through the retinohypothalamic tract of the optic nerve to the SCN situated above the optic chiasm (Berson, Dunn, & Takao, 2002). The transitions to dawn and to dusk are crucial moments because the melanopsin cells are sensitive to the light intensity characteristic of this period (Berson et al., 2002; Brainard et al., 2008). After receiving light-dark input, the SCN transmits this information to the pineal gland and adjustments are made to melatonin production. When dark, melatonin production increases; when light, melatonin production is suppressed (Lewy, Wehr, Goodwin, Newsome, & Markey, 1980). Thus, melatonin serves as the “hands of the clock” (Lack & Wright, 2007, p. 1206) adjusting the central clock to 24-hours every day.

Entrainment establishes a stable relationship between biological rhythms (e.g. melatonin onset and offset), exogenous rhythms (e.g. light-dark cycles), and behavioral rhythms (e.g. sleep-wake cycles) that is critical for efficient biological functioning (Bray & Young, 2007). This entrained relationship for the sleep-wake cycle is termed chronotype and is most evident in the habitual timing of sleeping and waking within the 24 hour day (Roenneberg, Kumar, et al., 2007b). However, two problems can occur with entrainment. If exogenous rhythms are dampened, the environmental cues may be too weak to properly align the central clock. If behavioral rhythms are out of sync with biological and exogenous rhythms, misalignment follows. Both situations may have a significant impact on health.

Environmental changes and behavioral changes have led to a dampening of the light-dark cues critical for entrainment. Increased exposure to light at night (e.g. outdoor ambient light, light emitting technology use) and reduced exposure to outdoor daytime light (e.g. increased indoor sedentary time) have dampened the amplitude of the light-dark cues required for entrainment. Roenneberg’s epidemiological studies on chronotype indicated that as population density increased and more artificial light at night exposure occurred near metropolitan hubs, sleep-wake timing became less aligned to the earth’s light-dark cycles (Roenneberg, Kumar, et al., 2007b). Furthermore, the average chronotype of populations living near metropolitan hubs is significantly later than populations living in more rural areas suggesting that the central clock is not aligning with the light-dark cues provided by the earth's rotation (Roenneberg, Kumar, et al., 2007b). Consequently, the central clock, with its longer intrinsic period, plays a more prominent role in determining sleep-wake timing causing later sleep-wake onsets.

Second, if an individual's entrained phase of sleep-wake timing, or chronotype, is out of sync with biological and exogenous rhythms, misalignment occurs. This type of misalignment is most evident in shift workers, however, it can also occur when any work/social schedule mandates sleep-wake timing that is at odds with an individual's chronotype. For example, on school days, high school students with late chronotypes go to bed late but rise early and at an earlier circadian phase (Duffy et al., 1999; Mongrain, Carrier, & Dumont, 2006). In contrast on free days, students with late chronotypes go to bed late but rise late. These chronic weekly shifts in sleep-wake timing, coined social jet lag (Wittmann et al., 2006) challenge the body's ability to re-establish synchrony (Garaulet & Madrid, 2010; Garaulet, Ordovas, & Madrid, 2010) and are most pronounced during adolescence (Roenneberg et al., 2012). Furthermore, they resemble the larger shifts in sleep-wake timing typical of shift workers, a group known to suffer disproportionately from cardio-metabolic disease and obesity (Knutsson et al., 1986; Suwazono, Dochi, Sakata, Okubo, Oishi, Tanaka, Kobayashi, Kido, et al., 2008; Suwazono, Dochi, Sakata, Okubo, Oishi, Tanaka, Kobayashi, & Nogawa, 2008; Suwazono et al., 2006).

The homeostatic process. In contrast to the circadian process' role in promoting wakefulness, the homeostatic process promotes sleep. According to the homeostatic process, the longer one is awake, the greater the pressure to sleep becomes. However, differences in the build-up and the dissipation of sleep pressure contribute to differences in sleep-wake timing. A slower build-up of sleep pressure delays sleep onset. A slower dissipation of sleep pressure delays waking.

Differences in the build up and the dissipation of sleep pressure exist between chronotypes. A slower dissipation of sleep pressure (e.g. increased morning sleepiness) was found in individuals with late chronotypes (Taillard, Philip, Coste, Sagaspe, & Bioulac, 2003). EEG findings corroborated and extended these subjective findings. For example, after fragmented sleep, adults with earlier chronotypes had a faster build up of sleep pressure (indicated by increased theta activity) than adults with later chronotypes (Mongrain & Dumont, 2007). Similarly, sleep pressure dissipated faster in individuals with early chronotypes (Mongrain & Dumont, 2007).

In sum, the circadian and homeostatic processes influence chronotype and shifts towards later chronotypes during adolescence are found across cultures (Gradisar, Gardner, & Dohnt, 2011) and species (Hagenauer, Perryman, Lee, & Carskadon, 2009). Having a later chronotype might not be problematic if lifestyles can be adjusted to accommodate later sleep-wake timing, however, early school start times prohibit this adjustment for many adolescents. Consequently, students with later chronotypes wake up early in the circadian phase and have greater differences in the duration and the timing of sleep on school nights and free nights (Roenneberg et al., 2003a). Conversely, students with earlier chronotypes wake up later in the circadian phase, and have smaller differences in the duration and the timing of sleep on school nights and free nights. These disparities can have important implications for health.

Overview of Sleep and Obesity

Interest in the association between sleep and obesity and in sleep's potential to modify subsequent weight gain has grown over the past decade. The relationship between sleep and obesity is largely rooted in conceptualizing sleep duration's association with obesity. Very few studies have considered the role of chronotype in modifying the relationship between sleep and obesity. While short sleep duration may impact BMI through hormonal and behavioral changes, chronotype may influence BMI through a different pathway (e.g. circadian misalignment).

Sleep Duration and Obesity

Recent interest in an association between short sleep duration and overweight/obesity is exemplified by the publication of at least two meta-analyses and several systematic reviews (Cappuccio et al., 2008; X. Chen, Beydoun, & Wang, 2008; Guidolin & Gradisar, 2012; Magee & Hale, 2012; Patel & Hu, 2008). In sum, cross-sectional and longitudinal evidence for an association between sleep duration and obesity in adults is mixed (Cappuccio et al., 2008; Magee & Hale, 2012; Patel & Hu, 2008). Few studies have focused exclusively on adolescent sleep duration and obesity and findings are inconclusive (Guidolin & Gradisar, 2012). Lastly, overall consistent cross-sectional and longitudinal evidence for association between sleep duration and obesity in children has been reported (X. Chen et al., 2008; Magee & Hale, 2012; Patel & Hu, 2008). One explanation for the inconsistent findings in adult studies may stem from an assumed linear relationship between sleep duration and obesity whereas a U-shaped relationship may more appropriately describe this relationship (Patel & Hu, 2008). Another explanation for the lack of an association between short sleep and subsequent weight gain in adults is that a weight threshold may have already been reached prior to the initiation of the study (Magee & Hale, 2012). Regardless, generalizing findings about the relationship between sleep duration and obesity from adult and children studies to adolescents may be inappropriate given the unique changes in adolescent sleep and body composition and adolescents remain an understudied population. Furthermore, several conceptual and measurement issues have made the interpretation of existing findings challenging.

Conceptual issues confounding sleep and obesity studies include inconsistent definitions of sleep duration (e.g. time in bed versus sleep onset), aggregated heterogenous groups with potentially different sleep needs, and the lack of clarity between sleep debt, short sleep, and/or sleep loss (Grandner, 2012). Measurement issues, such as the inclusion of different confounding variables, the omission of important confounding variables, the lack of valid and reliable sleep measures, and reliance on self reported height and weight to calculate BMI are further hindrances that may weaken associations between sleep and obesity (Guidolin & Gradisar, 2012; Magee & Hale, 2012; Nielsen, Danielsen, & Sorensen, 2011). For example, most adolescent sleep and obesity studies have relied on single non-validated questions to measure sleep, such as "how many hours of sleep do you usually get a night?" (Araujo, Severo, & Ramos, 2012; M. Y. Chen, Wang, & Jeng, 2006; Eisenmann, Ekkekakis, & Holmes, 2006; Garaulet et al., 2011; Knutson, 2005; Lytle, Pasch, & Farbakhsh, 2011; Ramos & Barros, 2007; Seicean et al., 2007; Sun, Sekine, & Kagamimori, 2009; Wells et al., 2008). In adolescents, this single question was weakly correlated with 24 hour timed diary reports of sleep and fails to account for the school night and free night sleep duration variability characteristic of adolescent sleep (Knutson & Lauderdale, 2007; National Sleep Foundation, 2006). Few adolescent sleep and obesity studies have used actigraphy to estimate sleep (Beebe et al., 2007; Gupta et al., 2002; A. Weiss et al., 2010) and none of these studies used actigraphy for the recommended length of five to seven nights (Acebo et al., 1999). This is particularly problematic given the wide variation between school night and free night sleep durations in adolescents. In sum, comparatively little has been demonstrated conclusively about the relationship between sleep duration and obesity, conceptual and methodological issues hamper our understanding of the sleep-obesity relationship, and adolescents remain an understudied population.

Chronotype and Obesity

Few studies have included chronotype as a variable when investigating the relationship between sleep duration and obesity. However, similarities in sleep-wake patterns exist between shift workers (a group known to suffer disproportionately from cardiovascular disease, metabolic diseases and obesity) and adolescents (Knutsson et al., 1986; Suwazono, Dochi, Sakata, Okubo, Oishi, Tanaka, Kobayashi, Kido, et al., 2008; Suwazono, Dochi, Sakata, Okubo, Oishi, Tanaka, Kobayashi, & Nogawa, 2008; Suwazono et al., 2006; Vyas et al., 2012). For example, shift work and trans-meridian travel require individuals to change their sleep-wake patterns on chronic or acute bases respectively. Similar patterns exemplify the sleep-wake patterns of adolescents. Forty four percent of high school students report greater than two-hour differences in sleep-wake patterns between school days and non-school days (National Sleep Foundation, 2006). This "resembles the situation of traveling across several time zones to the West on Friday evenings and ''flying'' back on Monday mornings" (Roenneberg et al., 2012, p.939). These chronic weekly differences between the sleep-wake timing on school days and free days have been coined “social jet lag” and are defined as the difference in midpoint of sleep times on school nights and free nights (Wittmann et al., 2006). Epidemiological data indicates that these differences are greater in adolescents than any other age group (Roenneberg et al., 2012) and are caused by the mismatch between early school start times and the later chronotype characteristic of adolescent development. Consequently, shifting sleep-wake timing by several hours on school days and free days parallels the shift in sleep-wake timing that occurs with rotating shift workers, albeit on a smaller scale. The similarities of this chronic pattern in adolescent high school students with shift workers and trans-meridian travelers suggest that adolescents (particularly adolescents with later chronotypes) may be susceptible to same health maladies as this population.

Findings from longitudinal studies in adult shift workers indicated that the greatest increases in BMI and the metabolic syndrome were in shift workers who rotated between day and night work hours (De Bacquer et al., 2009; Morikawa et al., 2007). Furthermore, Roenneberg et al. found a significant association between social jet lag and overweight/obesity in adults (Roenneberg et al., 2012). The implication for adolescents is that the developmental shift towards later chronotype is at odds with early school start times. Consequently, adolescents with later chronotypes may be particularly vulnerable to social jet lag and at a greater risk for overweight/obesity.

Studies that measured chronotype based on self-reported preferences for morning or evening activities in adolescents and young adults reported non-significant trends between later chronotypes and a higher BMI (Gaina et al., 2006; Schubert & Randler, 2008). Olds, Maher, and Matricianni were the first to report statistical significance between late bed/late rise times and BMI, independent of sleep duration in adolescents (T. S. Olds, Maher, & Matricciani, 2011). Interestingly, the differences in BMI were greatest between the groups that had similar sleep durations but the most disparate sleep times (early-bed/early-rise and late-bed/late-rise).

Potential Mechanisms Linking Sleep and Obesity

Several studies have investigated the potential mechanisms linking sleep and obesity. As illustrated in the conceptual model, sleep duration and chronotype (via circadian misalignment) influence BMI directly (through changes in hormones known to increase fat mass) or indirectly (e.g. through changes in eating habits and physical activity).

Hormones. Hormonal changes associated with subsequent increases in fat mass and central fat accumulation include increases in insulin resistance and cortisol (Adam et al., 2009; Cavagnini et al., 2000; Morrison, Glueck, Horn, Schreiber, & Wang, 2008). Findings that short sleep and circadian misalignment are associated with increased insulin resistance and altered cortisol secretion support this pathway as a potential mechanism linking short sleep and obesity (Buxton et al., 2010; Darukhanavala et al., 2011; Javaheri et al., 2011; Scheer et al., 2009; Spiegel, Leproult, et al., 2004). However, other studies indicate a reversed relationship (e.g. fat mass increases insulin resistance) (Hosking, Metcalf, Jeffery, Voss, & Wilkin, 2011). Consequently, the directionality of this relationship continues to be investigated.

Other hormonal changes linking sleep and obesity are changes in satiety and appetite hormones. For example, short sleep and circadian misalignment are associated with reductions in the satiety hormone (leptin), increases in the hunger hormone (ghrelin), and an increased appetite for energy dense food (Al-Disi et al., 2010; Scheer et al., 2009; Spiegel, Tasali, Penev, & Van Cauter, 2004; Taheri, Lin, Austin, Young, & Mignot, 2004). These hormonal changes may set the stage for behavioral changes related to eating habits conducive to weight gain.

Eating habits. Eating habits, such as the type of food eaten (e.g. carbohydrates, proteins, fats) and the timing of food intake (morning, afternoon, evening), differentially influence overall energy intake that may impact BMI over time (de Castro, 1987; Drewnowski et al., 2004; World Health Organization, 2003). Differences in the type and the quantity of food eaten as well as the timing of food consumption have been reported in individuals with short sleep durations and later chronotypes. These differences include increased overall energy consumption, carbohydrate consumption, fat consumption, fast food and regular soda consumption, as well as reduced fruit and vegetable consumption (Al-Disi et al., 2010; Baron et al., 2011; Brondel, Romer, Nougues, Touyarou, & Davenne, 2010; Fleig & Randler, 2009; Haghighatdoost, Karimi, Esmaillzadeh, & Azadbakht, 2012; Kanerva et al., 2012; Nedeltcheva, Kessler, Imperial, & Penev, 2009; A. Weiss et al., 2010). In one study, Baron argued that even when total energy intake was statistical insignificant between late and intermediate chronotype groups, clinical significance for weight gain remained possible (e.g. 2 pounds/month weight gain if not balanced by an increase in energy expenditure) (Baron et al., 2011). Furthermore, a relationship between short sleep and increased evening snacking (after 7 pm) has been reported (Nedeltcheva, Kessler, et al., 2009; A. Weiss et al., 2010). Individuals with late chronotypes are more likely to skip breakfast or have small morning meals and sharply increase food intake as the day progresses compared to individuals with intermediate chronotypes (Baron et al., 2011; Garaulet et al., 2013b). Interestingly, individuals who ate meals later in the day lost less weight and lost weight more slowly than individual who ate earlier in the day despite similar energy intake, energy expenditure, and sleep duration (Garaulet et al., 2013b). Taken together, the eating habits characteristic of individuals with shorter sleep duration are conducive to weight gain, if not counterbalanced by increases in energy expenditure.

Physical activity. Few longitudinal studies and/or experimental studies in adolescents aimed at discerning the relationship between physical activity and subsequent weight gain in adolescents exist and methodological issues confound the interpretation of findings from existing studies (Reichert, Baptista Menezes, Wells, Carvalho Dumith, & Hallal, 2009). Nonetheless, the theoretical plausibility for a relationship between physical activity (in combination with other factors such as eating habits) and BMI remains. Evidence for an association between sleep duration and physical activity is mixed. Short sleep and late chrontoype are associated with less moderate-to-vigorous physical activity and more sedentary behaviors in some studies (Darukhanavala et al., 2011; Gaina et al., 2006; Gupta et al., 2002; Kanerva et al., 2012; T. S. Olds et al., 2011; Schaal et al., 2010) whereas, other studies support an association between short sleep and increased physical activity (Brondel et al., 2010; Klingenberg et al., 2012). Furthermore, experimental evidence indicates that energy expenditure (e.g. physical activity being only one component of energy expenditure) does not differ significantly between individuals with short sleep duration and individuals with longer sleep duration (Nedeltcheva, Kilkus, et al., 2009). While reasons for these disparate findings are not known, differences in study settings (e.g. free living versus lab) may be a contributing factor.

Correlates and Determinants of Sleep Duration and Chronotype

Several person and environment factors are associated with sleep duration and chronotype including age, sex, puberty, race/ethnicity, and poverty. Therefore, as covariates that may explain some of the relationship between sleep duration, chronotype, and BMI, these concepts are discussed.

Person

Age. Age-related changes in sleep duration and chronotype have been reported and the pathways contributing to these changes are a confluence of socio-cultural and physiological factors. Nocturnal sleep duration declines at approximately 12 minutes/night per year of age on school nights and 4 minutes/night per year of age on free nights during adolescence (T. Olds, Maher, Blunden, & Matricciani, 2010). In the US, average sleep durations for high school students range from 6.9 to 7.6 hours on school nights and 8.4 to 9.22 hours on free nights (National Sleep Foundation, 2006). The transitions from 8^{th} to 9^{th} grade and from 9^{th} to 10^{th} grade are characterized by the greatest increases in students reporting short sleep durations. For example, 67% of 8^{th} grade students report sleeping less than eight hours, 78% of 9^{th} grade students report sleeping less than eight hours, and 87% of 10^{th} grade students report sleeping less than eight hours (National Sleep Foundation, 2006). Furthermore, differences in school night versus free night sleep duration increase significantly during high school. These differences (social jet-lag) increase from 25 minutes at 9 years of age to 86 minutes at 18 years of age (T. Olds, Maher, et al., 2010; Wittmann et al., 2006).

Socio-cultural factors that contribute to these declines in sleep duration include early high school start times, changing academic demands, expanding social opportunities, and decreasing parental influence. In the US, earlier high school start times over the past century have contributed to shorter sleep durations (Terman & Hocking, 1913). When high school start times are delayed, even by as little as 30 minutes, longer sleep durations are reported, the percentage of students sleeping less than seven hours declines, and improvements in adolescent health and behavior have been noted (Danner & Phillips, 2008; Owens, Belon, & Moss, 2010; Wahlstrom, 2002). Academic demands also influence sleep duration. Students enrolled in AP/college courses have reported sleeping about one hour less than students not enrolled in AP/college courses (Jin & Shi, 2008). Expanding social opportunities and the ability to stay connected 24/7 via cell phones or computer impinges on adolescent sleep. Sixty-two percent of adolescents reported continued cell phone use after lights were turned out for bedtime, including ongoing text messaging between 12am and 3am on school nights (Van den Bulck, 2007). Lastly, parental supervision over bedtimes decreases during high school. Only 39% of high school students report enforced bedtimes and many adolescent's enforced bedtimes are after 10 pm on school nights (National Sleep Foundation, 2006).

Age related differences in chronotypes also exist. Chronotypes are normally distributed across a population (Roenneberg, Kuehnle, et al., 2007a), however, the mean of the population systematically shifts across different age groups (Roenneberg, Kuehnle, et al., 2007a). For example, mean chronotype becomes progressively later as children progress through adolescence reaching a peak in lateness around 20 years of age (M. A. Carskadon et al., 1998; Park, Matsumoto, Seo, Kang, & Nagashima, 2002; Randler &

Bilger, 2009; Roenneberg, Kuehnle, et al., 2007b) After 20 years old, mean chronotype begins shifting earlier (Carrier, Monk, Buysse, & Kupfer, 1997; Park et al., 2002; Tonetti, Fabbri, & Natale, 2008).

Although the mechanisms underlying age related shifts in chronotype are not fully understood, physiological factors associated with the circadian processes may play a role (Baehr et al., 2000). Changes in sensitivity to light-dark cues during adolescence have been proposed. Consequently, if adolescents are more sensitive to evening light cues, sleep will be delayed; if adolescents are less sensitive to early morning light cues, waking will be delayed (M. A. Carskadon et al., 2004; M. A. Carskadon, Acebo, & Seifer, 2001). Although lines of evidence supporting these ideas remain tentative, adolescent sleep-wake timing was more delayed in the spring (greater evening light exposure) than in the winter (less evening light exposure) (Figueiro & Rea, 2010). Additionally, adolescents have been reported to be less sensitive to early morning sunrise than adults and early morning light treatments have not been effective in advancing sleep to an earlier phase (Borisenkov, Kosova, & Kasyanova, 2012; Crowley & Carskadon, 2010). Furthermore, the sleep inducing hormone, melatonin, is suppressed by light, particularly shorter wavelengths of light that are typically emitted from electronic devices such as television, video games, and computer screens (Brainard et al., 2008). As adolescents progress through high school, the number of electronic devices in their bedrooms increase (National Sleep Foundation, 2006). In 2006, 60% of high school students had a television in their bedroom and 32% had a computer in their bedroom (National Sleep Foundation, 2006). Furthermore, 76% of high school students report watching television one hour prior to bedtime (National Sleep Foundation, 2006). This implies that a large percentage of adolescents may be exposed to short wavelength light just prior to bedtime.

Sex. Sex-related differences in sleep duration and chronotype have been reported during adolescence. Females generally sleep longer and have earlier chronotypes than males. A meta-analysis of adolescent sleep duration data from 20 countries found that females sleep 11 minutes more per night than males on school nights and 29 minutes more per night on free nights (T. Olds, Blunden, Petkov, & Forchino, 2010). Over the course of one week, these differences may accumulate to a two-hour difference in total weekly sleep duration between males and females (M. Moore et al., 2011). Additionally, findings from large epidemiological studies in adults and adolescents report that females have earlier chronotypes than males (Adan & Natale, 2002; Lehnkering & Siegmund, 2007; Randler, 2011a; Tonetti et al., 2008).

Physiological support for sex differences in chronotype exists. Factors that influence sleep onset and serve as endogenous markers for chronotype (e.g. melatonin secretion and minimum core body temperature) occur earlier in the evening/night for females than males (Baehr et al., 2000; M. A. Carskadon et al., 1998). Additionally, estrogen shortens the internal circadian period (a factor related to early chronotype in humans) (Kruijver & Swaab, 2002). Given that females have more estrogen and progesterone receptors than males in the SCN (the master clock), estrogen may exert a greater effect on the circadian process in females than males contributing to an earlier chronotype (Kruijver & Swaab, 2002).

Puberty. The most commonly used scale to assess stages of secondary sexual development (e.g. breast development, genitalia development) during puberty is the

Tanner Scale (Cameron, 2002). This scale ranges from Tanner Stage 1 (prepubertal) to Tanner Stage 5 (maturation). Although the majority of ninth grade females may be late pubertal and the majority of ninth grade males may be mid-pubertal (Bond et al., 2006), the tempo of puberty varies greatly between individuals and differs from chronological age. Additionally, racial/ethnic differences have been reported with the onset and the completion of puberty occurring earlier in Black males and females than White males and females (Kaplowitz, 2006; Slyper, 2006).

Pubertal development is characterized by shorter sleep durations (8.9 hours at Tanner Stage 1 to 7.5 hours at Tanner Stage 5) and a shift towards later chronotypes (Roenneberg et al., 2004; Rutters, Nieuwenhuizen, Lemmens, Born, & Westerterp-Plantenga, 2010). Pubertal changes in circadian and homeostatic processes contribute to this characteristic shift in chronotype. Melatonin is secreted one hour earlier during Tanner Stage 1 (approximately 8:30 pm) than during Tanner Stage 5 (approximately 9:30 pm) (Taylor, Jenni, Acebo, & Carskadon, 2005). Additionally, sensitivity to homeostatic processes (e.g. the pressure to fall asleep) diminishes during adolescence because even after periods of extended wakefulness, adolescents at Tanner Stage 5 take longer to fall asleep than adolescents at Tanner Stage 1 or 2 (Borbely, 1982; Jenni, Achermann, & Carskadon, 2005; Taylor et al., 2005).

Race/Ethnicity. Racial/ethnic differences in sleep duration have increased over the past three decades (Stamatakis et al., 2007). Black adolescents have reported sleeping 20 minutes less per night than White adolescents, accumulating to a two hour difference in sleep over one week even after adjusting for confounding variables such as family income and education (M. Moore et al., 2011). Comparing the sleep duration of adolescents across several geographic regions, Asian adolescents slept one hour less than American adolescents and Australian and European adolescents reported the longest sleep durations. Similarly, the rates of decline in school night sleep duration with age were greater among Asian and American adolescents than European and Australian adolescents (T. Olds, Blunden, et al., 2010). The authors conjectured that these differences might be related to cultural differences such as bedtime practices and school work ethic (T. Olds, Blunden, et al., 2010). Little is known about racial/ethnic differences in chronotype.

Environment

Poverty. Adolescents from lower socio-economic households (e.g. income, education level) have shorter sleep and more irregular sleep patterns than adolescents from higher SES households (Marco et al., 2011). Cross sectional data support a progressive relationship between income and sleep duration (e.g. lower income, less sleep) in adolescents (Marco et al., 2011). Longitudinal data demonstrate that this relationship is persistent, enduring, and has increased over the past three decades in adults (Stamatakis et al., 2007). Although the underlying mechanism linking lower socio-economic status to short sleep duration has yet to be elucidated, contributing factors may include dense living conditions (e.g. number of people sharing sleeping space), night-time noise levels, and /or parental shift work schedules (Marco et al., 2011; M. Moore et al., 2011).

Assessment of Body Fat

Body composition changes throughout the lifespan and can be evaluated at several levels of complexity (e.g. atomic, molecular, cellular, tissue-system, whole body)

(Zemel, 2002). Most commonly, body composition is described in terms of fat mass and lean body mass (Zemel, 2002). Puberty heralds the onset of rapid changes in the amount, proportion, and distribution of fat mass and lean body mass (Zemel, 2002). In females, there is an increase in the percentage of fat mass and lower body fat deposition (e.g. hips and thighs). In males, there is an increase in the percentage of lean body mass and truncal fat deposition (Zemel, 2002). Several methods for determining fat mass and lean body mass exist (e.g. hydrodensitometry, air displacement plethysmography, isotope dilution methods, bioelectric impedance analyzers, DXA, computerized axial tomography) (Zemel, 2002), but their application in community settings, such as schools, is limited. These limitations and the challenges of measuring fat mass directly have led to overweight and obesity being commonly defined by BMI (Ogden & Flegal, 2010) and to recommended overweight/obesity screenings in youth using BMI (Barton, 2010; J. H. Himes & Dietz, 1994).

Body Mass Index

Body mass index was first proposed as a measure of body mass by Adolphe Quetelet, in the 19th century and later established as a valid and reliable measure in adults by Ancel Keys (Eknoyan, 2008; Keys et al., 1972). Since then it has become the most commonly used measure to classify individuals as overweight or obese (J. H. Himes & Dietz, 1994). In children and adolescents (2-20 years old), these definitions must account for age and sex variability in height and body weight. Therefore, overweight and obesity are defined in comparison to a reference population. Overweight is a BMI between the 85^{th} and less than the 95^{th} percentile for age and sex; obesity is a BMI greater than or equal to the 95^{th} percentile for age and sex (Ogden & Flegal, 2010). The reference population used for developing the 2000 CDC BMI-for-age growth charts was a nationally representative sample of US children from 1963 to 1980, sample weighted to adequately represent all racial/ethnic groups in the US population at that time (Kuczmarski et al., 2002). Data after 1988 was excluded for children over 6 years of age because of the increasing trend in overweight and obesity in youth evident during those years (Kuczmarski et al., 2002).

One limitation of BMI is that it does not distinguish fat mass from lean body mass (J.H. Himes, 2004). Consequently, different proportions of fat mass and lean body mass can result in a similar BMI. For example, high BMI in Hispanic youth are largely attributed to an increase in fat mass. However, high BMI in Black youth are largely attributed to an increase in lean body mass (Freedman et al., 2005). Furthermore, although BMI-for-age is highly correlated with fat mass (as measured by dual energy X-ray absorptiometry), the strength of this correlation diminishes with BMI less than the 84^{th} percentile for age (Freedman et al., 2005). BMI-for-age at the 85^{th} percentile and the 95^{th} percentile for overweight and obesity is highly specific (the likelihood that a person who is not overweight or obese will not be incorrectly identified as such), but less sensitive (the likelihood that a person who is overweight/obese is identified as such) (Polit & Beck, 2008). This means that BMI-for age may underestimate overweight and obesity in youth. Nonetheless, the area under the curve, a measure that describes how well a test discriminates those who have a condition and those who do not have a condition (Woodward, 2005), demonstrates that BMI is highly accurate in identifying overweight and obese youth (Freedman & Sherry, 2009).

Waist to Height Ratio

Waist measurements (e.g. waist circumference, waist to height ratios) are feasible anthropometric methods of assessing body composition in school settings that may add additional information about fat distribution. In contrast to BMI, waist measurements are not routinely measured in youth. Interest in supplementing BMI measurements with waist measurements (a proxy measure of central fat accumulation) has emerged because of the association between central fat accumulation and increased cardio-metabolic disease risk in normal weight and obese adolescents (Bacha, Saad, Gungor, & Arslanian, 2006; Kovacs, Gabor, Fajcsak, & Martos, 2010; Kursawe et al., 2010; S. Lee, Gungor, Bacha, & Arslanian, 2007; Lurbe, Alvarez, & Redon, 2001; Santos, Cintra Ide, Fisberg, & Martini, 2008; Tybor, Lichtenstein, Dallal, Daniels, & Must, 2011). Furthermore, evidence that waist measurements are significantly associated with triglycerides, insulin, c-peptide, and HOMA IR, independent of BMI in some populations, suggests that this may be an appropriate and feasible measure for screening youth for cardio-metabolic disease risk (Weber et al., 2014). Additionally, increases in WC have exceeded increases in BMI in youth suggesting that BMI measurements do not fully capture important changes in body composition (Garnett et al., 2005; McCarthy, Jarrett, Emmett, & Rogers, 2005; Must & Anderson, 2006; Okosun, Boltri, Eriksen, & Hepburn, 2006).

Intra-rater and inter-rater reliability for WC measurements in adolescents determined by the Technical Error of Measurement (the square root of measurement error variance) is acceptable, ranging from 0.47 cm to 1.14 cm (intra-rater) and 0.89 cm (inter-rater) (Moreno et al., 2003). Furthermore, intra-rater reliability for WC measurements in normal, overweight, and obese BMI groups ranges from intra class correlation coefficients (ICC) = 0.97 (obese group) to 0.99 (overweight and normal groups) (C. Y. Wang, Liu, & Chen, 2010). Combined this evidence suggests that WC can be precisely measured in adolescents across several ranges for BMI, although the small sample sizes in these studies limits the generalizability to these findings.

One advantage of waist to height ratio (WHtR) as a proxy measure for estimating central fat accumulation over WC and waist-hip ratio is that WHtR accounts for the correlation between height and WC. This is important because a statistically significant correlation between WC and height has been reported in youth. However, when adjusted for height using the WHtR, this correlation becomes non-significant (Nambiar, Hughes, & Davies, 2010). Thus, WHtR accounts for the expectation that taller people will have larger waists and vice versa.

Assessment of Sleep

Sleep duration and chronotype can be evaluated using a variety of instruments including polysomnography (PSG), actigraphy, sleep logs, sleep diaries, and questionnaires. Although PSG is considered the gold standard, its use for multiple nights in the home setting limits its use for assessing sleep in adolescents whose sleep patterns are characterized by significant school night to non-school night variation. In contrast, an actigraph is a useful instrument for the home setting capable of collecting data to estimate an individual's habitual sleep duration and sleep-wake timing patterns and it has been recommended for this use in the pediatric population (Morgenthaler et al., 2007).

Actigraphy

An actigraph is a small, watch-like device that uses a piezoelectric accelerometer to measure movement (e.g. acceleration, vibration), consequently it is a proxy measure for sleeping-waking (Minors et al., 1996). Movements generate a voltage that is transformed into an activity count based on a specific data mode (proportional integration, time above threshold, zero-crossing) for each epoch length (15 seconds, 30 seconds, or 1 minute). Very slow movements (< 0.25 Hz) and very fast movements (> 2-3 Hz) are eliminated because they are considered outside the range of voluntary human movement (Ancoli-Israel et al., 2003). Different brands (e.g. ActiWatch2, Mini Motionlogger), sensitivity settings (high, medium, low), automatic scoring algorithms (Cole-Kripke, Sadeh, UCSD), and data modes (proportional integration, time above threshold, zero-crossing) can produce different data for the same activity making it difficult to compare findings between studies and underscoring the significance of consistency in these areas within a study. For adolescents, intra-device (but not inter-device reliability) has been established (Meltzer, Walsh, Traylor, & Westin, 2012; Rupp & Balkin, 2011). Additionally, medium sensitivity threshold settings and time above threshold were most closely correlated with PSG for estimating sleep duration and all three automatic scoring algorithms were highly correlated with each other (Johnson et al., 2007; Spruyt, Gozal, Dayyat, Roman, & Molfese, 2011). High inter-rater reliability and good agreement determined by Bland-Altman plots have been reported for manually scoring actigraphy data (Blackwell et al., 2005).

Compared to PSG and sleep logs, sleep duration in adolescents was underestimated by actigraphy data (e.g. 11-33 minutes depending on the device and data mode compared to PSG) (Johnson et al., 2007; Meltzer et al., 2012; Short, Gradisar, Lack, Wright, & Carskadon, 2012). These differences may arise from differences in conceptual definitions of sleep onset between PSG and actigraphy, differences in operational definitions of sleep onset for actigraphy, or differences in wake after sleep onset data between sleep logs and actigraphy.

First, when considering sleep onset, PSG assumes that sleep consists only of the stages of sleep determined by PSG. An alternative view of sleep onset, termed the sleep onset spectrum, has challenged this assumption. According to the sleep onset spectrum, sleep onset is a gradual process that begins with inactivity, progresses to decreased muscle tone, and is completed with an increased auditory threshold. From this theoretical viewpoint, actigraphy (as a measure of inactivity-activity) marks the first phase of sleep onset (inactivity), whereas, PSG marks the second phase of sleep onset (decreased muscle tone) (Tryon, 2004). Inter and intra-individual variation in the rate of progress through the sleep onset spectrum stages also exists. In general, individuals traverse faster from sleeping to waking than vice versa (Tryon, 2004). This highlights systematic differences when PSG is the criterion against which actigraphy is compared and suggests that conceptual differences may be a source for the inconsistent findings in validation studies comparing actigraphy to PSG.

Second, operational definitions for sleep onset measured by actigraphy range from the first minute of three consecutively scored sleep minutes, the first 10 minutes with no more than one epoch scored as active, to “the beginning of the first interval containing 20 minutes…no more than one minute of wakefulness intervening” (Acebo et al., 1999; Baron et al., 2011; Cole, Kripke, Gruen, Mullaney, & Gillin, 1992, p. 465). Correlations for sleep onset between PSG and actigraphy are significantly stronger when the 20-minute definition is used, however, most researchers continue to define sleep onset as the first minute of inactivity (Ancoli-Israel et al., 2003; Cole et al., 1992). Similar discrepancies can be found for actigraph-defined sleep offset (Baron et al., 2011).

Third, differences in wake after sleep onset data between sleep logs and actigraphy have been reported in adolescent males in later pubertal stages contributing to shorter sleep durations reported by actigraphy (Short et al., 2012). However, lack of an association between shorter sleep duration and daytime fatigue, have led the authors to propose that sleep duration differences between actigraphy and sleep logs may be due to night-time sleep movement and not actual wakefulness (Short et al., 2012). Strong correlations have been reported between dim light melatonin onset and actigraph measured midpoint of sleep data in young adults on an unrestricted schedule make this a promising method for measuring chronotype in adolescents (Martin & Eastman, 2002).

Variations in actigraphy data can stem from several factors such as, the proximity of the actigraph to the hand or the elbow, participant watch removal and/or artifacts (Blackwell et al., 2005; Rupp & Balkin, 2011). Artifacts can be created from movement caused by co-sleeping with humans or pets, sleeping on a waterbed, riding in a moving vehicle, sleeping with wrist actigraph on chest or abdomen, a loosened actigraph wrist watch strap and/or reduced movement caused by actigraphy removal not recorded in the sleep log or lying still while awake (Tryon, 2004). Cross referencing actigraphy data with sleep logs is recommended (Lockley, Skene, & Arendt, 1999). Also, to improve the reliability and the validity of actigraphy data three to seven nights of continuous monitoring are recommended (Acebo et al., 1999; Morgenthaler et al., 2007).

Gaps in Knowledge

Sleep and obesity research is rooted in the relationships between sleep duration, eating habits, physical activity and obesity. Although more research is needed in these areas, particularly in adolescents, our understanding of a complex interplay between the circadian processes, metabolic processes, and BMI continues to advance (Garaulet et al., 2010; Gimble, Bray, & Young, 2009). Yet, these concepts have rarely been included in sleep and obesity studies. This study will advance this line of inquiry by investigating sleep duration and chronotype-specific differences in BMI by means of a detailed analysis of sleep-wake timing on school days and non-school days in a racially/ethnically diverse sample of adolescents. If chronotype is an important variable in sleep and BMI research, concern over how many hours adolescents sleep will shift to concern over how to best align adolescent sleep with their endogenous circadian rhythm. For example, adolescents with early chronotypes will have greater circadian alignment by attending morning schools: later chronotypes will have greater circadian alignment by attending late morning/afternoon school. This novel approach may provide initial answers to the conundrum of why all short sleepers are not overweight/obese and vice versa. Furthermore, this study will build upon recommendations from previous studies. Sleep will be measured with a validated questionnaire in all participants and with actigraphy in a subgroup of participants. Sleep measurements will include school nights and free nights. Confounding variables known to influence sleep and/or BMI will be controlled including, age, sex, race/ethnicity, eating habits, physical activity, puberty stage, and poverty. These improved measurement methods may help explain the inconsistent findings of earlier studies.

CHAPTER 3: METHODS

Study Design

This was a prospective cross-sectional observational study. In Phase I, participants completed questionnaires about their sleep-wake patterns and pubertal development, as well as several anthropometric measurements. For Phase II, participants from Phase I were recruited for a more detailed assessment of sleep-wake patterns.

Setting

A four-year comprehensive public high school located in the coastal city of Long Branch, NJ was selected because of the investigator's association with the school nurse supervisor and written support from the superintendent and the school physician. Long Branch High School enrolls approximately 1,121 students (37% Hispanic; 31% Black; 31% White, 1% Asian). Fifty three percent of the students are male, 47% are female. Fifty one percent of the students are eligible for free lunch and 12% are eligible for reduced lunch (Public School Review) under the National School Lunch Program. In this study, students in 9th and 10th grade were targeted because the greatest increases in short sleep duration occurs during the transitions from 8th to 9th grade, followed by 9th to 10th grade, social jet lag worsens in 9th grade, and the greatest percentage of students preferring evening activities, indicative of a later chronotype, are 10th grade students (National Sleep Foundation, 2006).

Selection of Participants

Sample Size

The sample size and power calculations for this study were calculated using PASS software and relied on the estimated width of confidence intervals for parameter estimates of interest for each of the aims. Details are provided with each aim in the data analysis section of this chapter based on 100 participants in Phase I and 40 participants in Phase II.

Sample Recruitment

Participants were recruited and enrolled in the study throughout the school year beginning in October 2013 and continuing through May 2014. Recruitment and enrollment occurred at the local school district through compulsory health and physical education classes, back to school nights, and prior to swimming and wrestling team practices. Both parent/guardian informed consent and student assent were required prior to enrollment in the study. To be eligible for enrollment in Phase I, participants were required be full time 9th or 10th grade students and able to actively participate in physical education classes. At a later date, participants from Phase I were invited to participate in Phase II. After obtaining parent/guardian informed consent and student assent, potential participants were screened for eligibility. This screening process took place in a private location in the school health office at a time convenient for the potential participant and to minimize out of class time.

Inclusion/exclusion criteria were justified based on their potential to alter normal sleeping patterns (e.g. acute illness, sleep disorders, developmental disorders) or body composition (e.g. pregnancy, medical conditions such as Prader-Willi Syndrome). See Table 2: Phase II Inclusion and Exclusion Criteria.

Table 2

Phase II Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
9^{th} or 10^{th} grade full time student	Pregnancy (self-reported)
Non-restricted participation in school based physical education classes	Diagnosed sleep disorder (obstructive sleep apnea, restless leg syndrome)
	Diagnosed medical condition affecting growth
	Diagnosed physical conditions affecting diet/activity levels or making measurement completion difficult
	Developmental disorder
	Acute illness/infection within one week prior to the study (seven days or less prior to measurements)

Instrumentation

Table 3

Reliability and Validity Data for Instruments

Instrument and Operational Definition	**Reliability and Validity**	**References**
Height	Mean differences in adolescents' height measured two weeks apart ranged from 0.23 cm to 0.25 cm by the same technician and by different technicians respectively.	(Hamill, Johnston, & Lemeshow, 1973)
Weight	Mean differences in adolescents' weight measured two weeks apart ranged from 0.23 kg to 0.55 kg by the same technician and by different technicians respectively.	(Hamill et al., 1973)
BMI z score: "deviation of the value for an individual from the mean value of the reference population divided by the standard deviation for the reference population"	Correlations with fat mass measured by dual energy X-ray absorptiometry ranged from $r = 0.85 – 0.96$ (BMI greater than or equal to the 85^{th} percentile) to $r = 0.44 – 0.70$ (BMI less than the 84^{th} percentile) in adolescents. AUC (for BMI) = 0.95.	(Freedman & Sherry, 2009; Freedman et al., 2005; Kuczmarski et al., 2002)
Waist Circumference	Intra-rater TEM ranged from 0.47 cm to 1.14 cm and inter-rater TEM was 0.89 cm in adolescents. Across several BMI groups, test-retest intra-observer ICC ranged from 0.83 (underweight group), 0.99 (normal weight and overweight group), 0.97 (obese group) in adults.	(Moreno et al., 2003; Y. Wang, 2002)
Waist to Height Ratio: WC (cm) / height	Correlations with intra-abdominal adipose tissue measured by computed tomography $r = 0.83$ in adults. Correlation with triceps and subscapular skinfolds ranged from $r = 0.57$	(Ashwell et al., 1996; Nambiar et al., 2010; Nambiar,

Instrument and Operational Definition	Reliability and Validity	References
(cm)	– 0.80 in adolescents.	Truby, Abbott, & Davies, 2009)
Sleep Habits Survey: Sleep duration = (self reported school night sleep duration x 5) + (self-reported free night sleep duration x 2) / 7	Sleep duration and actigraphy $r = 0.53$ to 0.31 (school nights and free nights). Sleep duration and sleep logs r = 0.61 to 0.38 (school nights and free nights). Bedtime and sleep onset (actigraphy and sleep log) $r = 0.70$ to 0.76 (school nights) and 0.48 to 0.46 (free nights). Wake time and sleep offset (actigraphy and sleep log) $r = 0.77$ to 0.71 (school nights) and r = 0.52 to 0.46 (free nights). Differences for bedtimes and sleep onsets ranged from 8-13 minutes. Differences for wake times and sleep offset were about one hour (attributed to reduced reliability of two days of actigraphy data or greater variability in weekend sleep timing and duration.)	(Acebo et al., 1999; Wolfson et al., 2003)
Morningness/ Eveningness Questionnaire (M/EQ)	Evening types have later bedtimes than morning types ($p < 0.001$). Correlations with bedtimes $\rho = -0.25$ to -0.34 ($p < 0.001$). Correlations with wake times $\rho =$ -0.25 to -0.52 ($p < 0.001$). A non-significant correlation was reported for weekday wake times for females. Cronbach's $\alpha = 0.73$	(M. A. Carskadon et al., 1993; Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002)
Munich Chronotype Timing Questionnaire (MCTQ)	MCTQ sleep timing data was significantly correlated with sleep log data ($p < 0.0001$). MCTQ midpoint of sleep was correlated with other morning/ eveningness questionnaires in adults $r = 0.60$ to 0.72. Chronotype status determined by midpoint of sleep calculated from self-reported sleep onset and sleep offset was significantly correlated with dim light melatonin onset in adolescents ($p < 0.001$).	(Crowley, Acebo, Fallone, & Carskadon, 2006; Roenneberg, Wirz-Justice, & Merrow, 2003b; Zavada, Gordijn, Beersma, Daan, & Roenneberg, 2005)
Actigraphy: Sleep duration = (mean school night sleep duration x 5) + (mean free night sleep duration x 2) / 7] Midpoint of sleep = midpoint between the mean sleep onset + mean sleep offset	Intra-device reliability: $r = 0.99$. Inter-rater reliability for manual scoring ICC = 0.95. Correlations with PSG for sleep onset vary depending on sleep onset definitions and range from $r = 0.53$ to 0.94 in adults (Cole Kripke formula). Correlations with PSG for sleep onset and sleep offset range from $r = 0.57$ to 1.0 in adolescents (Sadeh formula). Correlations with sleep logs for data aggregated across school nights and free nights (5 nights) ranged from $r =$ 0.45 (sleep duration) to 0.75 (sleep onset) (Sadeh formula). Chronotype status determined by midpoint of sleep was significantly correlated with dim light melatonin onset in adults on an unrestricted schedule $r = 0.82$ to 0.89.	(Acebo et al., 1999; Baron et al., 2011; Blackwell et al., 2005; M. A. Carskadon, Acebo, Richardson, Tate, & Seifer, 1997; Cole et al., 1992; Martin & Eastman, 2002; M. Moore et al., 2011)
Youth Risk Behavior Survey: Eating Habit Questions 72 – 80	Correlation of self reported food intake with 24 hour diet recalls $r = 0.54$	(Rockett et al., 1997)
Youth Risk Behavior Survey (YRBS): Physical and Sedentary Activity Questions	Physical activity question: Test-retest reliability for a modified version of YRBS question 81 ICC = 0.51 (moderate physical activity), 0.46 (vigorous physical activity); Correlation with accelerometry kappa coefficient = -0.05 – 0.03 (moderate physical activity), -0.002 – 0.06	(Schmitz et al., 2004; Troped et al., 2007)

Instrument and Operational Definition	Reliability and Validity	References
81, 83, 84, and 86	(vigorous physical activity). Sedentary activity question modified (TV viewing): ρ with 7 day log = 0.47.	
Pubertal Self Rating Scale	Agreement with the Sexual Maturation Scale: weighted kappa = 0.5 – 0.6. Cronbach's α = 0.67 to 0.78	(Bond et al., 2006; M. A. Carskadon & Acebo, 1993)
r (Pearson's Correlation Coefficient) TEM (Technical errors of measurement) ICC (Intraclass Correlation Coefficient) ρ (Spearman's Rank Order Correlation Coefficient)		

Measurement of Body Mass Index

Calculating BMI requires precise height and weight measurements. Common sources of error for linear measurements that lead to inaccurate data include incorrect technique and imprecise equipment (Lipman et al., 2000). However, interventions such as training in linear measurement techniques have been demonstrated to reduce the degree of inaccuracy between raters to 0.5 cm (Lipman et al., 2004). Several steps were taken to minimize height and weight measurement errors. The investigator participated in anthropometric training as directed by her mentor. Height and weight were measured following the protocols described in Appendix A and Appendix B. Laminated copies of protocols related to participant position, measurement landmarks, calibration, clothing, and exclusion criteria were available on site as a reminder of the proper procedure (J. H. Himes, 2009). Standing height was measured with a calibrated portable stadiometer on non-carpeted flooring to the nearest 0.1 cm. Weight was measured on a calibrated digital scale to the nearest 0.1 kg with the participant wearing light indoor clothing (excluding shoes) (Gordon, 1988). Following the protocols described in Appendices A and B, the investigator obtained both measurements. The mean of three height and the mean of three weight measures was used in the analysis for the calculation of BMI (J. H. Himes &

Bouchard, 1989). Height, weight, and waist measurements were repeated for participants in Phase II to account for potential growth between the Phase I and Phase II.

Body mass index z scores. To determine participants' BMI-for-age z score, the CDC's SAS program for the 2000 CDC growth charts was downloaded (Centers for Disease Control and Prevention). Weight, height, age in months, sex, and measurement data were exported into SAS and used to calculate age and sex specific BMI z scores for each participant for Phase I and Phase II. These BMI z scores were imported into SPSS for further analysis. Advantages for using BMI-for age z scores as a proxy measure for fat mass include the ability to calculate means and standard deviations, to compare means between groups (e.g. different age groups), and to describe individuals at the extremes of the distribution (e.g. less than the third percentile or greater than the 97^{th} percentile) (Kuczmarski et al., 2002). Additionally, BMI-for-age z scores can be converted to BMI-for-age percentiles that are commonly used in the school setting (Kuczmarski et al., 2002).

Measurement of Waist

Waist to Height Ratio. Calculating WHtR requires precise height and WC measurements. Several steps were taken to mitigate errors in WC measurements. Positioning the tape with the plane of the tape perpendicular to the floor and applying tension to the tape to fit snugly around the waist but not compress subcutaneous adipose tissue was important (Callaway, 1988). WC was measured following adaptations to the protocols described for abdominal circumference by Callaway (see Appendix C) (Callaway, 1988). Although Callaway describes this measurement strategy as an abdominal circumference measurement, this is similar to the WC measurement used to calculate WHtRs described by Nambiar et al. (Nambiar et al., 2009). Laminated copies of protocols related to participant position, measurement landmarks, clothing, and exclusion criteria were available on site as a reminder of the proper procedure (J. H. Himes, 2009). The investigator was the sole person collecting WC measurements (Ulijaszek & Kerr, 1999). Three measurements were taken and the mean was used in the analysis. Finally, the TEM was calculated to determine intra-observer reliability in this study (Ulijaszek & Kerr, 1999).

Measurement of Sleep Duration and Chronotype

In Phase I, sleep duration and chronotype for all participants was calculated from the Sleep Habits Survey, the Morningness/Eveningness Questionnaire (M/EQ), and the Munich Chronotype Timing Questionnaire (MCTQ). The midpoint of sleep (half-way between sleep onset and sleep offset) was calculated from the MCTQ (Roenneberg, Kuehnle, et al., 2007b). In Phase II, sleep duration and the midpoint of sleep were calculated from actigraphy data.

Sleep Habits Survey. The Sleep Habits Survey is part of a larger School Sleep Habits Survey that assesses school performance, daytime sleepiness, sleep-wake behavior, and depressive mood (Wolfson & Carskadon, 1998). The Sleep Habits Survey alone consists of six items that query students about their usual sleep-wake behavior over the previous two weeks. Questions that asked about usual bedtimes and usual wake times on school nights and weekends required a specific time to be entered (e.g. 10:15 pm). Questions that asked about sleep duration on school nights and on weekends (Friday and Saturday nights) required the participant to record the number of hours and minutes slept, not including time awake in bed (e.g. 8 hours 30 minutes). See Appendix D.

Daytime Naps. Two questions were added to the Sleep Habits Survey by the investigator. Although questions about daytime sleep were not included in the original survey, daytime sleeping increases as adolescents' transition from middle school to high school. Thirty eight percent of high school students have reported at least two daytime sleep periods (naps) in the past two weeks with an mean duration of 1.2 hours (National Sleep Foundation, 2006). Taking two or more naps in a two week period is indicative of insufficient nocturnal sleep (National Sleep Foundation, 2006). Daytime sleep was coded as a dichotomous variable in Phase I. In Phase II, daytime naps were identified as periods of inactivity between 6:00 and 18:00 from actigraphy data. These naps were confirmed using sleep diaries and verified with participants.

Morningness/Eveningness Questionnaire. The Morningness/Eveningness Questionnaire (M/EQ) measures activity/rest preferences in children (M. A. Carskadon et al., 1993). It was developed by modifying questions from a valid and reliable morningness/eveningness preference scale for adults (Smith, Reilly, & Midkiff, 1989). In this 10-item multiple choice scale, participants responded to prompts about preferred timing for activities such as tests, physical activity, bedtimes etc. Responses were scored on a range from one to five with some items requiring reverse scoring. Scores range from 10-42 with higher scores indicating greater morningness (early chronotype) (see Appendix D).

Munich Chronotype Timing Questionnaire. The Munich Chronotype Timing Questionnaire (MCTQ) was developed to measure chronotype based on sleep-wake timing as opposed to preferences for the timing of specified activities (Roenneberg et al., 2003b). In this 12-item fill in the blank form participants were asked to respond to items about sleep habits (e.g. bedtime, wake time, time lapsed between bedtime and sleep onset) on school days and free days (see Appendix E). Sleep-wake timing and the differences in sleep-wake timing between school days and free days were used to determine chronotype by calculating the midpoint of sleep (Roenneberg, Kuehnle, et al., 2007a). This accounts for the fact that participants often sleep longer on free days to compensate for shorter sleep on school days (Roenneberg et al., 2012). Results were in local time with "0" representing midpoints of sleep less than midnight (see Appendix F) (Wittmann et al., 2006).

Actigraphy. Estimating sleep duration and the midpoint of sleep from actigraphy data hinges on collecting accurate actigraphy data. In previous studies, 28% of data collected by actigraphy over seven consecutive days in children and adolescents was not usable for a variety of reasons, including technical failures (Acebo et al., 1999). Consequently, the investigator followed an Actigraph Data Collection, Proofing, and Scoring Protocol. A sample protocol (including a sleep validity check sheet) and actigraph communication sheet are provided in Appendix G, Appendix H and Appendix I. Briefly, data were collected at 1-min epochs in the proportional integration mode using Actiwatch 2 devices. Analyses were based on 'medium' threshold for sleep/wake detection in Actiware 5.7 from the manufacturer (Cole-Kripke formula). Actigraphs were worn on the non-dominant wrist as described by Sadeh et al. for seven continuous days (Acebo et al., 1999; Sadeh, Sharkey, & Carskadon, 1994). The sleep parameters used to determine sleep duration on school nights (Sunday through Thursday) and free nights (Friday and Saturday) were sleep onset, sleep offset, and wake after sleep onset as defined by the automated scoring method. The concurrent use of sleep diaries provided a cross-reference (see Appendix K).

At a time convenient to the participant during the school day, the investigator instructed participants in small groups on how to use the actigraph monitor (see Appendix L) and how to maintain the sleep diary (Appendix K). They were provided instructions to post in convenient places as reminders for following the actigraph protocol (see Appendix M), and provided with a parent memo to encourage and support adherance to the actigraphy protocol (see Appendix N). Monitoring was initiated in school on the date of instruction at 15:00. The investigator called participants at a pre-arranged time each day to encourage retention, adherence to the protocol, and to trouble-shoot problems. Monitoring concluded seven days later when the participant returned to the school health office to have the actigraph removed, the data downloaded, and the sleep diary submitted. Actigraph data and sleep diary data were documented on the Actigraph Scoring Form (see Appendix O). Discrepancies between actigraphy data and sleep diary data were reconciled with each participant at the earliest convenient time (see Appendix P). Ninety-nine percent of Phase II participants completed 7 continuous days of actigraphy data.

Social Jet Lag. Social jet lag represents differences between school night sleep and free night sleep and may be calculated from the MCTQ and actigraphy data. Although social jet lag is most pronounced in individuals with later chronotypes, social jet lag can also be present in individuals with early chronotypes (Wittmann et al., 2006). Social jet lag was calculated from the MCTQ and actigraphy as the absolute difference between the midpoint of sleep on school days and the midpoint of sleep on free days (Wittmann et al., 2006).

Measurement of Confounding Variables

Several confounding variables were controlled for in this study because of their reported associations between sleep and/or obesity. These included eating habits, physical activity, age, sex, puberty, race/ethnicity, and poverty (see Appendix Q). Free and reduced lunch participation was used as a proxy measure for poverty. Free and reduced lunch participation is available through the National School Lunch Program, a federally assisted meal program administered through Food and Nutrition Service at the federal level and state education agencies at the state level. To qualify for free meals, family income must be less than or equal to 130% of the poverty level. To qualify for reduced-price meal, family income must be between 130% and 185% of the poverty level. In 2012 to 2013, this represents a family of four income equal to $29,965 for free meal eligibility and $42,643 for reduced-price meal eligibility (US Department of Agriculture Food and Nutrition Services, 2012). This data was collected from parent/guardian report on official school records.

Eating Habits. The CDC established the Youth Risk Behavior Survey (YRBS) in 1990 to monitor priority health risk behaviors in youth including injuries and violence, sexual behavior, alcohol and other drug use, tobacco use, unhealthy dietary behavior, and inadequate physical activity. This survey is administered to 9th through 12th grade students across the nation every two years. It includes nine questions (questions 72-80) about specific food intake (e.g. fruit consumption) and eating patterns (e.g. breakfast skipping) over the previous seven days (see Appendix R). There are seven response options for each question ranging from not eating/drinking the item over the previous seven days to eating/drinking the item four or more times per day. Responses to questions 72 to 79 were scored as follows A) did not eat/drink the specified item during the past seven days (0), B) one to three times over the past seven days (2), C) four to six times over the past seven days (5), D) one time per day (7), E) two times per day (14), F) three times per day (21), G) four or more times per day (28). An average number of fruit and vegetable servings per day was calculated by adding the responses to questions 73 to 77 and dividing by seven. Questions regarding fruit juice consumption (question 72), soft drink consumption (question 78), and milk consumption (question 79) were analyzed separately. Responses to question 80 (breakfast consumption) ranged from 0 days (0) to 7 days. This question was analyzed separately.

Importantly, results from the YRBS are used to monitor progress towards national health goals, assess trends in risky behavior, and evaluate the impact of broad school and community interventions (Centers for Disease Control and Prevention, 2013). Therefore, the data collected are presented with nationwide and statewide data for these specific questions in Appendix S (Centers for Disease Control and Prevention, 2013).

Physical Activity. The YRBS includes six questions about physical activity (questions 81 – 86). Two questions related to physical activity (questions 81 and 86) and two questions related to sedentary activity (questions 83 and 84) were included in this study (see Appendix R). The State of NJ Department of Education requires physical education class in 9th through 12th grades; therefore question 85 was excluded.

Responses to physical activity (e.g. "…activity that increases your heart rate and made breathe hard…") ranged from zero days to seven days over the previous seven days (question 81). Responses to sports team participation over the previous 12 months ranged from zero teams to three or more teams. Responses to sedentary activity on an average school day (TV viewing, video/computer game use) ranged from zero to five or more hours per day. The data collected are presented with nationwide and statewide data for these specific questions in Appendix S (Centers for Disease Control and Prevention, 2013).

Puberty. The Pubertal Self Rating Scale is a five to six item scale that was developed for use in a classroom setting (M. A. Carskadon & Acebo, 1993). Participants self-reported on items related to secondary sexual characteristics such as growth, body hair, and skin changes. Male participants were also asked about voice changes and facial hair (see Appendix T). Female participants were asked about breast development and menstruation onset (see Appendix U). Response were scored as follows: “not yet started” (1 point), “barely started” (2 points), “definitely started” (3 points), “seems complete” (4 points), “yes” for menstruation (4 points), “no” for menstruation (1 point), “seems complete” (4 points). For females, menstruation is coded as “yes” (4 points) or “no” (1point). “I don’t know” is also a response option that is coded as missing. Responses were coded into one of five puberty categories. See Table 4: Pubertal Self Rating Scale Scoring Criteria. Despite minimal evidence of reliability, interest in the Pubertal Self Rating Scale for use in school settings has emerged due to resistance by some districts to use the Sexual Maturation Scale and the significantly greater missing data found with Sexual Maturation Scale (4% for the Pubertal Self Rating Scale, 13% for the Sexual Maturation Scale, $p < 0.001$) (Bond et al., 2006). The investigator added one question to the female pubertal self-rating scale about the first day of the participant’s last menstrual period because the influence of the menstrual cycle on sleeps patterns in adolescents has not been determined.

Table 4

Pubertal Self-Rating Scale Scoring Criteria

Males	
Pre-puberty	3
Early puberty	4 - 5 and no 3 point responses
Mid-puberty	6 – 8 and no 4 point responses
Late puberty	9 - 11
Post-puberty	12
Females	
Pre-puberty	3
Early puberty	3 and no menarche
Mid-puberty	4 and no menarche
Late puberty	≤ 7 and menarche
Post-puberty	8 and menarche

Data Collection

Prior to data collection, approval was obtained from the Institutional Review Board at the University of Pennsylvania. Information about the study was presented and recruitment of participants took place during the academic school year (September – June) in compulsory health and/or physical education classes, back to school nights, and prior to swimming and wresting team practices as approved by the administration at the school district. Informed consent and student assent was required prior to participation. Participants were compensated with a five-dollar gift certificate. Data collection took place during the academic school year (October – May) excluding school breaks, standardized testing periods, and the week following the transition to daylight savings time. For Phase I, one or two typical class periods (45 min.) were ample time for participants to complete the necessary questionnaires and for the researcher to obtain the necessary anthropometric measurements. See Table 5: Summary of Data Collection

Methods and Participant Time Required. If needed, accommodations were made on an individual basis. At a time convenient for the participant and with minimal disruption to their academic schedule, he/she reported to the school health office to complete questionnaires and for height, weight, and waist measurements. The investigator completed these measurements in a private examination room. Race/ethnicity and poverty status were collected from official school administrative records (see Figure 2: Data Collection).

Table 5

Summary of Data Collection Methods and Participant Time Required

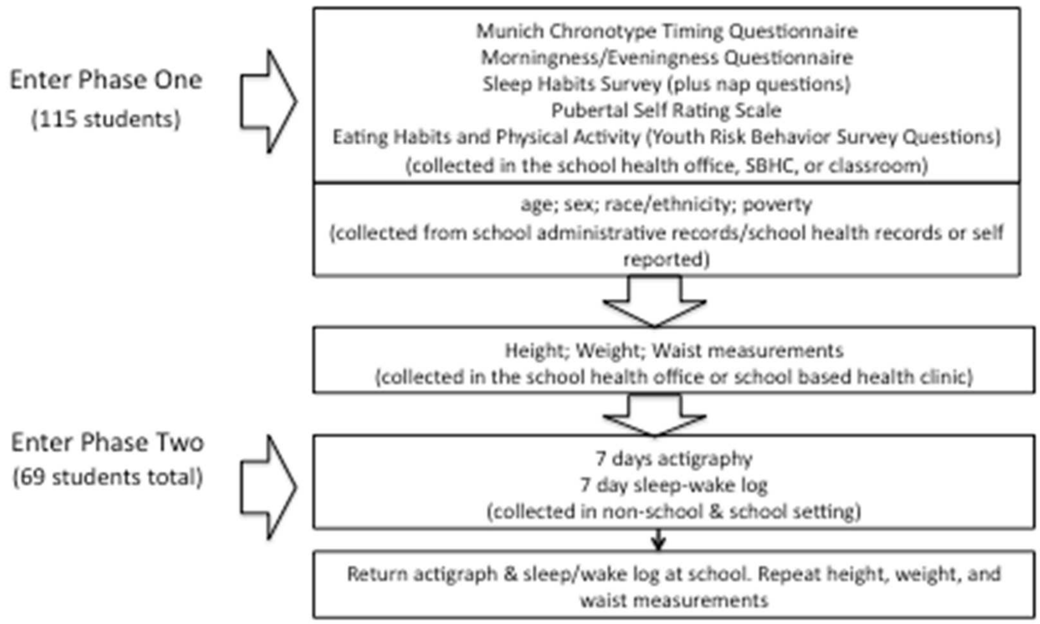
Variable	Measurement Method	Type of Variable	Participant Time Required
BMI WHtR WC	• Height • Weight • WC	Continuous (ratio) Continuous (ratio)	5 minutes 5 minutes
Sleep Duration	Phase I • Sleep Habits Survey Phase II • Actigraphy	Continuous (ordinal) Continuous (interval)	5 minutes
Daytime Naps	Phase I • Sleep Habits Survey Phase II • Actigraphy	Categorical (dichotomous)	
Chronotype	Phase I • Munich Chronotype Timing Questionnaire (midpoint of sleep) • Morningness/Eveningness Questionniare Phase II • Actigraphy (midpoint of sleep)	Continuous (interval) Continuous (ordinal) Continuous (interval)	10 minutes 10 minutes
Social jet lag	Phase I • Munich Chronotype Timing Questionnaire (midpoint of sleep) Phase II • Actigraphy (midpoint of sleep)	Continuous (interval) Continuous (interval)	
Age	• Official school records	Continuous (interval)	
Sex	• self-reported	Categorical (dichotomous)	
Race/ethnicity	• Official school health records	Categorical (nominal)	
Eating habits	• YRBS questions 73 – 77 • YRBS questions, 72, 78, 79, 80	Continuous (ratio)	5 minutes

Variable	Measurement Method	Type of Variable	Participant Time Required
Physical activity	• YRBS questions 81, 83, 84, 86	Continuous (ratio)	5 minutes
Puberty	• Pubertal Self Rating Scale	Categorical (ordinal)	5 minutes
Poverty	• Official school records	Categorical (dichotomous)	
Total Testing Time for Phase I			**50 minutes**
Total Testing Time for Phase II			**7 days**

For Phase II, eligible participants and their parent/guardian were re-contacted for informed consent and assent. The investigator screened participants willing to participate in a private location in the school health office during the school day at a time convenient for the student and least disruptive to their academic schedule. If eligible, the investigator provided verbal and written instruction to the participants on actigraphy use and sleep diary documentation. For the following seven consecutive days, the investigator called the participants at a prearranged time to remind them to replace the wrist actigraph if it had been removed. To encourage recruitment and retention, participants were compensated for their time. On day seven, participants received a fifteen-dollar gift certificate when they returned the actigraph and the sleep diary to the investigator during the school day. Participants' enrollment in Phase II was seven days. See Figure 2: Data Collection.

Figure 2

Data Collection



Data Analysis

Prior to analysis, all data were entered into RedCap from paper and pencil records. All hard copies were compared to the data in RedCap to check for accurate data entry. Data were checked for normality using the Kolomogorov-Smirnov and Shapiro-Wilk tests and met the statistical test assumptions for normality and linearity (Allison, 1999; Woodward, 2005; Wooldridge, 2009). Where Levene's tests were significant for heterskedasticity, inferential statistics where equal variances were not assumed are reported. Missing values for items on the Pubertal Self-rating Scale were replaced by the mean calculated from the non-missing items at the individual level. One student with an implausible midpoint of sleep value (3 pm) was excluded from Phase I. Although multicollinearity does not violate linear regression test assumptions, it does make it difficult to estimate reliable coefficients of the affected variables (Allison, 1999). Multicollinearity was diagnosed if the index of tolerance was less than 0.40 and/or the variance inflation factor is greater than 2.50 (Allison, 1999). In these instances, separate general linear models were analyzed.

The reliabilities of the study instruments were assessed. The average technical error of measurements for height, weight and WC for Phase I were 0.13 cm, 0.12 kg, and 0.55 cm respectively. The average technical error of measurements for height, weight and WC for Phase II were 0.15 cm, 0.03 kg, and 0.47 cm respectively. The Cronbach's alpha for the Pubertal Self-rating Scale was 0.33 for females and 0.60 for males. The Cronbach's Alpha for the M/E Q was 0.60.

The descriptive data for all normally distributed continuous variables are reported as means and standard deviations. For non-normally distributed continuous variables, medians and interquartile ranges are reported (D. Moore & McCabe, 2003). The descriptive data for categorical variables are reported as frequencies and percentages.

Aim 1) To describe sleep duration and chronotype in 9th and 10th grade students and examine whether variations in sleep duration and chronotype exist by race/ethnicity, sex, and /or pubertal stage.

The sample size and power calculation for this aim relied on the estimated width of confidence intervals for parameter estimates of interest in this aim (sex, puberty, race/ethnicity). The true population parameter will fall within this interval and is adequately powered for descriptive purposes. Sleep duration and chronotype were estimated in various sex, puberty, and race/ethnicity categories with a total sample size of

115 students. Sleep duration and chronotype (midpoint of sleep) were measured on a continuum.

Sleep duration & sex: A sample size of 53 males produces a two-sided 95% confidence interval for sleep duration with a distance from the means to the limits that is equal to 0.19 when the estimated standard deviation is 0.70 (Iglowstein et al., 2003). A sample size of 47 females produces a two-sided 95% confidence interval for sleep duration with a distance from the mean to the limits that is equal to 0.21 when the estimated standard deviation in 0.700 (Iglowstein et al., 2003).

Sleep duration & puberty: A sample size of 28 mid-pubertal males (Bond et al., 2006) produces a two-sided 95% confidence interval for sleep duration with a distance from the mean to the limits that is equal to 0.27 when the estimated standard deviation is 0.70 (Iglowstein et al., 2003). A sample size of 25 late pubertal males (Bond et al., 2006) produces a two-sided 95% confidence interval for sleep duration with a distance from the mean to the limits that is equal to 0.30 when the estimated standard deviation is 0.70 (Iglowstein et al., 2003). A sample size of 40 late pubertal females (Bond et al., 2006) produces a two-sided 95% confidence interval for sleep duration with a distance from the means to the limits that is equal to 0.22 when the estimated standard deviation is 0.70 (Iglowstein et al., 2003). Confidence intervals for the post pubertal females are not presented due to a sample size of less than seven (Bond et al., 2006).

Sleep duration & race/ethnicity: A sample size of 31 students (for separate analyses of White and Black students) produces a two-sided 95% confidence interval for sleep duration with a distance from the mean to the limits that is equal to 0.26 when the estimated standard deviation is 0.70 (Iglowstein et al., 2003). A sample size of 37

Hispanic students produces a two-sided 95% confidence interval for sleep duration with a distance from the mean to the limits that is equal to 0.23 when the estimated standard deviation is 0.70 (Iglowstein et al., 2003).

Chronotype & sex: A sample size of 53 males produces a two-sided 95% confidence interval for midpoint of sleep with a distance from the means to the limits that is equal to 0.35 when the estimated standard deviation is 1.28 (Wittmann et al., 2006). A sample size of 47 females produces a two-sided 95% confidence interval for midpoint of sleep with a distance from the mean to the limits that is equal to 0.38 when the estimated standard deviation is 1.28 (Wittmann et al., 2006).

Chronotype & puberty: A sample size of 28 mid-pubertal males (Bond et al., 2006) produces a two-sided 95% confidence interval for midpoint of sleep with a distance from the mean to the limits that is equal to 0.50 when the estimated standard deviation is 1.28 (Wittmann et al., 2006). A sample size of 25 late-pubertal males (Bond et al., 2006) produces a two-sided 95% confidence interval for midpoint of sleep with a distance from the mean to the limits that is equal to 0.53 when the estimated standard deviation is 1.28. (Wittmann et al., 2006). A sample size of late-pubertal 40 females (Bond et al., 2006) produces a two-sided 95% confidence interval for midpoint of sleep with a distance from the mean to the limits that is equal to 0.41 when the estimated standard deviation is 1.28 (Wittmann et al., 2006). Confidence intervals for the post pubertal females are not presented due to a sample size of less than seven (Bond et al., 2006).

Chronotype & race/ethnicity: A sample size of 31 students (for separate analyses of White and Black students) produces a two-sided 95% confidence interval for midpoint of sleep with a distance from the mean to the limits that is equal to 0.47 when the estimated standard deviation is 1.28 (Wittmann et al., 2006). A sample size of 37 Hispanic students produces a two-sided 95% confidence interval for midpoint of sleep with a distance from the mean to the limits that is equal to 0.43 when the estimated standard deviation is 1.28 (Wittmann et al., 2006).

Bivariate analyses for each independent variable and each dependent variable of sleep duration (school night, free night, total night) and chronotype (M/E Q, midpoint of sleep) were tested with the appropriate statistical method. T-tests, Analysis of Variance tests, Pearson's Correlations, and Spearman's Rank Correlations (Woodward, 2005). Statistical significance was set at the alpha level of 0.05 based on the two-tailed test. See Appendix AA.

Next, general linear models were used to build more formal multivariable models to examine independent predictors of school night sleep duration, free night sleep duration, total night sleep duration, the morningness/eveningness questionnaire and the midpoint of sleep (computed from the MCTQ for Phase I and actigraphy data for Phase II). Only variables significant at alpha level of 0.2 from the univariate analysis were included in the final adjusted models. Statistical significance was set at an alpha level of 0.05 based on the two-tailed test.

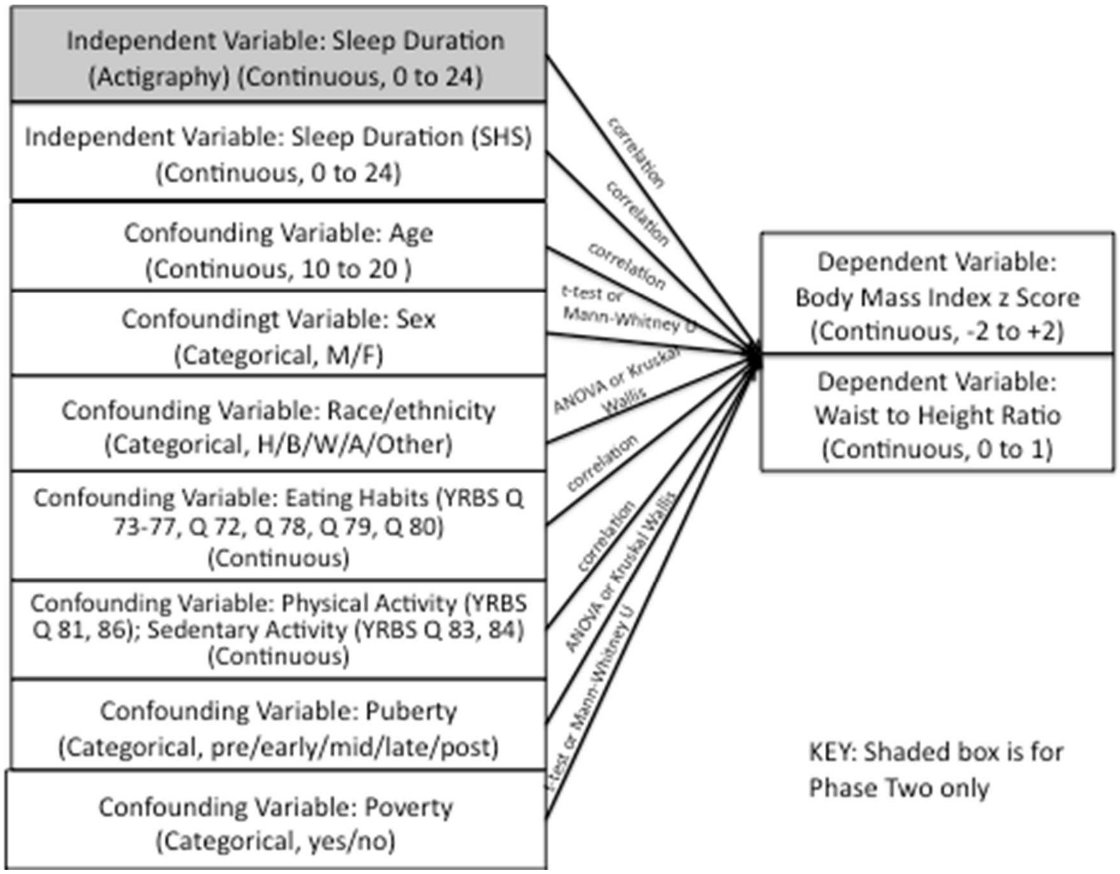
Aim 2) To determine if there is a relationship between sleep duration and BMI z scores in 9th and 10th grade students.

The sample size and power calculation for this aim relied on the estimated width of confidence intervals for the parameter of interest in this aim, sleep duration. A sample size of 100 produces a two-sided confidence interval with a distance from the sample slope to the limits that is equal to 0.29 when the sample slope is 0.09 (Lytle et al., 2011), the standard deviation of the X's is 0.70 (Iglowstein et al., 2003), the standard deviation of the Y's is 1.00 (based on a standardized z score), and the standard deviation of the residuals is 1.00. A sensitivity analysis with sample slopes of 0.2 and 0.5 were estimated and the distance from the sample slope to the limits ranged from 0.28 to 0.27 respectively.

Bivariate data analyses for each independent variable and each dependent variable, BMI and WHtR are described in Figure 3: Aim Two: Bivariate Data Analysis Outline for Sleep Duration, BMI, and WHtR. Pearson's correlations were used for normally distributed variables. Spearman's Rank correlations were used for variables with non-normal distributions (e.g. eating habits and physical activity variables). Additional bivariate analyses between daytime sleep and the dependent variables, BMI and WHtR, were completed for Phase I and Phase II using t-tests. Statistical significance was set at an alpha level of 0.05 based on the two-tailed test. See Appendix BB.

Figure 3

Aim Two: Bivariate Data Analysis Outline for Sleep Duration, BMI, and WHtR



Next, general linear models were used to build more formal multivariable models to examine independent predictors of BMI z scores and WHtR. Only variables significant at alpha level of 0.2 from the univariate analysis were included in the final adjusted models. Statistical significance was set at an alpha level of 0.05 based on the two-tailed test. Age, sex, puberty, race/ethnicity, eating habits, physical activity, and poverty were included as confounding variables because of their reported association with BMI, sleep duration, and/or chronotype (Marco et al., 2011; Stamatakis et al., 2007). The parameter estimate of interest in the GLM was sleep duration.

Aim 3) To determine if chronotype modifies the relationship between sleep duration

and BMI z scores in 9th and 10th grade students.

The examination of effect modification can be viewed in terms of power estimations for parameter estimates within the three chronotype categories (as calculated by PASS). Given the sample size of 115, it was estimated that approximately 20 participants had earlier chronotypes, approximately 20 participants had later chronotypes, and approximately 60 participants had intermediate chronotypes (Adan, Lachica, Caci, & Natale, 2010; BaHammam, Almistehi, Albatli, & AlShaya, 2011). A sample size of 20 produces a two-sided 95% confidence interval with a distance from the sample slope to the limits that is equal to 0.71 when the sample slope is 0.09 (Lytle et al., 2011), the standard deviation of the X's is 0.70 (Iglowstein et al., 2003) the standard deviation of the Y's is 1.00 (based on a standardized z score), and the standard deviation of the residuals is 1.03. A sensitivity analysis with sample slopes of 0.2 and 0.5 was estimated and the distance from the sample slope to the limits ranged from 0.70 (standard deviation of the residuals equal to 1.02) to 0.66 (standard deviation of the residuals equal to 0.96) respectively. A sample size of 80 produces a two-sided 95% confidence interval with a distance from the sample slope to the limits that is equal to 0.32 when the sample slope is 0.00, the standard deviation of the X's is 0.70 (Iglowstein et al., 2003) the standard deviation of the Y's is 1.00 (based on a standardized z score), and the standard deviation of the residuals is 1.01. A sensitivity analysis with sample slopes of 0.2 and 0.5 was estimated and the distance from the sample slope to the limits ranged from 0.32 (standard deviation of the residuals equal to 1.00) to 0.30 (standard deviation of the residuals equal to 0.94) respectively.

Bivariate analyses for each independent variable (M/E Q, midpoint of sleep, social jet lag) and the dependent variable (BMI z scores) were tested using Pearson's Correlations. Statistical significance was set at the alpha level of 0.05 based on the two-tailed test. See Appendix CC.

Next, general linear models were used to build more formal multivariable models to examine independent predictors of BMI z scores and WHtR. Only variables significant at alpha level of 0.2 from the univariate analysis were included in the final adjusted models. Statistical significance was set at an alpha level of 0.05 based on the two-tailed test. Age, sex, puberty, race/ethnicity, eating habits, physical activity, and poverty were included as confounding variables because of their reported association with BMI, sleep duration, and/or chronotype (Marco et al., 2011; Stamatakis et al., 2007).

To statistically test the hypothesis that chronotype or social jet lag would moderate the relationship between sleep duration and BMI z scores, interaction terms were computed. In Phase II, collinearity existed between the independent variables, (actigraphy-estimated chronotype and actigraphy estimated social jet lag) and the dependent variables (actigraphy-estimated sleep duration parameters). Therefore, only chronotype, estimated from the M/E Q was considered in the modeling. The significant threshold for the interaction terms was set at the alpha level of 0.05 based on the two-tailed test. Age, sex, puberty, race/ethnicity, eating habits, physical activity, and poverty were included as confounding variables because of their reported association with BMI, sleep duration, and/or chronotype (Marco et al., 2011; Stamatakis et al., 2007).

To further examine chronotype as an effect modifier between sleep duration and BMI, separate general linear models for participants whose midpoint of sleep computed from the MCTQ was less than or equal to the 20th percentile ($\leq$ 2:42: earlier chronotype) and greater than or equal to the 80th percentile (> 5:06: later chronotype) based on the MCTQ were generated. The small sample of early and late chronotypes in Phase II (*n* = 15 each) precluded stratifying this sample for further analyses. The primary interest in this modeling was to estimate and compare the parameter estimates for sleep duration across earlier and later chronotypes.

Aim 4) to assess the concurrent validity of the Morningness Eveningness Questionnaire, the Munich Chronotype Timing Questionnaire, and actigraphy measurements for estimating chronotype in 9th and 10th grade students.

To estimate the association between the MCTQ and the M/EQ scale, Pearson's product correlation coefficients *(r)* were calculated. A non-parametric Spearman's Rank correlation coefficient was also computed to confirm results obtained from the Pearson's correlation (Woodward, 2005). Furthermore, a Bland-Altman plot was generated to assess the agreement between the midpoints of sleep computed from the MCTQ and from actigraphy-estimated sleep parameters (Bland & Altman, 1986, 1995, 2012). For the Bland-Altman plot, the x-axis represents the average of the midpoints of sleep computed from the MCTQ and actigraphy data [(midpoint of sleep from MCTQ) + (midpoint of sleep from actigraphy)] / 2: the y-axis represents the difference between these two values. The limits of agreement were calculated as two standard deviations from the mean difference (estimated bias). An a priori level of agreement for less than 30 minutes was determined an acceptable level of agreement for using these two measures interchangeably (Werner, Lebourgeois, Geiger, & Jenni, 2009).

Data Management

The principal investigator was responsible for data management. Each participant was given a unique identification number (e.g. 001, 002). Information linking the identification number to the participant was stored separately from the data. Data was entered into RedCap from paper and pencil records by the investigator. Data is backed up on a secure site on the University of Pennsylvania School of Nursing's server. This server is protected by a firewall. Nightly and weekly back ups are stored at a secure off-site location.

Data analysis was completed on the School of Nursing network drive. Files were only shared with the investigator's dissertation committee as needed for consultation through the School of Nursing network drive. All data has been used for research purposed only.

Human Subjects Consideration and Protection

This cross-sectional observational study had two phases. During Phase I, participants were recruited from the general population of ninth and tenth grades at Long Branch High School. All Phase I participants were re-contacted and invited to participate in Phase II. Recruited participants were screened for eligibility. Eligible participants were enrolled in Phase II, which involved a more detailed analysis of sleep-wake patterns. Separate parent/guardian consent forms and student assent forms were completed prior to participation in Phase I and Phase II. The University of Pennsylvania Institutional Review Board approved all informed consent and assent forms prior to use.

Recruitment and Consent Procedures

Recruitment took place in the school setting by the investigator. Recruitment for Phase I and Phase II included informed parental consent (Parent/Guardian Informed Consent: Phase I) (see Appendix V) and student assent (Student Assent: Phase I) (see

Appendix W). On the Parent/Guardian Informed Consent: Phase I form and the Student Assent: Phase I form, parents/guardians and students indicated whether or not they would be willing to be contacted for participation in Phase II of the study. Students who indicated that they would not be willing to be re-contacted in Phase Two were not contacted after Phase I was completed. An additional consenting/assenting process was used to recruit participants for Phase II. This included active informed parental consent (Parent/Guardian Informed Consent: Phase II) (see Appendix X) and student assent (Student Assent: Phase II) (see Appendix Y).

Phase I and Phase II were minimal risk studies, therefore, consent of one parent was sufficient (DHHS: CFR 45 vol 46 subpart D). Below is a list of steps that the applicant may have taken to address any concerns regarding recruitment and retention of participants. The University of Pennsylvania Institutional Review Board approved all verbal and written communications for this study.

Administration and Faculty

The school administration may participate in outreach efforts by making school announcements, permitting notices to be placed around the school, and including parent/guardian informed consent forms in mailings sent home (via email or postal services). To facilitate this support, the investigator will:

- Seek approval to present the study to faculty throughout the school year as needed during Professional Development Days. This presentation will explain the study, its risks and benefits, and answer any questions. Information will also be provided in writing.

- Seek approval to present the study to parents/guardians throughout the school year as needed during Back to School Nights, Parent –Teacher Association (PTA) meetings, and/or parent-teacher conferences. These formal and/or informal presentations will explain the study, its risks and benefits and answer any questions. Information will also be provided in writing.
- Seek permission to contact health teachers, physical education teachers, school nurses, and SBHC staff to identify champions for the study within the school.
- At the beginning of each academic quarter, seek teacher permission to present the study to students during health class, physical education and/or study hall classes. Specific guidelines for when and where students are to return forms will be communicated with the teacher.

Parents/Guardians: Phase I

Informed parent/guardian consent for Phase I will be obtained by sending written information about the study and the Parent/Guardian Informed Consent: Phase One home after PTA, back-to school-night presentations, during parent/teacher conferences, via postal mail or email, and through students when the study is presented in health, physical education and/or study hall. All parent/guardian written materials will be in English and Spanish at a 6th to 8th grade reading level. A parent means a child's biological or adoptive parent. A guardian means an individual who is authorized under applicable state or local law to consent on behalf of the child to general medical care (DHHS: CFR 45 vol 46 subpart D). This was a minimal risk study, therefore, consent of one parent was sufficient (DHHS: CFR 45 vol 46 subpart D). Student assent was also necessary (see below). To facilitate the informed parent/guardian consent process, the investigator:

- Provided written instruction on how to return the forms
- See Appendix Z for protocol on how to resolve dissent between parents/guardians and students

Students: Phase I

To facilitate the student assent process, the investigator:

- Presented the study to students during health classes, physical education classes, and study halls. This presentation included the following:
    - an explanation of the study.
    - the risks and benefits of the study.
    - efforts taken to minimize potential risks.
    - answers to any student/teacher questions.
    - distribution of Parental/Guardian Informed Consent: Phase One and Student Assent forms: Phase One.
    - directions on how to return informed consent and assent forms.
- Maintained frequent contact with classrooms teachers during the assent period to collect forms.
- See Appendix Z for protocol on how to resolve dissent between parents/guardians and students.

Parents/guardians: Phase II

Parents/guardians informed consent was required for participation in Phase II. To facilitate the parent/guardian informed consent process, the investigator sent a reminder notice to parents/guardians of their child's eligibility for participation in Phase II. The purpose of the study, eligibility criteria, risks/benefits, and directions on how to opt out at any time were explained (See Appendix X). To facilitate the informed parent/guardian consent process, the investigator:

- Sent Parent/guardian Informed Consent: Phase Two home with students
- Contacted parents/guardians via email, phone calls, and/or face-to-face at times throughout the school year when parents are expected to be present (e.g. parent/teacher conferences, PTA meetings). The purpose of the study, eligibility criteria, risks/benefits, and directions on how to opt out at any time were explained. Parent/Guardian Informed Consent: Phase Two forms were distributed at that time.
- Provided written information about the study in English and Spanish at a 6th- 8th grade reading level.
- See protocol on resolving parent/guardian and student participation disagreements (see Appendix Z).

Students Assent: Phase II

Student assent, in addition to Parent/Guardian Informed Consent, was required for participation in Phase II. Parental/Guardian Informed Consent: Phase One or Student Assent: Phase One requests not to be re-contacted were respected. To facilitate the student assent process participation in Phase II, the investigator:

- Explained the study to eligible participants, including its risks and benefits, efforts taken to minimize potential risks, and answer questions. Parent/Guardian Informed Consent: Phase Two and Student Assent: Phase Two were provided along with directions on how to return these forms.

Potential participants with informed parent/guardian consent and student assent indicating willingness to participate were screened for eligibility in the privacy of the school health office. Due to the availability of actigraphs, there was a lag before between assent/consent time and study enrollment. Consequently, after being screened for eligibility, participants were verbally reminded of the study, its risks and benefits, as well as their ability to withdraw at any time without penalty. Written information was also provided and included counseling and support contact information.

Retention

Phase I was completed during one or two classes during the school day. To encourage recruitment, all participants who completed Phase I were compensated with a five-dollar gift certificate. Phase II was completed on the seventh day of continuous actigraphy wear time. Daily phone calls at a pre-arranged time were made by the investigator to reinforce adherence to the protocol during that 7-day period. Participants returned their actigraph and their sleep log to the investigator 7 days later during school hours. On the seventh day, participants received a fifteen-dollar gift certificate for compensation.

Potential risks and Adequacy of Protection against Risks

While there was no risk for physical harm in this study, potential risks were related to participant burden, embarrassment, social harm, and/or breaches in confidentiality. Participant burden may have been associated with the completion of questionnaires and the loss of time from health class, physical education, and/or study hall or with wearing the wrist actigraph. Embarrassment and/or social harm may have been caused by questions in the self-administered questionnaires and/or height, weight, and/or waist circumference measurements. Nonetheless, height and weight measures are required annually of all NJ students unless a parent/guardian requests that these measurements not be taken. Also, participants may have perceived the school health/SBHC visits an escape from the normal routine school day.

Measures to protect against risk were taken at the applicant and participant level. The facilities at Long Branch High School consist of a school health office staffed by a school nurse certified by the State of NJ Department of Education. The school health office has one private examination room. Additionally, the School Based Health Clinic (SBHC) is located within the Long Branch High School building. This clinic is staffed by one full time nurse practitioner and one part time nurse practitioner. The clinic has two private examination rooms and a small conference room. The school health office protects all student information in accordance with FERPA. The SBHC protects all student information in accordance with HIPPA.

Applicant

Through her clinical experience and coursework, the investigator has knowledge of and sensitivity to the social, emotional, and psychological issues related to overweight and obesity. Nonetheless, she will seek assistance with members of her dissertation committee as need arises. All anthropometric measurements took place in a private exam room in the school health office or SBHC. If it was noted that the participant was distressed during the anthropometric measurements, while completing the questionnaires, or by following the sleep/activity measurement protocol, the investigator stopped and contacted the school nurse, the nurse practitioner at the SBHC, the school nurse supervisor, or the school counselors in order to gain assistance in assessing the participant. If the participant was overly burdened by the questionnaires, the questionnaires were able to be completed at a later date to accommodate the participant's individual needs and schedule. See also data management plan for steps taken to protect the confidentiality of the data collected.

Participants

In order to protect against risks involved in this study, participants were given information on mental health and counseling resources at the study onset and as needed throughout their enrollment in the study. Additionally, participation in this study was voluntary and participants had the right to withdraw at any time without penalty.

Potential Benefits of the Proposed Research to Human Subjects and Others

It is possible that while these results may benefit families in the future, participants in this study will not realize immediate or direct benefit from participating. While some may find participation in the study stressful, the degree of stress is likely to be minimal. Indirect benefits may have resulted from an increased awareness of their own sleep habits and an escape from the normal routine school day when questionnaires were administered and anthropometric measurements obtained. Additionally, adolescents from diverse socio-economic backgrounds view their participation in non-beneficial research as a type of charitable activity and appreciate the opportunity to contribute to a project that may help others.

Importance of Knowledge to be Gained

This data will provide researchers with a more complete understanding of the association between sleep duration, chronotype, and BMI. It will identify whether or not certain chronotypes are more susceptible to the deleterious metabolic effects of short sleep. From this, screening guidelines to identify chronotypes at greatest risk may be developed along with chronotype specific weight management preventative/treatment interventions. Urban planning policies regarding light at night exposure and school policies regarding start times and evening/night athletic events may also be developed to prevent a shift towards even later chronotypes during this developmental period.

Limitations

1. The school, located in a coastal city of NJ, and the sample of students recruited from this school are a convenience sample. Drawing this sample from a single school, city, and state may limit the generalizability of these findings to other populations.
2. All efforts will be made to recruit a sample representative of the school district. However, recruitment of students from minority backgrounds is a challenge for many researchers (Esbensen, Miller, Taylor, He, & Freng, 1999; Tigges, 2003).
3. As a cross-sectional study, the direction of the relationships between sleep, chronotypes, and body composition will not be determined (Rosenbaum, 2010).
4. Some variables that could impact body composition that will not analyzed in this study. These variables may include: eating habits, physical activity, catch-up growth in students born small for gestational age, and seasonal fluctuations in BMI.
5. Many variables outside the control of the researcher could contribute to variations in chronotype. These variables may include the season that sleep measurements were recorded, the lag time between the initial analysis of self-reported sleep measurements and the analysis of the actigraphy data, season of birth.

6. Variables such as race/ethnicity and sex will be obtained from parent/guardian reports on school records that are limited to socially constructed categories.
7. As a complex, multifaceted condition, obesity is influenced by the slow, gradual impact of factors over time. More advanced statistical analysis may be required to analyze this constellation of interrelated variables (Auchincloss & Diez Roux, 2008).

Assumptions

This study included the following assumptions:

1. The participants responded to the surveys accurately and indicated their preferences for morning or evening activities, their most representative sleep and wake times on school days and non-school days; sleep duration; and questions about pubertal changes.
2. The participants understood the vocabulary associated with the surveys for morning / evening preferences, sleep-wake timing, sleep duration, and pubertal development.
3. The selected participants for more detailed sleep-wake measurements were the participants who actually wore the actigraphs and kept accurate sleep-wake timing records (e.g. they weren't given to another student or family member for use).
4. The weeks selected for actigraphy and sleep-wake record measurement and were representative of the participant's typical sleep-wake times during the academic school year.
5. The data collected measured the participant's sleep duration, sleep-wake timing, sleep duration, pubertal category, BMI, and WHtR.

6. The interpretation of the data accurately reflected preferences for morning or evening activities, sleep-wake times on school days and non-school days, sleep duration, pubertal changes, fat mass, and body fat distribution.

Summary

This chapter restated the specific aims of this research. The reliability and the validity of the instruments that were used to collect data were presented. The data collection, data analyses for each specific aim, and data management plan were discussed. Lastly, consideration for the protection of human subjects was presented.

CHAPTER 4: RESULTS

The aim of this study was to examine sleep duration and chronotype, to explore associations between sleep duration and BMI, and to examine whether chronotype moderated this association in ninth and tenth grade students. Sleep duration and chronotype were assessed using validated surveys in Phase I and using seven days of actigraphy data in Phase II. Correlations and levels of agreement between self-reported and actigraphy-estimated chronotype data were also determined. The characteristics of the participants are presented first. Findings from the unadjusted and adjusted general linear models for each dependent variable follow.

Participant Characteristics

Socio-demographic Characteristics

Phase I. Participants were recruited from 9^{th} and 10^{th} grades of a comprehensive high school in New Jersey as described in Chapter 3. Parent/guardian consent and student assent was received from approximately 21% of the 9^{th} and 10^{th} grade class (N=116). One student with an implausible midpoint of sleep value (3 pm) was excluded leaving a total sample of 115. Participants were racially/ethnically diverse (37% Hispanic, 30% White, 28% Black), free/reduced lunch participants (65%), and mostly female (70%) with a mean age of 15.2 (range 13.4 – 16.8).

Phase II. Parent/guardian consent and student assent was received from approximately 60% of Phase I participants (N = 70). One student with the diagnosis of Type 2 diabetes was excluded leaving a total sample of 69.

There were no statistically significant differences in socio-demographic characteristics between individuals who participated in Phase I only, compared to individuals who participated in Phases I and II. See Table 6.

Table 6

Demographic Characteristics

Characteristic	Overall sample (N = 115) n (%) or *M (SD)*	Phase I (N = 46) n (%) or *M (SD)*	Phase I and II (N = 69) n (%) or *M (SD)*	*p*
Age^	15.41 (0.70)	15.27 (0.76)	15.50 (0.65)	0.095
Sex (male)	35 (30.43)	17 (36.96)	18 (26.09)	0.217
Race/ethnicity				
Hispanic	43 (37.39)	18 (39.13)	25 (36.23)	0.091
White	35 (30.43)	9 (19.57)	26 (37.68)	
Black	33 (28.70)	18 (39.13)	15 (21.74)	
Asian	4 (3.48)	1 (2.17)	3 (4.35)	
Free/reduced lunch (yes)	75 (65.22)	31 (67.39)	44 (63.77)	0.689

Note. *M* = mean. *SD* = standard deviation. ^ *M (SD).*

Physical Characteristics

Phase I. Nineteen percent of the study participants were overweight and 18% were obese. Abdominal obesity among male and female participants was 37% and 45%, respectively. Most male participants were mid-pubertal (43%) or late- pubertal (50%). Most female participants were post-pubertal (99%).

Phase II. Twenty five percent of the study participants were overweight and 15% were obese. Abdominal obesity among male and females participants was 44% and 57% respectively. Most participants were post pubertal (75%).

There were no statistically significant differences in physical characteristics between individuals who participated in Phase I only, compared to individuals who participated in Phases I and II. See Table 7.

Table 7

Physical Characteristics

Characteristic	Overall Sample n (%) or *M (SD)*	Overall Sample range	Phase I n (%) or *M (SD)*	Phase I and II n (%) or *M (SD)*	*p*
BMI z score^	0.63 (1.04)	-2.44 to 2.69	0.59 (1.20)	0.66 (0.93)	0.719
BMI percentiles^	67.20 (28.39)	0.74 to 99.64	63.28 (32.05)	69.45 (25.66)	0.299
$\geq 85^{th}$	45 (39.13)	-	17 (36.96)	28 (40.58)	0.696
males	18 (51.43)	-	9 (52.94)	9 (50.00)	
females	27 (33.75)	-	8 (27.59)	19 (37.25)	
WHtR^	0.50 (0.08) [a]	0.37 to 0.83	0.50 (0.09)	0.50 (0.06)	0.744
≥ 0.5	53 (46.90)	-	16 (36.36)	37 (53.62)	0.072
males	15 (42.86)	-	7 (41.18)	8 (44.44)	
females	38 (48.72)	-	9 (33.33)	29 (56.86)	
Pubertal category					
mid	16 (13.91)	-	6 (13.04)	10 (14.49)	0.435
late	18 (15.65)	-	11 (23.91)	7 (10.14)	
post	81 (70.43)	-	29 (63.04)	52 (75.36)	

Note. M = mean. *SD* = standard deviation. ^ *M (SD)*. [a] N = 113

Behavioral Characteristics

Sleep. *Phase I.* Sixty two percent of the study participants self-reported insufficient school night sleep (less than eight hours) and only 8% reported optimal school night sleep (greater than or equal to nine hours). In contrast, 68% of participants reported optimal free night sleep. Average total night sleep was approximately eight hours. Mean sleep onsets and offsets were 22:32 and 6:01(school nights), and 00:02 and 9:59 (free nights). Fifty nine percent of the study participants reported daytime naps. For chronotype, the average M/E Q score was 27 and the mean midpoint of sleep time was 3:36. Mean social jet lag was 2.6 hours. See Table 8.

Phase II. Eighty six percent of the study participants had insufficient school night sleep and 48% had insufficient free night sleep. Average total night sleep was approximately seven hours. Mean sleep onsets and offsets were 23:17 and 6:28 (school nights) and 23:55 and 8:20 (free nights). Eleven percent of the study participants napped during the daytime. For chronotype, the mean M/E Q score was 27 and the mean midpoint of sleep time was 3:29. Mean social jet lag was 1.3 hours. See Table 8.

Table 8

Sleep Characteristics

	Phase I (self-report)		Phase II (actigraphy)	
Characteristic	n (%) or *M (SD)*	range	n (%) or *M (SD)*	range
Total night time sleep duration[^, a]	7.91 (1.22)	3.33 - 11.29	7.28 (0.76)	5.30 - 9.00
School Nights [a]				
Sleep duration (hrs)^	7.32 (1.41)	2.50 -12.00	7.07 (0.79)	5.30 - 8.60
< 8.0	71 (62.28)	-	59 (85.50)	-
≥ 8.0 to < 9.0	33 (28.95)	-	10 (14.49)	-
≥ 9.0	10 (8.77)	-	0 (0.00)	-
Sleep onset (hrs:min)^	22:32 (01:12)	20:00 - 3:00	23:17 (1:01)	21:18 - 1:47
Sleep offset (hrs:min)^	6:01 (00:39)	4:00 - 8:15	6:28 (00:42)	4:58 - 8:30
Daytime naps				
yes	51 (44.34)	-	28 (40.58)	-
no	64 (56.14)	-	41 (59.42)	-
Free Nights[a,b]				
Sleep duration (hrs)^	9.38 (2.00)	3.00 - 15.50	8.11 (1.53)	5.00 - 12.00
< 8.0	18 (15.79)	-	33 (48.53)	-
≥ 8.0 to < 9.0	18 (15.79)	-	19 (27.94)	-
≥ 9.0	78 (68.42)	-	16 (23.53)	-
Sleep onset (hrs:min)^	00:02 (1:26)	20:30 - 6:00	23:55 (1:15)	21:08 - 3:27
Sleep offset (hrs:min)^	9:59 (1:45)	5:00 - 16:00	8:20 (1:43)	5:02 - 15:26
Daytime naps				
yes	68 (59.65)	-	8 (11.76)	-
no	47 (41.23)	-	61 (89.71)	-
Chronotype				
Morningness/ Eveningness^	26.55 (2.88)	15 - 35	26.88 (4.24)	18 - 35
Midpoint of sleep ^	3:56 (1:28)	00:25 - 8:45		3:29 (1:11)
Social Jet lag (hrs)^ [a, b]	2.56 (1.42)	0 – 7.42	1.31 (0.91)	0 – 4.00
0 to < 1.0	14 (12.28)	-	16 (23.53)	-
≥ 1.0 to < 2.0	23 (20.18)	-	25 (36.76)	-
≥ 2.0 to < 3.0	33 (28.95)	-	21 (30.88)	-
≥ 3.0 to < 4.0	29 (25.44)	-	4 (5.88)	-
≥ 4.0	16 (14.04)	-	2 (2.94)	-

Note. M = mean. *SD* = standard deviation. ^ *M (SD).* [a] N =114 (Phase I). [b] N = 68 (Phase II).

Eating habits and physical activity. Most participants did not meet the recommended guidelines for milk intake (greater than or equal to three servings per day), fruit/vegetable intake (greater than or equal to four servings per day), physical activity (60 minutes seven days per week), or screen time (less than or equal to two hours per day) (Centers for Disease Control and Prevention, 2012; US Department of Agriculture & US Department of Health and Human Services, 2010). Table 9 reports the percent of study participants' eating and physical activity behaviors as nationally reported from the YRBS survey. Median and interquartile ranges used in Phase I and Phase II analyses are presented in Table 10.

There were no statistically significant differences in eating habits or physical activity between individuals who participated in Phase I only, compared to individuals who participated in Phases I and II. See Table 9 and 10.

Table 9

Eating Habits and Physical Activity

Behavior	Overall Sample n (%)	Phase I n (%)	Phase I and II n (%)	*p*
Did not eat fruit or drink juice on any day^	17 (14.78)	5 (10.87)	12 (17.39)	0.327
Did not eat vegetables on any day^	9 (7.83)	3 (6.52)	6 (8.70)	0.668
Did not drink milk on any day^	64 (55.65)	29 (63.04)	35 (50.72)	0.191
Drank soda $\geq$ once a day^	19 (16.52)	7 (15.22)	12 (17.39)	0.758
Did not eat breakfast on all 7 days^	80 (69.57)	36 (78.26)	44 (63.77)	0.094
Did not participate in 60 minutes of physical activity on any day^	13 (11.30)	7 (15.22)	6 (8.70)	0.284
Watched TV $\geq$ 3 hours /day^^, [a]	35 (30.70)	15 (33.33)	20 (28.99)	0.624
Used computer $\geq$ 3 hours/day^^^	69 (60.00)	26 (56.52)	43 (62.32)	0.535
Played on at least 1 sports team	75 (65.22)	31 (67.39)	44 (63.77)	0.689

Note. ^ during the 7 days preceeding the survey. ^^ on an average school day. ^^^ video or computer time not related to school work on an average school day. [a] N = 114

Table 10

Median and Interquartile Ranges for Eating Habits and Physical Activity

Characteristic	Overall Sample *Median (IQR)*	Phase I *Median (IQR)*	Phase I and II *Median (IQR)*	*p*
Screen time (hours/day)[a]	5.00 (3.00)	5.00 (3.00)	5.00 (3.00)	0.999
Physically active for 60 minutes (days/week)	4.00 (4.00)	4.00 (4.00)	3.00 (4.00)	0.948
Played on a sports team (number/year)	1.00 (2.00)	1.00 (2.00)	1.00 (3.00)	0.750
Breakfast (days/week)	4.00 (5.00)	3.00 (5.00)	4.00 (5.00)	0.207
Servings per day				
fruit/vegetables	1.57 (2.00)	1.57 (2.28)	1.86 (1.71)	0.654
milk	0.29 (1.00)	0.29 (0.71)	0.29 (0.71)	0.180
soda	0.29 (0.71)	0.29 (0.71)	0.29 (0.71)	0.665
juice	0.71 (0.71)	0.29 (0.43)	0.71 (0.71)	0.836

Note. IQR: Interquartile range. [a] N = 114

Aim 1

The primary aim of this study was to describe sleep duration and chronotype in 9th and 10th grade students and to examine whether variations in self-reported (Phase I) or actigraphy-estimated (Phase II) sleep duration and chronotype existed by race/ethnicity, sex, and /or pubertal stage. Unadjusted general linear models were examined first. Variables associated with the dependent variable at the alpha level of 0.2 were selected for the adjusted general linear model as discussed in Chapter 3. School nights and free nights were analyzed separately because most participants reported insufficient sleep on school nights but optimal sleep on free nights.

School Night Sleep Duration: Socio-demographic and Behavioral Characteristics

Phase I. Not participating in the free/reduced lunch program ($F(1, 112) = 1.97$, $p = 0.16$), taking naps on school and free days ($F(1, 112) = 3.83$, $p = 0.05$; ($F(1, 112) = 2.20$, $p = 0.14$), eating fewer fruits/vegetables ($F(1, 112) = 5.06$, $p = 0.03$), drinking more soda ($F(1, 112) = 2.97$, $p = 0.09$), reporting greater screen time ($F(1, 111) = 2.31$, $p = 0.13$), participating in fewer sports ($F(1, 112) = 3.98$, $p = 0.05$), and reporting a later chronotype preference ($F(1, 112) = 6.35$, $p = 0.01$) were associated with shorter school night sleep durations in the unadjusted general linear model. When these variables were included in the adjusted general linear model, none remained predictors of school night sleep duration at the alpha level of 0.05 (See Table 11).

Phase II. Taking naps on school and free days ($F(1, 67) = 5.60$, $p = 0.02$; $F(1, 67) = 5.79$, $p = 0.02$), and reporting a later chronotype preference ($F(1, 67) = 1.71$, $p = 0.20$) were associated with shorter school night sleep durations in the unadjusted general linear model. When these variables were included in the adjusted general linear model, none remained predictors of school night sleep duration at the alpha level of 0.05 (See Table 12).

Table 11

Predictors of School Night Sleep Duration by Demographic Characteristics, Behavioral Characteristics and Chronotype: Phase I (N =115)

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	0.004	-0.03, 0.04	0.803			
Sex (reference: females)	0.33	-0.23, 0.90	0.246			
Race/Ethnicity (reference: Hispanic)			0.416			
Free/reduced lunch (reference: yes)	-0.39	-0.93, 0.16	0.164	-0.49	-1.03, 0.04	0.071
Pubertal category(reference: post)			0.497			
Naps (reference: yes)						
school days	0.51	0.01, 1.03	0.053	0.38	-0.14, 0.90	0.151
free days	0.40	-0.13, 0.93	0.141	0.04	-0.55, 0.62	0.905
Eating Habits						
juice	0.07	-0.21, 0.35	0.633			
fruit/vegetables	0.15	0.02, 0.28	0.026	0.11	-0.02, 0.24	0.107
soda	-0.21	-0.45, 0.03	0.088	-0.12	-0.38, 0.14	0.362
milk	0.02	-0.29, 0.34	0.879			
breakfast	0.02	-0.08, 0.12	0.733			
Physical Activity						
screen time	-0.08	-0.19, 0.03	0.131	-0.03	-0.14, 0.08	0.594
days active	0.04	-0.07, 0.16	0.448			
sports	0.22	-0.01, 0.44	0.049	0.19	-0.04, 0.41	0.099
Chronotype preference (M/E Q)	0.08	0.02, 0.15	0.013	0.05	-0.03, 0.13	0.258
Chronotype (midpoint of sleep)	0.04	-0.14, 0.22	0.682			
Social jet lag	0.03	-0.16, 0.22	0.764			

Note. CI = confidence intervals.

Table 12

Predictors of School Night Sleep Duration by Demographic Characteristics, Behavioral Characteristics and Chronotype: Phase II (N = 69)

Parameter	Unadjusted Model			Adjusted Model		
	b	95% CI	*p*	*b*	95% CI	*p*
Age	-0.004	-0.03, 0.02	0.761			
Sex (reference: females)	-0.01	-0.44, 0.43	0.982			
Race/Ethnicity (reference: Hispanic)			0.350			
Free/reduced lunch (reference: yes)	0.03	-0.37, 0.43	0.892			
Pubertal category (reference: post)			0.731			
Naps (reference: yes)						
school days	0.45	0.07, 0.82	0.021	0.28	-0.13, 0.70	0.176
free days	0.69	0.12, 1.27	0.019	0.53	-0.08, 1.14	0.089
Eating Habits						
juice	-0.05	-0.26, 0.15	0.613			
fruit/vegetables	-0.03	-0.12, 0.06	0.565			
soda	-0.03	-0.2, 0.14	0.717			
milk	-0.05	-0.27, 0.15	0.581			
breakfast	0.01	-0.07, 0.08	0.863			
Physical Activity						
screen time	-0.04	-0.12, 0.04	0.320			
days active	0.01	-0.08, 0.09	0.865			
sports	0.82	-0.08, 0.24	0.303			
Chronotype preference (M/E Q)	0.02	-0.02, 0.08	0.196	0.02	-0.03, 0.06	0.471

Note. CI = confidence intervals.

Free Night Sleep Duration: Demographic and Behavioral Characteristics

Phase I. Race/ethnicity ($F(3, 110) = 3.68$, $p = 0.01$), participating in the free/reduced lunch program ($F(1, 112) = 4.44$, $p = 0.04$), taking naps on school days ($F(1, 112) = 2.37$, $p = 0.13$), *not* taking naps on free days ($F(1, 112) = 2.87$, $p = 0.09$), eating more fruits and vegetables ($F(1, 112) = 5.03$, $p = 0.03$), drinking more soda ($F(1, 112) = 6.66$, $p = 0.2$), eating breakfast less frequently ($F(1, 112) = 5.01$, $p = 0.03$), being less physically active ($F(1, 112) = 2.02$, $p = 0.16$), and reporting greater social jet lag ($F(1, 112) = 1.99$, $p = 0.16$) were associated with shorter free night sleep durations in the unadjusted general linear models. When these variables were included in the adjusted general linear model, race/ethnicity, fruit/vegetable consumption, and social jet lag remained predictors of free night sleep duration explaining 18.0% of the variation in sleep duration (F (11, 102) = 3.3 $p = 0.001$, adjusted $R^2 = 0.180$). With every one serving increase in fruit/vegetable servings per day, free night sleep duration decreased 0.2 hours ($p = 0.02$). With every one-hour decrease in social jet lag, free night sleep duration decreased 0.3 hours ($p = 0.05$). Table 13. Black participants reported 1.3 hours shorter free night sleep duration on average compared to Hispanic participants, ($p = 0.02$). Although not reaching statistical significance, there was a similar trend for shorter self-reported free night sleep duration in Black participants compared to White participants ($p = 0.065$). There were no other statistically significant racial/ethnic differences in free night sleep duration (see Table 14).

Phase II. Race/ethnicity ($F(3, 64) = 1.97$, $p = 0.13$), sex ($F(1, 66) = 2.02$, $p = 0.16$), taking naps on school days ($F(1, 66) = 3.35$, $p = 0.07$), taking naps on free days ($F(1, 66) = 1.73$, $p = 0.19$), drinking more juice ($F(1, 66) = 1.89$, $p = 0.17$), and drinking more milk ($F(1, 66) = 2.83$, $p = 0.10$) were associated with shorter free night sleep duration in the unadjusted general linear model. When these variables were included in the adjusted general linear model, only race/ethnicity remained a predictor of free night sleep duration explaining 14.8% of the variation in free night sleep duration ($F(8, 59)$, $p = 0.023$, adjusted $R^2 = 0.148$). Compared to Hispanic participants, Black participants slept 1.2 hours less on free nights ($p = 0.01$). See Table 15. Although not reaching statistical significance, there was a similar trend for shorter self-reported free night sleep duration in Black participants compared to White participants ($p = 0.19$). There were no other statistically significant racial/ethnic differences in free night sleep duration (see Table 16).

Table 13

Predictors of Free Night Sleep Duration by Demographic Characteristics, Behavioral Characteristics and Chronotype: Phase I (N = 114)

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	0.004	-0.04, 0.05	0.859			
Sex (reference: females)	-0.14	-0.95, 0.67	0.738			
Race/Ethnicity (reference: Hispanic)			0.014			**0.026**
White	-0.04	-0.92, 0.84	0.932	-0.40	-1.31, 0.51	0.390
Black	-1.35	-2.24 -0.45	0.003	-1.29	-2.16, -0.43	0.009
Asian	-0.81	-2.82, 1.20	0.426	-1.25	-3.28, 0.78	0.225
Free/reduced lunch (reference: yes)	0.82	0.05, 1.59	0.037	0.59	-0.29, 1.42	0.160
Pubertal category (reference: post)			0.237			
Naps (reference: yes)						
school days	0.58	-0.17, 1.32	0.127	0.48	-0.22, 1.18	0.177
free days	-0.64	-1.2, 0.11	0.093	-0.63	-1.34, 0.08	0.080
Eating Habits						
juice	-0.04	-0.44, 0.36	0.830			
fruit/vegetables	-0.21	-0.40, -0.02	0.027	-0.21	-0.39, -0.03	**0.024**
soda	-0.23	-0.57, 0.12	0.199	-0.01	-0.56, 0.39	0.717
milk	-0.07	-0.53, 0.38	0.746			
breakfast	0.16	0.02, 0.30	0.027	0.11	-0.03, 0.24	0.132
Physical Activity						
screen time	0.01	-0.14, 0.17	0.883			
days active	0.12	-0.05, 0.28	0.158	0.12	-0.04, 0.27	0.150
sports	0.17	-0.15, 0.49	0.293			
Chronotype preference (M/E Q)	-0.01	-0.11, 0.08	0.802			
Chronotype (midpoint of sleep)	-0.10	-0.35, 0.16	0.459			
Social jet lag	0.19	-0.08, 0.45	0.161	0.25	0.00, 0.511	**0.053**

Note. CI = confidence intervals.

Table 14

Phase I post hoc analysis for race/ethnicity: Predictors of Free Night Sleep Duration by Demographic Characteristics, Behavioral Characteristics and Chronotype (N = 114)

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	0.004	-0.04, 0.05	0.859			
Sex (reference: females)	-0.14	-0.95, 0.67	0.738			
Race/Ethnicity (reference: White)						**0.026**
Black				-0.90	-1.86, 0.06	0.065
Hispanic				0.40	-0.51, 1.31	0.390
Asian				-0.98	-2.80, 1.09	0.385
Free/reduced lunch (reference: yes)	0.82	0.05, 1.59	0.037	0.59	-0.29, 1.42	0.160
Pubertal category (reference: post)			0.237			
Naps (reference: yes)						
school days	0.58	-0.17, 1.32	0.127	0.48	-0.22, 1.18	0.177
free days	-0.64	-1.2, 0.11	0.093	-0.63	-1.34, 0.08	0.080
Eating Habits						
juice	-0.04	-0.44, 0.36	0.830			
fruit/vegetables	-0.21	-0.40, -0.02	0.027	-0.21	-0.39, -0.03	**0.024**
soda	-0.23	-0.57, 0.12	0.199	-0.01	-0.56, 0.39	0.717
milk	-0.07	-0.53, 0.38	0.746			
breakfast	0.16	0.02, 0.30	0.027	0.11	-0.03, 0.24	0.132
Physical Activity						
screen time	0.01	-0.14, 0.17	0.883			
days active	0.12	-0.05, 0.28	0.158	0.12	-0.04, 0.27	0.150
sports	0.17	-0.15, 0.49	0.293			
Chronotype preference (M/E Q)	-0.01	-0.11, 0.08	0.802			
Chronotype (midpoint of sleep)	-0.10	-0.35, 0.16	0.459			
Social jet lag	0.19	-0.08, 0.45	0.161	0.254	0.00, 0.511	**0.053**

Note. CI = confidence intervals.

Table 15

Predictors of Free Night Sleep Duration by Demographic Characteristics, Behavioral Characteristics and Chronotype: Phase II (N = 68)

Parameter	Unadjusted Model *b*	Unadjusted Model 95% CI	Unadjusted Model *p*	Adjusted Model *b*	Adjusted Model 95% CI	Adjusted Model *p*
Age	-0.01	-0.06, 0.04	0.635			
Sex (reference: females)	-0.59	-1.43, 0.24	0.160	-0.65	-1.52, 0.22	0.140
Race/Ethnicity (reference: Hispanic)			0.128			**0.046**
White	-0.24	-1.10, 0.61	0.570	-0.58	-1.43, 0.27	0.177
Black	-1.02	-2.00, -0.04	0.042	-1.21	-2.16, -0.26	0.013
Asian	0.74	-1.10, 2.57	0.425	0.68	-1.09, 2.46	0.446
Free/reduced lunch (reference: yes)	0.17	-0.61, 0.95	0.667			
Pubertal category (reference: post)			0.805			
Naps (reference: yes)						
school days	0.68	-0.06, 1.42	0.072	0.72	-0.09, 1.52	0.079
free days	0.76	-0.39, 1.90	0.193	0.62	-0.56, 1.79	0.301
Eating Habits						
juice	-0.28	-0.69, 0.13	0.174	-0.18	-0.57, 0.22	0.369
fruit/vegetables	0.05	-0.13, 0.22	0.602			
soda	-0.13	-0.46, 0.20	0.435			
milk	-0.34	-0.74, 0.06	0.097	-0.27	-0.70, 0.15	0.206
breakfast	0.01	-0.13, 0.15	0.915			
Physical Activity						
screen time	-0.02	-0.17, 0.13	0.813			
days active	-0.04	-0.21, 0.13	0.680			
sports	0.17	-0.13, 0.48	0.266			
Chronotype preference (M/E Q)	0.05	-0.04, 0.14	0.313			

Note. CI = confidence intervals.

Table 16

Phase II post hoc analysis for race/ethnicity: Predictors of Free Night Sleep Duration by Demographic Characteristics, Behavioral Characteristics and Chronotype (N = 68)

Parameter	Unadjusted Model			Adjusted Model		
	b	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.06, 0.04	0.635			
Sex (reference: females)	-0.59	-1.43, 0.24	0.160	-0.65	-1.52, 0.22	0.140
Race/Ethnicity (reference: White)						**0.046**
Hispanic				-0.58	-0.27, 1.43	0.177
Black				-0.63	-1.58, 0.32	0.189
Asian				1.26	-0.52, 3.04	0.162
Free/reduced lunch (reference: yes)	0.17	-0.61, 0.95	0.667			
Pubertal category (reference: post)			0.805			
Naps (reference: yes)						
school days	0.68	-0.06, 1.42	0.072	0.72	-0.09, 1.52	0.079
free days	0.76	-0.39, 1.90	0.193	0.62	-0.56, 1.79	0.301
Eating Habits						
juice	-0.28	-0.69, 0.13	0.174	-0.18	-0.57, 0.22	0.369
fruit/vegetables	0.05	-0.13, 0.22	0.602			
soda	-0.13	-0.46, 0.20	0.435			
milk	-0.34	-0.74, 0.06	0.097	-0.27	-0.70, 0.15	0.206
breakfast	0.01	-0.13, 0.15	0.915			
Physical Activity						
screen time	-0.02	-0.17, 0.13	0.813			
days active	-0.04	-0.21, 0.13	0.680			
sports	0.17	-0.13, 0.48	0.266			
Chronotype preference (M/E Q)	0.05	-0.04, 0.14	0.313			

Note. CI = confidence intervals.

Total Night Sleep Duration: Demographic and Behavioral Characteristics

Phase I. Race/ethnicity (F(3, 110) = 2.31, p = 0.08), taking naps on school days (F(1, 112) = 5.57, p = 0.02), drinking more soda (F(1, 112) = 4.12, p = 0.04), eating breakfast less frequently (F(1, 112) = 1.74, p = 0.19), being less physically active (F(1, 112) = 1.69, p = 0.2), participating in fewer sports (F(1, 112) = 4.64, p = 0.03), and reporting a later chronotype preference (F(1, 112) = 3.75, p = 0.055) were associated with shorter total night sleep duration in the unadjusted general linear model. When these variables were included in the adjusted general linear model, none remain predictors of total night sleep duration at the alpha level of 0.05 (See Table 17).

Phase II. Taking naps on school (F(1, 67) = 10.58, p = 0.002), taking naps on free days (F(1, 67) = 6.68, p = 0.01), and reporting a later chronotype preference (F(1, 67) = 2.81, p = 0.1) were associated with shorter total night sleep durations in the unadjusted general linear models. When these variables were included in the adjusted general linear model, napping on school days remained a predictor of total night sleep duration explaining 14.3% of the variation in total night sleep (F(4.8, 65), p = 0.01, adjusted R^2 = 0.143). Adolescents taking naps on school days had 0.4 hours less total nocturnal sleep compared to adolescents not taking naps (p = 0.04). See Table 18.

Table 17

Predictors of Total Night Sleep Duration by Demographic Characteristics, Behavioral Characteristics and Chronotype: Phase I (N = 114)

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	0.004	-0.02, 0.03	0.772			
Sex (reference: females)	0.20	-0.29, 0.69	0.424			
Race/Ethnicity (reference: Hispanic)			0.080			0.212
White	-0.31	-0.85, 0.24	0.318			
Black	-0.71	-1.26, -0.15	0.013			
Asian	-0.75	-2.00, 0.49	0.254			
Free/reduced lunch (reference: yes)	-0.04	-0.52, 0.43	0.860			
Pubertal category (reference: post)			0.978			
Naps (reference: yes)						
school days	0.53	0.09, 0.98	0.020	0.40	-0.06, 0.85	0.085
free days	0.10	-0.36, 0.56	0.670			
Eating Habits						
juice	0.04	-0.21, 0.28	0.770			
fruit/vegetables	0.05	-0.07, 0.16	0.433			
soda	-0.22	-0.43, -0.01	0.043	-0.10	-0.33, 0.13	0.371
milk	-0.004	-0.28, 0.27	0.979			
breakfast	0.06	-0.03, 0.14	0.189	0.03	-0.05, 0.12	0.438
Physical Activity						
screen time	-0.06	-0.15, 0.04	0.236			
days active	0.06	-0.04, 0.16	0.197	-0.01	-0.12, 0.10	0.858
sports	0.21	0.02, 0.40	0.033	0.17	-0.04, 0.38	0.103
Chronotype preference (M/E Q)	0.06	-0.00, 0.11	0.055	0.02	-0.04, 0.09	0.437
Chronotype (midpoint of sleep)	-0.001	-0.16, 0.16	0.992			
Social jet lag	0.07	-0.09, 0.24	0.365			

Note. CI = confidence intervals.

Table 18

Predictors of Total Night Sleep Duration by Demographic Characteristics, Behavioral Characteristics and Chronotype: Phase II (N = 69)

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.03, 0.02	0.605			
Sex (reference: females)	-0.12	-0.53, 0.30	0.582			
Race/Ethnicity (reference: Hispanic)			0.660			
Free/reduced lunch (reference: yes)	0.08	-0.31, 0.46	0.691			
Pubertal category (reference: post)			0.669			
Naps (reference: yes)						
school days	0.57	0.22, 0.94	0.002	0.41	0.03, 0.80	**0.036**
free days	0.71	0.16, 1.26	0.012	0.47	-0.09, 1.04	0.099
Eating Habits						
juice	-0.09	-0.28, 0.11	0.370			
fruit/vegetables	-0.02	-0.10, 0.07	0.656			
soda	-0.05	-0.22, 0.11	0.526			
milk	-0.11	-0.31, 0.10	0.294			
breakfast	0.02	-0.05, 0.09	0.568			
Physical Activity						
screen time	-0.03	-0.11, 0.04	0.358			
days active	-0.01	-0.09, 0.08	0.914			
sports	0.09	-0.06, 0.24	0.225			
Chronotype preference (M/E Q)	0.04	-0.01, 0.08	0.099	0.02	-0.02, 0.06	0.376

Note. CI = confidence intervals.

In sum, to answer the question of whether or not differences in sleep duration existed by socio-demographic characteristics, our data indicate that Black participants slept approximately one hour less than Hispanic participants on free nights when estimated by self-report and actigraphy. Although a similar trend for shorter school and total night sleep duration for Black participants was evident, it did not reach statistical significance. There were no other self-reported or actigraphy-estimated racial/ethnic differences in sleep duration. Other predictors of shorter free night sleep duration included increased fruit and vegetable consumption and less social jet lag. Taking naps on school days was the only predictor of shorter total night sleep duration.

Morningness /Eveningness Questionnaire (M/E Q): Demographic and Behavioral Characteristics

Phase I. Pubertal category ($F(2, 112) = 2.05$, $p = 0.13$) and older ages ($F(1, 13) = 2.75$, $p = 0.1$) were associated with later chronotype preferences (lower M/E Q scores). Additionally, taking naps on school days ($F(1, 113) = 2.57$, $p = 0.11$), taking naps on free days ($F(1, 113) = 30.12$, $p < 0.001$), eating fewer fruits and vegetables ($F(1, 113) = 3.05$, $p = 0.08$), drinking more soda ($F(1, 113) = 13.58$, $p < 0.001$), reporting greater screen time ($F(1, 112) = 5.17$, $p = 0.03$), eating breakfast less frequently ($F(1, 113) = 2.14$, $p = 0.15$), being less physically active ($F(1, 113) = 11.9$, $p = 0.001$), and participating in fewer sports ($F(1, 113) = 4.6$, $p = 0.03$) were associated with later chronotype preferences in the unadjusted general linear model. Separate adjusted linear models were created for the M/E Q and sex (model 1) and the M/E Q and pubertal category (model 2). In model 1, age, soda consumption, physical activity, and free day naps remained predictors of the M/E Q explaining 33.7% of the variation in M/E Q scores (F (10, 103) = 6.7, $p = 0.000$, adjusted $R^2 = 0.337$). In model 2, age, soda consumption, and free day naps remained predictors of the M/E Q explaining 32.9% of the variation in the M/E Q (F (11, 102) = 6, $p = .000$, adjusted $R^2 = 0.329$). Both models support an association between later chronotype preferences (lower M/E Q scores) and older ages. For every one-month increase in age, M/E Q scores decreased 1 unit ($p = 0.03$). Both models support associations between specific behaviors and later chronotype preferences, including drinking more soda and taking naps on free days. For every additional serving of soda per day, M/E Q scores decreased approximately 1 unit in model 1 ($p = 0.05$) and 0.6 units in model 2 ($p = 0.05$). Participants reporting free day naps had 3 units lower M/E Q scores than non-nappers ($p < 0.0$ both models). In model 1, less physical activity was also associated with later chronotype preference. For every additional day *not* physically active during the week, M/E Q scores decreased 0.3 units ($p = 0.05$). See Table 19 and 20.

Phase II. Taking naps on school days ($F(1, 67) = 6.6$, $p = 0.03$), eating fewer fruits and vegetables ($F(1, 67) = 3.53$, $p = 0.07$), drinking more soda ($F(1, 67) = 8.88$, $p = 0.004$), reporting more screen time ($F(1, 67) = 8.15$, $p = 0.01$), eating breakfast less frequently ($F(1, 67) = 2.67$, $p = 0.11$), being less physically active ($F(1, 67) = 8.34$, $p = 0.01$), and participating in fewer sports ($F(1, 67) = 2.26$, $p = 0.14$) were associated with later chronotype preferences (lower M/E Q scores) in the unadjusted general linear models at the alpha level of 0.2. When these variables were included in the adjusted general linear model, fruit/vegetable and soda intake remained predictors of the M/E Q explaining 26.1% of the variance in the M/E Q score (F (7, 61) = 4.4, $p < 0.00$, adjusted $R^2 = 0.261$). For every one less serving of fruits/vegetables per day, M/E Q scores decreased 0.5 units ($p = 0.03$). For every additional serving of soda per day, M/E Q scores decreased 0.9 units ($p = 0.05$). See Table 21.

Table 19

Prediction of the Morningness/Eveningness Questionnaire by Demographic and Behavioral Characteristics, Model 1: Phase I (N = 115)

	Unadjusted			Model 1		
Parameter	*b*	95% C	*p*	*b*	95% CI	*p*
Age	-0.07	-0.16, 0.01	0.100	-0.09	-0.16, -0.01	**0.027**
Sex (reference: females)	1.06	-0.49, 2.61	0.179	-0.25	-1.62, 1.12	0.722
Race/ethnicity (reference: Hispanic)			0.802			
Free/reduced lunch (reference: yes)	0.77	-0.74, 2.28	0.313			
Pubertal category (reference: post)			0.134			
mid	1.29	-0.80, 3.79	0.379			
late	1.80	-0.18, 3.79	0.077			
Naps (reference: yes)						
school days	1.16	-0.27, 2.60	0.112	0.33	-0.91, 1.57	0.596
free days	3.61	2.31, 4.91	0.000	3.04	1.80, 4.27	**0.000**
Eating Habits						
juice	0.33	-0.44, 1.10	0.395			
fruit/vegetables	0.32	-0.04, 0.68	0.084	0.30	-0.17, 0.61	0.063
soda	-1.18	-1.82, -0.55	0.000	-0.63	-1.25, -0.02	**0.045**
milk	0.24	-0.63, 1.11	0.589			
breakfast	0.20	-0.07, 0.47	0.146	0.15	-0.09, 0.39	0.208
Physical Activity						
screen time	-0.34	-0.64, -0.04	0.025	-0.20	-0.46, 0.07	0.144
days active	0.52	0.22, 0.81	0.001	0.30	0.00, 0.60	**0.047**
sports	0.65	-0.05, 1.25	0.034	0.17	-0.42, 0.75	0.578

Note. CI: confidence intervals.

Table 20

Prediction of the Morningness/Eveningness Questionnaire by Demographic and Behavioral Characteristics, Model 2: Phase I (N = 115)

	Unadjusted			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.07	-0.16, 0.01	0.100	-0.09	-0.16, -0.09	**0.031**
Sex (reference: females)	1.06	-0.49, 2.61	0.179			
Race/ethnicity (reference: Hispanic)			0.802			
Free/reduced lunch (reference: yes)	0.77	-0.74, 2.28	0.313			
Pubertal category (reference: post)			0.134			0.999
mid	1.29	-0.80, 3.79	0.379			
late	1.80	-0.18, 3.79	0.077			
Naps (reference: yes)						
school days	1.16	-0.27, 2.60	0.112	0.35	-0.91, 1.60	0.587
free days	3.61	2.31, 4.91	0.000	3.03	1.78, 4.29	**0.000**
Eating Habits						
juice	0.33	-0.44, 1.10	0.395			
fruit/vegetables	0.32	-0.04, 0.68	0.084	0.29	-0.02, 0.61	0.069
soda	-1.18	-1.82, -0.55	0.000	-0.63	-1.24, -0.01	0.047
milk	0.24	-0.63, 1.11	0.589			
breakfast	0.20	-0.07, 0.47	0.146	0.14	-0.10, 0.39	0.247
Physical Activity						
screen time	-0.34	-0.64, -0.04	0.025	-0.19	-0.46, 0.08	0.162
days active	0.52	0.22, 0.81	0.001	0.29	-0.01, 0.59	0.061
sports	0.65	-0.05, 1.25	0.034	0.17	-0.42, 0.76	0.570

Note. CI: confidence intervals.

Table 21

Prediction of the Morningness/Eveningness Questionnaire by Demographic and Behavioral Characteristics: Phase II (N = 69)

	Unadjusted			Adjusted		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.07	-0.20, 0.06	0.290			
Sex (reference: females)	1.21	-1.11, 3.53	0.302			
Race/ethnicity (reference: Hispanic)			0.367			
Free/reduced lunch (reference: yes)	0.37	-1.77, 2.51	0.731			
Pubertal category (reference: post)			0.286			
Naps (reference: yes)						
school days	2.57	0.57, 4.57	0.012	-1.42	-3.35, 0.51	0.147
free days	1.00	-2.20, 4.20	0.535			
Eating Habits						
juice	0.19	-0.91, 1.28	0.735			
fruit/vegetables	0.44	-0.03, 0.90	0.065	0.49	0.05, 0.92	**0.029**
soda	-1.30	-2.16, -0.43	0.004	-0.86	-1.72, 0.00	**0.051**
milk	0.33	-0.80, 1.47	0.561			
breakfast	0.31	-0.07, 0.69	0.107	0.21	-0.15, 0.57	0.243
Physical Activity						
screen time	-0.56	-0.95, -0.17	0.006	-0.32	-0.71, 0.06	0.100
days active	0.63	0.20, 1.07	0.005	0.43	-0.02, 0.88	0.063
sports	0.63	-0.21, 1.47	0.137	-0.19	-1.03, 0.65	0.656

Note. CI: confidence intervals.

Midpoint of Sleep: Demographic and Behavioral Characteristics

Phase 1. Sex ($F(1, 113) = 1.93$, $p = 0.17$), taking naps on free days ($F(1, 113) = 1.89$, $p = 0.17$), drinking more soda ($F(1, 113) = 3.06$, $p = 0.08$), reporting more screen time ($F(1, 112) = 2.26$, $p = 0.14$), and being less physically active ($F(1, 113) = 5.63$, $p = 0.02$) were associated with later chronotypes (later midpoints of sleep) in the unadjusted general linear models. When these variables were included in the adjusted general linear model, only sex and physical activity remained predictors of the midpoint of sleep explaining 7.8% of the variation in the midpoint of sleep ($F\ (5, 108) = 2.9$ $p = .016$, adjusted $R^2 = 0.078$). Males had 0.7 hours later midpoints of sleep than females ($p = 0.02$). For every additional day not physically active during the week, midpoints of sleep were 0.13 hours later. See Table 22.

Phase II. Pubertal category ($F(2, 65) = 1.77$, $p = 0.18$), taking naps on school days ($F(1, 66) = 7.92$, $p = 0.01$), being less physically active ($F(1, 66) = 2.46$, $p = 0.12$), participating in fewer sports ($F(1, 66) = 4.12$, $p = 0.05$), and reporting more screen time ($F(1, 66) = 4.02$, $p = 0.05$) were associated with later chronotypes (later midpoints of sleep) in the general linear model. When these variables were included in the adjusted general linear model, only school day naps remained a predictor of the midpoint of sleep explaining 12% of the variance in the midpoint of sleep ($F\ (6, 61) = 2.5$, $p = 0.03$, adjusted R^2 0.120). Participants who nap on school days had a 0.6-hour later midpoint of sleep ($p = 0.02$). See Table 23.

Table 22

Prediction of the Midpoint of Sleep by Demographic and Behavioral Characteristics: Phase I (N = 115)

	Unadjusted			Adjusted		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	0.003	-0.03, 0.04	0.872			
Sex (reference: females)	0.41	-0.18, 1.00	0.167	0.69	0.10, 1.28	**0.023**
Race/ethnicity (reference: Hispanic)			0.560			
Free/reduced lunch (reference: yes)	0.18	-0.39, 0.75	0.536			
Pubertal category (reference: post)			0.431			
Naps (reference: yes)						
school days	-0.09	-0.63, 0.46	0.754			
free days	-0.38	-0.93, 0.17	0.172	-0.32	-0.86, 0.22	0.239
Eating Habits						
juice	-0.02	-0.31, 0.28	0.913			
fruit/vegetables	0.07	-0.07, 0.21	0.330			
soda	0.22	-0.03, 0.47	0.083	0.14	-0.12, 0.40	0.302
milk	0.13	-0.20, 0.46	0.442			
breakfast	-0.01	-0.11, 0.10	0.868			
Physical Activity						
screen time	0.09	-0.03, 0.20	0.136	0.07	-0.05, 0.18	0.233
days active	-0.14	-0.25, -0.02	0.019	-0.13	-0.25, -0.01	**0.031**
sports	-0.03	-0.27, 0.20	0.824			

Note. CI: confidence intervals.

Table 23

Prediction of the Midpoint of Sleep by Demographic and Behavioral Characteristics: Phase II (N =68)

	Unadjusted			Adjusted		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.05, 0.03	0.592			
Sex (reference: females)	-0.32	-0.97, 0.33	0.325			
Race/ethnicity (reference: Hispanic)			0.588			
Free/reduced lunch (reference: yes)	-0.10	-0.70, 0.50	0.740			
Pubertal category (reference: post)			0.179			0.476
mid	-0.18	-0.99, 0.62	0.650			
late	-0.88	-1.81, 0.06	0.066			
Naps (reference: yes)						
school days	-0.78	-1.33, -0.23	0.006	-0.65	-1.21, -0.09	**0.025**
free days	-0.38	-1.27, 0.51	0.394			
Eating Habits						
juice	-0.18	-0.50, 0.13	0.245			
fruit/vegetables	-0.05	-0.18, 0.08	0.443			
soda	0.13	-0.13, 0.38	0.324			
milk	-0.14	-0.45, 0.18	0.388			
breakfast	-0.04	-0.15, 0.07	0.454			
Physical Activity						
screen time	0.11	0.00, 0.22	0.049	0.07	-0.05, 0.18	0.254
days active	-0.10	-0.23, 0.03	0.122	-0.03	-0.18, 0.11	0.634
sports	-0.23	-0.46, 0.00	0.046	-0.13	-0.38, 0.13	0.323

Note. CI: confidence intervals.

Social Jet Lag: Demographic and Behavioral Characteristics

Phase I. Participating in the free/reduced lunch program ($F(1, 113) = 2.16$, $p = 0.15$), taking naps on free days ($F(1, 113) = 2.70$, $p = 0.1$), eating more fruits and vegetables ($F(1, 113) = 4.08$, $p = 0.05$), and being less physically active ($F(1, 113) = 2.66$, $p = 0.11$) were associated with greater social jet lag in the unadjusted general linear models. When these variables were included in the adjusted general linear model, only fruit/vegetable consumption predicted social jet lag explaining 7.6% of the variation in social jet lag (F (4,110) = 3.4, $p = 0.012$, adjusted $R^2 = 0.076$). For every one serving increase in fruit/vegetables per day, social jet lag increased approximately 0.2 hours ($p = 0.02$). See Table 24.

Phase II. Sex ($F(1, 66) = 5.83$, $p = 0.02$), pubertal category ($F(2, 65) = 4.88$, $p = 0.1$), drinking less juice ($F(1, 66) = 2.59$, $p = 0.11$), eating breakfast less frequently ($F(1, 66) = 2.16$, $p = 0.15$), being less physically active ($F(1, 66) = 1.71$, $p = 0.2$), participating in fewer sports ($F(1, 66) = 2.37$, $p = 0.13$), and reporting more screen time ($F(1, 66) = 1.73$, $p = 0.2$) were associated with greater social jet lag in the unadjusted general linear models at the alpha level of 0.2. When these variables were included in the adjusted general linear model, none remained predictors of social jet lag. See Table 25 and 26.

Table 24

Prediction of Social Jet Lag by Demographic and Behavioral Characteristics: Phase I (N = 115)

	Unadjusted			Adjusted		
Parameter	*b*	95% CI	*p*	*b*	95% C	*p*
Age	-0.01	-0.04, 0.03	0.671			
Sex (reference: females)	0.09	-0.49, 0.66	0.765			
Race/ethnicity (reference: Hispanic)			0.743			
Free/reduced lunch (reference: yes)	0.41	-0.14, 0.95	0.145	0.45	-0.08, 0.99	0.094
Pubertal category (reference: post)			0.940			
Naps (reference: yes)						
school days	0.10	-0.43, 0.63	0.699			
free days	-0.44	-0.97, 0.09	0.103	-0.43	-0.95, 0.09	0.106
Eating Habits						
juice	0.02	-0.26, 0.30	0.898			
fruit/vegetables	0.13	0.00, 0.26	0.046	0.15	0.03, 0.28	**0.019**
soda	0.12	-0.13, 0.36	0.340			
milk	0.11	-0.21, 0.43	0.506			
breakfast	-0.05	-0.15, 0.05	0.336			
Physical Activity						
screen time	0.05	-0.06, 0.16	0.387			
days active	-0.09	-0.21, 0.02	0.106	-0.10	-0.21, -0.01	0.076
sports	0.01	-0.22, 0.23	0.967			

Note. CI: confidence intervals.

Table 25

Prediction of Social Jet Lag by Demographic and Behavioral Characteristics, Model 1: Phase II (N = 68)

	Unadjusted			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.04, 0.02	0.380			
Sex (reference: females)	-0.58	-1.07, -0.10	0.019	-0.42	-0.94, 0.11	0.120
Race/ethnicity (reference: Hispanic)			0.723			
Free/reduced lunch (reference: yes)	-0.05	-0.52, 0.41	0.824			
Pubertal category (reference: post)			0.011			
mid	-0.48	-1.08, 0.12	0.113			
late	-1.00	-1.69, -0.31	0.005			
Naps (reference: yes)						
school days	-0.13	-0.59, 0.32	0.553			
free days	0.20	-0.49, 0.89	0.567			
Eating Habits						
juice	-0.19	-0.43, 0.05	0.112	-0.19	-0.42, 0.05	0.127
fruit/vegetables	0.01	-0.09, 0.11	0.822			
soda	0.04	-0.16, 0.24	0.696			
milk	-0.06	-0.03, 0.15	0.269			
breakfast	-0.06	-0.14, 0.02	0.146	-0.05	-0.13, 0.03	0.233
Physical Activity						
screen time	0.06	-0.03, 0.15	0.193	0.04	-0.05, 0.13	0.408
days active	-0.07	-0.17, 0.03	0.195	-0.01	-0.12, 0.10	0.884
sports	-0.14	-0.32, 0.04	0.128	-0.08	-0.28, 0.12	0.424

Note. CI: confidence intervals.

Table 26

Prediction of Social Jet Lag by Demographic and Behavioral Characteristics, Model 2: Phase II (N = 68)

	Unadjusted			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.04, 0.02	0.380			
Sex (reference: females)	-0.58	-1.07, -0.10	0.019			
Race/ethnicity (reference: Hispanic)			0.723			
Free/reduced lunch (reference: yes)	-0.05	-0.52, 0.41	0.824			
Pubertal category (reference: post)			0.011			0.079
mid	-0.48	-1.08, 0.12	0.113			
late	-1.00	-1.69, -0.31	0.005			
Naps (reference: yes)						
school days	-0.13	-0.59, 0.32	0.553			
free days	0.20	-0.49, 0.89	0.567			
Eating Habits						
juice	-0.19	-0.43, 0.05	0.112	-0.16	-0.40, 0.08	0.197
fruit/vegetables	0.01	-0.09, 0.11	0.822			
soda	0.04	-0.16, 0.24	0.696			
milk	-0.06	-0.03, 0.15	0.269			
breakfast	-0.06	-0.14, 0.02	0.146	-0.05	-0.14, 0.03	0.205
Physical Activity						
screen time	0.06	-0.03, 0.15	0.193			
days active	-0.07	-0.17, 0.03	0.195	0.01	-0.12, 0.12	0.927
sports	-0.14	-0.32, 0.04	0.128	-0.07	-0.27, 0.13	0.486

Note. CI: confidence intervals.

In sum, to answer the question of whether or not differences in chronotype preferences existed by socio-demographic characteristics, our data indicate that having a later chronotype preference (lower M/E Q score) was associated with older ages. Several behavioral characteristics associated with later chronotype preferences included drinking more soda, eating fewer fruits/vegetables, and napping more on free days. Males reported later chronotypes (later midpoints of sleep) than females. Behavioral characteristics associated with later chronotypes included less physical activity and more free day naps. There were no socio-demographic characteristics associated with social jet lag, however, eating more fruits and vegetables was associated with greater social jet lag.

Aim 2

The purpose of this aim was to determine if there was a relationship between sleep duration and BMI z scores. Unadjusted general linear models were examined first. Variables associated with the dependent variable at the alpha level of 0.2 were selected for the adjusted general linear model as discussed in Chapter 3 to test the hypothesis that shorter sleep duration would be associated with higher BMI z scores. The relationship between BMI z scores and self-reported sleep duration parameters (Phase I) and actigraphy-estimated sleep duration parameters (Phase II) findings are presented. Males and females were also analyzed separately due to differences in body composition changes during growth and development. The relationship between WHtR and self-reported sleep duration parameters (Phase I) and actigraphy-estimated sleep duration parameters (Phase II) findings are presented last. Males and females were also analyzed separately for these analyses.

Sleep Duration and BMI z scores

Phase I. Younger ages ($F(1, 113) = 6.80$, $p = 0.01$), sex ($F(1, 113) = 2.70$, $p = 0.1$), reporting longer sleep on school nights ($F(1, 112) = 9.2$, $p = 0.003$) and total nights ($F(1, 112) = 4.34$, $p = 0.04$) were associated with higher BMI z scores in the unadjusted general linear models. Separate adjusted general linear models were created for school night sleep duration (model 1), and total night sleep duration (model 2). In both models, age and sleep duration (school night and total night) remained predictors of BMI z scores (model 1: $F(3, 110) = 6.2$, $p = 0.001$, $R^2 = 0.122$; model 2: ($F(3, 110) = 4.5$, $p = 0.005$ adjusted $R^2 = 0.085$). In both models, for every one-month decrease in age, BMI z scores increased 0.03 ($p = 0.01$) and for every one-hour increase in sleep duration on school nights or total nights, BMI z scores increased 0.2 (model 1: $p = 0.003$; model 2: $p = 0.04$). See Table 27 and 28.

Phase II. Sex ($F(1, 113) = 6.80$, $p = 0.01$), eating more fruit/vegetables ($F(1, 67) = 2.76$, $p = 0.10$), reporting more screen time ($F(1, 67) = 2.60$, $p = 0.11$), sleeping longer on school nights ($F(1, 67) = 2.75$, $p = 0.10$) and total nights ($F(1, 67) = 2.01$, $p = 0.16$), and napping on school days ($F(1, 67) = 5.03$, $p = 0.03$) and free days ($F(1, 67) = 8.14$, $p = 0.01$) were associated with higher BMI z scores in the unadjusted general linear models at the alpha level of 0.2. When these variables were included in the adjusted general linear model, none remained predictors of BMI z scores. See Table 29.

Table 27

Prediction of BMI z scores by Demographic and Behavioral Characteristics, Model 1: Phase I (N = 115)

	Unadjusted Model			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.03	-0.05, -0.01	0.010	-0.03	-0.05, -0.01	**0.009**
Sex (reference: female)	0.35	-0.07, 0.76	0.103	0.26	-0.14, 0.66	0.202
Race/ethnicity (reference: Hispanic)			0.431			
Free/reduced lunch (reference: yes)	-0.26	-0.66, 0.15	0.213			
Pubertal category (reference: post)			0.212			
Eating Habits						
juice	0.04	-017, 0.25	0.710			
fruit/vegetables	0.04	-0.06, 0.14	0.449			
soda	-0.10	-0.28, 0.08	0.289			
milk	0.05	-0.19, 0.28	0.686			
breakfast	0.04	-0.04, 0.11	0.344			
Physical Activity						
screen time	-0.01	-0.09, 0.07	0.821			
days active	0.04	-0.04, 0.12	0.355			
sports	-0.02	-0.19, 0.14	0.781			
Sleep duration						
school nights	0.21	0.07, 0.34	0.003	0.20	0.07, 0.33	**0.003**
free nights	-0.04	-0.14, 0.06	0.440			
total night	0.17	0.01, 0.33	0.040			
Naps: school days (reference: yes)	0.18	-0.21, 0.57	0.356			
Naps: free days (reference: yes)	0.05	-0.34, 0.45	0.794			

Note. CI: confidence intervals.

Table 28

Prediction of BMI z scores by Demographic and Behavioral Characteristics, Model 2: Phase I (N = 115)

	Unadjusted Model			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.03	-0.05, -0.01	0.010	-0.03	-0.05, -0.01	**0.011**
Sex (reference: female)	0.35	-0.07, 0.76	0.103	0.29	-0.11, 0.70	0.156
Race/ethnicity (reference: Hispanic)			0.431			
Free/reduced lunch (reference: yes)	-0.26	-0.66, 0.15	0.213			
Pubertal category (reference: post)			0.212			
Eating Habits						
juice	0.04	-017, 0.25	0.710			
fruit/vegetables	0.04	-0.06, 0.14	0.449			
soda	-0.10	-0.28, 0.08	0.289			
milk	0.05	-0.19, 0.28	0.686			
breakfast	0.04	-0.04, 0.11	0.344			
Physical Activity						
screen time	-0.01	-0.09, 0.07	0.821			
days active	0.04	-0.04, 0.12	0.355			
sports	-0.02	-0.19, 0.14	0.781			
Sleep duration						
school nights	0.21	0.07, 0.34	0.003			
free nights	-0.04	-0.14, 0.06	0.440			
total night	0.17	0.01, 0.33	0.040	0.16	0.01, 0.32	**0.038**
Naps: school days (reference: yes)	0.18	-0.21, 0.57	0.356			
Naps: free days (reference: yes)	0.05	-0.34, 0.45	0.794			

Note. CI: confidence intervals.

Table 29

Prediction of BMI z scores by Demographic and Behavioral Characteristics, Model 1: Phase II (N = 69)

	Unadjusted Model			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.04, 0.02	0.484			
Sex (reference: female)	0.36	-0.14, 0.86	0.157	0.28	-0.20, 0.76	0.243
Race/ethnicity (reference: Hispanic)			0.749			
Free/reduced lunch (reference: yes)	-0.13	-0.60, 0.33	0.571			
Pubertal category (reference: post)			0.418			
Eating Habits						
juice	0.001	-0.24, 0.24	0.993			
fruit/vegetables	0.09	-0.02, 0.19	0.101	0.08	-0.02, 0.18	0.115
soda	-0.08	-0.28, 0.12	0.432			
milk	0.06	-0.19, 0.31	0.618			
breakfast	0.05	-0.04, 0.13	0.256			
Physical Activity						
screen time	-0.07	-0.16, 0.02	0.112	-0.03	-0.12, 0.06	0.541
days active	0.06	-0.04, 0.16	0.268			
sports	0.00	-0.19, 0.19	0.996			
Sleep duration						
school nights	0.23	-0.05, 0.51	0.102	0.13	-0.16, 0.41	0.382
free nights	0.05	-0.10, 0.20	0.501			
total night	0.21	-0.09, 0.50	0.161			
Naps: school days (reference: yes)	0.50	0.05, 0.94	0.028	0.22	-0.25, 0.70	0.344
Naps: free days (reference: yes)	0.95	0.28, 1.61	0.006	0.64	-0.09, 1.36	0.086

Note. CI: confidence intervals.

Table 30

Prediction of BMI z scores by Demographic and Behavioral Characteristics, Model 2: Phase II (N = 69)

	Unadjusted Model			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.04, 0.02	0.484			
Sex (reference: female)	0.36	-0.14, 0.86	0.157	0.29	-0.20, 0.77	0.237
Race/ethnicity (reference: Hispanic)			0.749			
Free/reduced lunch (reference: yes)	-0.13	-0.60, 0.33	0.571			
Pubertal category (reference: post)			0.418			
Eating Habits						
juice	0.001	-0.24, 0.24	0.993			
fruit/vegetables	0.09	-0.02, 0.19	0.101	0.08	-0.02, 0.18	0.125
soda	-0.08	-0.28, 0.12	0.432			
milk	0.06	-0.19, 0.31	0.618			
breakfast	0.05	-0.04, 0.13	0.256			
Physical Activity						
screen time	-0.07	-0.16, 0.02	0.112	-0.03	-0.12, 0.06	0.526
days active	0.06	-0.04, 0.16	0.268			
sports	0.00	-0.19, 0.19	0.996			
Sleep duration						
school nights	0.23	-0.05, 0.51	0.102			
free nights	0.05	-0.10, 0.20	0.501			
total night	0.21	-0.09, 0.50	0.161	0.08	-0.23, 0.39	0.599
Naps: school days (reference: yes)	0.50	0.05, 0.94	0.028	0.23	-0.26, 0.71	0.351
Naps: free days (reference: yes)	0.95	0.28, 1.61	0.006	0.66	-0.07, 1.40	0.076

Note. CI: confidence intervals.

In sum, the hypothesis that shorter sleep duration would be associated with higher BMI z scores was not supported. In this sample, longer self-reported school night sleep duration and total night sleep were associated with higher BMI z scores. Although not reaching statistical significance, the trends for actigraphy-estimated sleep durations and BMI z scores were in the same direction (longer school night and total night sleep duration and higher BMI z scores).

Sleep Duration and BMI z scores in Males

Phase I. Younger ages ($F(1, 33) = 4.33$, $p = 0.05$) and sleeping longer on school nights ($F(1, 33) = 2.21$, $p = 0.15$) were associated with higher BMI z scores in males in the unadjusted general linear model. When these variables were included in the adjusted general linear model, only age remained a predictor of BMI z scores in males explaining 15.2% of the variation in BMI z scores (F (2, 35) = 4.4, $p = 0.027$, $R^2 = 0.152$). For every one-month decrease in age, BMI z scores increased 0.05 units in males ($p = 0.03$). See Table 31.

Phase II. Drinking less juice ($F(1, 16) = 5.80$, $p = 0.03$) and sleeping longer on free nights ($F(1, 16) = 2.04$, $p = 0.17$) were associated with higher BMI z scores in males in the unadjusted general linear models. When these variables were included in the adjusted general linear model, only juice remained a predictor of BMI z scores in males explaining 24.2 % of the variance in BMI z scores in males ($F(2, 15) = 3.7$, $p = 0.048$, adjusted $R^2 = 0.244$). For every one serving less of juice per day, BMI z scores increased 0.5 units in males ($p = 0.04$). See Table 32.

Table 31

Prediction of BMI z scores in Males (n = 35): Phase I

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.05	-0.10, 0.00	0.045	-0.05	-0.1, -0.01	**0.025**
Race/ethnicity (reference: Hispanic)			0.785			
Free/reduced lunch (reference: yes)	0.08	-0.76, 0.91	0.850			
Pubertal category (reference: post)			0.443			
Eating Habits						
juice	-0.12	-0.52, 0.29	0.564			
fruit/vegetables	-0.01	-0.23, 0.22	0.938			
soda	-0.20	-0.74, 0.35	0.468			
milk	-0.01	-0.41, 0.39	0.977			
breakfast	0.09	-0.07, 0.24	0.256			
Physical Activity						
screen time	0.08	-0.07, 0.24	0.288			
days active	-0.03	-0.21, 0.14	0.731			
sports	-0.07	-0.39, 0.26	0.683			
Sleep duration						
school nights	0.22	-0.08, 0.52	0.146	0.26	-0.03, 0.55	0.073
free nights	-0.07	-0.25, 0.10	0.398			
total night	0.12	-0.24, 0.47	0.496			
Naps: school days (reference: yes)	-0.32	-1.11, 0.47	0.418			
Naps: free days (reference: yes)	-0.44	-1.21, 0.34	0.263			

Note. CI: confidence intervals.

Table 32

Prediction of BMI z scores in Males (n =18): Phase II

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	0.01	-0.05, 0.07	0.667			
Race/ethnicity (reference: Hispanic)			0.904			
Free/reduced lunch (reference: yes)	-0.19	-1.16, 0.77	0.672			
Pubertal category (reference: post)			0.767			
Eating Habits						
juice	-0.56	-1.05, -0.07	0.028	-0.51	-1.01, -0.02	**0.042**
fruit/vegetables	0.03	-0.21, 0.27	0.764			
soda	-0.12	-0.59, 0.36	0.613			
milk	-0.22	-0.64, 0.21	0.294			
breakfast	0.10	-0.07, 0.27	0.244			
Physical Activity						
screen time	-0.02	-0.18, 0.15	0.848			
days active	-0.03	-0.25, 0.19	0.774			
sports	-0.001	-0.35, 0.35	0.996			
Sleep duration						
school nights	0.04	-0.54, 0.61	0.897			
free nights	0.21	-0.10, 0.51	0.173	0.16	-0.12, 0.44	0.239
total night	0.23	-0.40, 0.85	0.454			
Naps: school days (reference: yes)	0.16	-0.78, 1.09	0.727			
Naps: free days (reference: yes)	0.32	-1.67, 2.30	0.740			

Note. CI: confidence intervals.

Sleep Duration and BMI z scores in Females

Phase I. Younger ages ($F(1, 78) = 2.92$, $p = 0.09$), participating in the free/reduced lunch program ($F(1, 78) = 2.98$, $p = 0.09$), sleeping longer on school nights ($F(1, 77) = 6.14$, $p = 0.02$) and not taking naps on school days ($F(1, 78) = 3.12$, $p = 0.08$) were associated with higher BMI z scores in females in the unadjusted general linear models. Separate adjusted general linear models were created for school night sleep duration (model 1) and total night sleep duration (model 2). In model 1, school night sleep duration remained a predictor of BMI z scores explaining 9.8% of the variance in BMI z scores ($F(4, 74) = 3.1$, $p = 0.02$, adjusted $R^2 = 0.098$). For every one-hour increase in school night sleep duration, BMI z scores increased approximately 0.2 units ($p = 0.05$). See Table 33. In model 2 (total night sleep duration), there were no predictors of BMI z scores. See Table 34.

Phase II. Eating more fruit and vegetables ($F(1, 49) = 2.78$, $p = 0.1$), reporting more screen time ($F(1, 49) = 2.88$, $p = 0.096$), sleeping longer on school days ($F(1, 49) = 3.5$, $p = 0.07$), and not taking naps on school days ($F(1, 49) = 5.68$, $p = 0.02$) and free days ($F(1, 49) = 7.81$, $p = 0.01$) were associated with higher BMI z scores in females in the unadjusted general linear models. When these variables were included in the adjusted general linear model, none remained predictors of BMI z scores in females. See Tables 35 and 36.

Table 33

Prediction of BMI z scores in Females, Model 1 (n = 80): Phase I

	Unadjusted Model			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.02	-0.05, 0.00	0.092	-0.02	-0.05, 0.00	0.096
Race/ethnicity (reference: Hispanic)			0.704			
Free/reduced lunch (reference: yes)	-0.40	-0.86, 0.06	0.097	-0.34	-0.79, 0.12	0.141
Eating Habits						
juice	0.08	-0.17, 0.33	0.513			
fruit/vegetables	0.05	-0.06, 0.16	0.379			
soda	-0.06	-0.25, 0.13	0.558			
milk	-0.003	-0.33, 0.32	0.984			
breakfast	-0.003	-0.09, 0.08	0.939			
Physical Activity						
screen time	-0.04	-0.14, 0.06	0.409			
days active	0.05	-0.05, 0.13	0.341			
sports	-0.02	-0.21, 0.17	0.834			
Sleep duration						
school nights	0.19	0.04, 0.34	0.015	0.15	0.00, 0.31	**0.053**
free nights	-0.01	-0.13, 0.11	0.848			
total night	0.17	-0.01, 0.35	0.057			
Naps: school days (reference: yes)	0.39	-0.05, 0.83	0.081	0.21	-0.24, 0.66	0.360
Naps: free days (reference: yes)	0.25	-0.21, 0.70	0.287			

Note. CI: confidence intervals.

Table 34

Prediction of BMI z scores in Females, Model 2 (n = 80): Phase I

	Unadjusted Model			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.02	-0.05, 0.00	0.092	-0.02	-0.05, 0.00	0.098
Race/ethnicity (reference: Hispanic)			0.704			
Free/reduced lunch (reference: yes)	-0.40	-0.86, 0.06	0.097	-0.39	-0.84, 0.07	0.093
Eating Habits						
juice	0.08	-0.17, 0.33	0.513			
fruit/vegetables	0.05	-0.06, 0.16	0.379			
soda	-0.06	-0.25, 0.13	0.558			
milk	-0.003	-0.33, 0.32	0.984			
breakfast	-0.003	-0.09, 0.08	0.939			
Physical Activity						
screen time	-0.04	-0.14, 0.06	0.409			
days active	0.05	-0.05, 0.13	0.341			
sports	-0.02	-0.21, 0.17	0.834			
Sleep duration						
school nights	0.19	0.04, 0.34	0.015			
free nights	-0.01	-0.13, 0.11	0.848			
total night	0.17	-0.01, 0.35	0.057	0.15	-0.03, 0.32	0.109
Naps: school days (reference: yes)	0.39	-0.05, 0.83	0.081	0.23	-0.22, 0.69	0.312
Naps: free days (reference: yes)	0.25	-0.21, 0.70	0.287			

Note. CI: confidence intervals.

Table 35

Prediction of BMI z scores in Females, Model 1 (n =51): Phase II

	Unadjusted Model			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.02	-0.05, 0.02	0.318			
Race/ethnicity (reference: Hispanic)			0.664			
Free/reduced lunch (reference: yes)	-0.10	-0.64, 0.45	0.726			
Eating Habits						
juice	0.12	-0.15, 0.39	0.376			
fruit/vegetables	0.10	-0.02, 0.21	0.102	0.08	-0.03, 0.19	0.154
soda	-0.06	-0.29, 0.17	0.606			
milk	0.14	-0.21, 0.49	0.423			
breakfast	0.02	-0.08, 0.12	0.738			
Physical Activity						
screen time	-0.09	-0.1, 0.02	0.096	-0.02	-0.14, 0.1	0.714
days active	0.06	-0.06, 0.18	0.342			
sports	-0.04	-0.27, 0.19	0.739			
Sleep duration						
school nights	0.30	-0.02, 0.63	0.067	0.14	-0.14, 0.19	0.416
free nights	0.03	-0.14, 0.21	0.725			
total night	0.22	-0.12, 0.56	0.195			
Naps: school days (reference: yes)	0.60	0.10, 1.11	0.021	0.24	-0.36, 0.83	0.429
Naps: free days (reference: yes)	0.99	0.28, 1.71	0.007	0.68	-0.13, 1.49	0.099

Note. CI: confidence intervals.

Table 36

Prediction of BMI z scores in Females, Model 2 (n =51): Phase II

	Unadjusted Model			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.02	-0.05, 0.02	0.318			
Race/ethnicity (reference: Hispanic)			0.664			
Free/reduced lunch (reference: yes)	-0.10	-0.64, 0.45	0.726			
Eating Habits						
juice	0.12	-0.15, 0.39	0.376			
fruit/vegetables	0.10	-0.02, 0.21	0.102	0.08	-0.04, 0.19	0.181
soda	-0.06	-0.29, 0.17	0.606			
milk	0.14	-0.21, 0.49	0.423			
breakfast	0.02	-0.08, 0.12	0.738			
Physical Activity						
screen time	-0.09	-0.1, 0.02	0.096	-0.03	-0.15, 0.09	0.623
days active	0.06	-0.06, 0.18	0.342			
sports	-0.04	-0.27, 0.19	0.739			
Sleep duration						
school nights	0.30	-0.02, 0.63	0.067			
free nights	0.03	-0.14, 0.21	0.725			
total night	0.22	-0.12, 0.56	0.195	-0.02	-0.40, 0.36	0.926
Naps: school days (reference: yes)	0.60	0.10, 1.11	0.021	0.31	-0.29, 0.94	0.291
Naps: free days (reference: yes)	0.99	0.28, 1.71	0.007	0.71	-0.10, 1.53	0.085

Note. CI: confidence intervals.

An association between longer self-reported school night sleep durations and higher BMI z scores were found in females. Although not reaching statistical significance, trends for most self-reported and actigraphy-estimated sleep duration parameters existed for longer nocturnal sleep and higher BMI z scores in both sexes.

Sleep duration and Waist to Height Ratios

Phase I. Younger ages ($F(1, 111) = 6.75$ $p = 0.01$), participating in the free/reduced lunch program ($F(1, 111) = 2.11$ $p = 0.15$), participating in fewer sports ($F(1, 111) = 2.96$, $p = 0.09$), longer school night ($F(1, 110) = 5.23$, $p = 0.02$) and total night sleep duration ($F(1, 110) = 4.23$, $p = 0.04$), and not taking naps on school days ($F(1, 111) = 2.57$, $p = 0.11$) were associated with higher WHtRs in the unadjusted general linear models. Separate adjusted general linear models were created for school night sleep duration (model 1) and total night sleep duration (model 2). In both models, age and sleep duration (school night or total night) remained predictors of WHtR (model 1: ($F(5, 105) = 3.4$, $p = 0.01$, adjusted $R^2 = 0.097$; model 2: $F(5, 106) = 3.3$, $p = 0.01$, adjusted $R^2 = 0.092$). In both models, for every one-hour increase in sleep duration, WHtR increased 0.01 (model 1: $p = 0.03$; model 2: $p = 0.04$). In both models, for every one-month decrease in age, WHtR increased 0.002 (models 1 and 2: $p = 0.03$). See Tables 37 and 38.

Phase II. Eating more fruits and vegetables ($F(1, 67) = 4.21$ $p = 0.04$), participating in fewer sports ($F(1, 67) = 2.79$ $p = 0.1$), and not taking naps on free days ($F(1, 67) = 2.12$ $p = 0.15$) were associated with higher WHtR in the unadjusted general linear models. When these variables were included in the adjusted general linear model, fruit/vegetable intake and sports participation remained predictors of WHtR explaining 11.7% of the variation in WHtR ($F(3, 65) = 4.0$, $p = 0.01$, adjusted $R^2 = 0.117$). For every one serving increase in fruit/vegetables per day, WHtR increased 0.01 ($p = 0.01$). For every one less sport team participated in per year, WHtR increased 0.01 ($p = 0.03$). See Table 39.

Table 37

Prediction of Waist to Height Ratios, Model 1: Phase I (N =113)

	Unadjusted Model			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.002	0.004, 0.001	0.011	-0.002	-0.004, 0.000	**0.034**
Sex (reference: female)	-0.008	-0.039, 0.023	0.616			
Race/ethnicity (reference: Hispanic)			0.409			
Free/reduced lunch (reference: yes)	-0.022	-0.052, 0.008	0.149	-0.014	-0.044, 0.016	0.364
Pubertal stage (reference: post)			0.342			
Eating Habits						
juice	0.008	-0.007, 0.024	0.283			
fruit/vegetables	0.001	-0.006, 0.009	0.700			
soda	-0.008	-0.021, 0.006	0.245			
milk	-0.003	-0.020, 0.015	0.745			
breakfast	0.002	-0.004, 0.007	0.551			
Physical Activity						
screen time	0.003	-0.003, 0.009	0.380			
days active	-0.001	-0.008, 0.005	0.664			
sports	-0.010	-0.022, 0.002	0.088	-0.008	-0.021, 0.005	0.209
Sleep duration						
school nights	0.012	0.002, 0.022	0.024	0.012	0.001, 0.023	0.026
free nights	0.001	-0.006, 0.009	0.715			
total night	0.013	0.000, 0.025	0.042			
Naps: school days (reference: yes)	0.023	-0.006, 0.052	0.112	0.014	-0.015, 0.044	0.305
Naps: free days (reference: yes)	0.009	-0.020, 0.039	0.538			

Note. CI: confidence intervals.

Table 38

Prediction of Waist to Height Ratios, Model 2: Phase I N = (113)

	Unadjusted Model			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.002	0.004, 0.001	0.011	-0.002	-0.004, 0	**0.033**
Sex (reference: female)	-0.008	-0.039, 0.023	0.616			
Race/ethnicity (reference: Hispanic)			0.409			
Free/reduced lunch (reference: yes)	-0.022	-0.052, 0.008	0.149	-0.018	-0.048, 0.011	0.226
Pubertal stage (reference: post)			0.342			
Eating Habits						
juice	0.008	-0.007, 0.024	0.283			
fruit/vegetables	0.001	-0.006, 0.009	0.700			
soda	-0.008	-0.021, 0.006	0.245			
milk	-0.003	-0.020, 0.015	0.745			
breakfast	0.002	-0.004, 0.007	0.551			
Physical Activity						
screen time	0.003	-0.003, 0.009	0.380			
days active	-0.001	-0.008, 0.005	0.664			
sports	-0.010	-0.022, 0.002	0.088	-0.008	-0.021, 0.005	0.227
Sleep duration						
school nights	0.012	0.002, 0.022	0.024			
free nights	0.001	-0.006, 0.009	0.715			
total night	0.013	0.000, 0.025	0.042	0.013	0.001, 0.025	**0.036**
Naps: school days (reference: yes)	0.023	-0.006, 0.052	0.112	0.013	-0.016, 0.042	0.348
Naps: free days (reference: yes)	0.009	-0.020, 0.039	0.538			

Note. CI: confidence intervals.

Table 39

Prediction of Waist to Height Ratios: Phase II (N =69)

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	0.000	-0.002, 0.002	0.775			
Sex (reference: female)	-0.018	-0.053, 0.016	0.292			
Race/ethnicity (reference: Hispanic)			0.370			
Free/reduced lunch (reference: yes)	-0.018	-0.049, 0.014	0.271			
Pubertal stage (reference: post)			0.270			
Eating Habits						
juice	0.003	-0.013, 0.019	0.701			
fruit/vegetables	0.007	0.000, 0.014	0.044	0.009	0.002, 0.016	**0.012**
soda	-0.005	-0.019, 0.008	0.439			
milk	-0.001	-0.018, 0.016	0.910			
breakfast	0.002	-0.004, 0.007	0.603			
Physical Activity						
screen time	-0.001	-0.007, 0.005	0.670			
days active	-0.001	-0.007, 0.006	0.877			
sports	-0.010	-0.023, 0.002	0.099	-0.014	-0.026, -0.002	**0.026**
Sleep duration						
school nights	0.000	-0.019, 0.020	0.977			
free nights	0.002	-0.008, 0.012	0.682			
total night	0.000	-0.021, 0.020	0.973			
Naps: school days (reference: yes)	0.016	-0.015, 0.047	0.307			
Naps: free days (reference: yes)	0.034	-0.013, 0.082	0.150	0.032	-0.012, 0.077	0.154

Note. CI: confidence intervals.

In sum, shorter sleep durations were not associated with a higher WHtR. Longer self-reported school and total night sleep were associated with higher WHtR but this association was not significant in the actigraphy-estimated sleep parameters. Eating more fruits and vegetables and participating in fewer sports were associated with higher WHtR in Phase II. Although not reaching statistical significance in Phase II, the trends for these associated was similar (more fruits and vegetable – higher WHtR; less sports participation- higher WHtR).

Sleep duration and Waist to Height Ratios in Males

Phase I. Younger ages ($F(1, 33) = 6.88$ $p = 0.01$), reporting more screen time ($F(1, 33) = 1.82$ $p = 0.19$), and sleeping longer on school nights ($F(1, 33) = 1.71$ $p = 0.2$) were associated with higher WHtRs in the unadjusted general linear models. When these variables were included in the adjusted general linear model, age remained a predictor of WHtR explaining 17.6% of the variance in WHtR ($F(3, 31) = 3.4$, $p = 0.03$ adjusted $R^2 = 0.176$). For every one-month decrease in age, WHtR increased 0.005 units ($p = 0.02$). See Table 40.

Phase II. Drinking more juice ($F(1, 16) = 4.1$ $p = 0.06$) and sleeping longer on free nights ($F(1, 16) = 3.07$ $p = 0.1$) were associated with higher WHtRs in males in the unadjusted general linear model. When these variables were included in the adjusted general linear model, none were predictors of WHtR in males. See Table 41.

Table 40

Prediction of Waist to Height Ratios by Demographic and Behavioral Characteristics in Males (n = 35): Phase I

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.004	-0.008, -0.001	0.013	-0.005	-0.008, -0.001	0.016
Race/ethnicity (reference: Hispanic)			0.902			
Free/reduced lunch (reference: yes)	0.000	-0.061, 0.061	0.992			
Pubertal category (reference: post)			0.970			
Eating Habits						
juice	0.003	-0.026, 0.033	0.815			
fruit/vegetables	-0.007	-0.024, 0.010	0.388			
soda	-0.020	-0.059, 0.019	0.305			
milk	-0.014	-0.042, 0.015	0.349			
breakfast	0.008	-0.004, 0.018	0.237			
Physical Activity						
screen time	0.008	-0.004, 0.019	0.187	0.002	-0.014, 0.011	0.803
days active	-0.007	-0.020, 0.006	0.278			
sports	-0.010	-0.034, 0.014	0.388			
Sleep duration						
school nights	0.014	-0.008, 0.037	0.200	0.018	-0.003, 0.039	0.088
free nights	0.000	-0.013, 0.013	0.939			
total night	0.013	-0.013, 0.039	0.318			
Naps: school days (reference: yes)	0.004	-0.054, 0.063	0.882			
Naps: free days (reference: yes)	-0.027	-0.084, 0.030	0.346			

Note. CI: confidence intervals.

Table 41

Prediction of Waist to Height Ratios by Demographic and Behavioral Characteristics in Males (n = 18): Phase II

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	0.001	-0.004, 0.005	0.813			
Race/ethnicity (reference: Hispanic)			0.859			
Free/reduced lunch (reference: yes)	-0.038	-0.110, 0.033	0.271			
Pubertal category (reference: post)			0.604			
Eating Habits						
juice	-0.037	-0.077, 0.002	0.060	-0.033	-0.071, 0.005	0.085
fruit/vegetables	8.2×10^{-5}	-0.018, 0.018	0.993			
soda	-0.017	-0.053, 0.018	0.315			
milk	-0.019	-0.051, 0.013	0.233			
breakfast	0.005	-0.009, 0.018	0.461			
Physical Activity						
screen time	-0.002	-0.015, 0.011	0.759			
days active	-0.008	-0.025, 0.009	0.321			
sports	-0.011	-0.037, 0.016	0.394			
Sleep duration						
school nights	-0.007	-0.051, 0.037	0.742			
free nights	0.019	-0.004, 0.042	0.099	0.016	-0.006, 0.038	0.138
total night	0.009	-0.040, 0.057	0.707			
Naps: school days (reference: yes)	-0.019	-0.090, 0.052	0.586			
Naps: free days (reference: yes)	-0.015	-0.168, 0.137	0.837			

Note. CI: confidence intervals.

Sleep duration and Waist to Height Ratios in Females

Phase I. Younger ages ($F(1, 76) = 2.1$ $p = 0.15$), participating in the free/reduced lunch program ($F(1, 76) = 3.36$ $p = 0.07$), drinking more juice ($F(1, 76) = 1.68$ $p = 0.2$), participating in fewer sports ($F(1, 76) = 6.75$ $p = 0.01$), sleeping longer on school days ($F(1, 75) = 3.84$ $p = 0.05$), and not taking naps on school days ($F(1, 77) = 3.60$ $p = 0.06$) and free days ($F(1, 76) = 2.39$ $p = 0.13$) were associated with higher WHtRs in the unadjusted general linear models. When these variables were included in the adjusted general linear model, none were predictors of WHtR in females. See Tables 42 and 43.

Phase II. Drinking more juice ($F(1, 49) = 2.29$ $p = 0.14$) and milk ($F(1, 49) = 2.26$ $p = 0.14$), eating more fruits and vegetables ($F(1, 49) = 6.01$ $p = 0.02$) being more physically active ($F(1, 49) = 2.39$ $p = 0.13$), and not taking naps on school days ($F(1, 49) = 2.72$ $p = 0.11$) and free days ($F(1, 49) = 3.53$ $p = 0.07$) were associated with higher WHtRs in females in the unadjusted general linear models. When these variables were included in the adjusted general linear model, none were predictors of WHtR in females. See Table 44.

Table 42

Prediction of Waist to Height Ratios by Demographic and Behavioral Characteristics in Females (n = 78): Model 1 Phase I

Parameter	Unadjusted Model *b*	95% CI	*p*	Model 1 *b*	95% CI	*p*
Age	-0.001	-0.003, 0.001	0.151	-0.001	-0.003, 0.001	0.302
Race/ethnicity (reference: Hispanic)			0.270			
Free/reduced lunch (reference: yes)	-0.032	-0.67, 0.003	0.071	-0.021	-0.057, 0.014	0.239
Eating Habits						
juice	0.012	-0.007, 0.031	0.199	0.005	-0.025, 0.005	0.623
fruit/vegetables	0.004	-0.004, 0.013	0.295			
soda	-0.007	-0.021, 0.008	0.353			
milk	0.009	-0.016, 0.033	0.480			
breakfast	-6×10^{-7}	-0.007, 0.007	1.000			
Physical Activity						
screen time	-8×10^{-5}	-0.007, 0.007	0.983			
days active	0.002	-0.006, 0.009	0.665			
sports	-0.010	-0.025, 0.004	0.158	-0.010	-0.025, 0.005	0.201
Sleep duration						
school nights	0.012	0.000, 0.024	0.054	0.009	-0.004, 0.021	0.161
free nights	0.002	-0.007, 0.012	0.594			
total night	0.013	-0.001, 0.027	0.068			
Naps: school days (reference: yes)	0.032	-0.002, 0.066	0.062	0.016	-0.020, 0.059	0.384
Naps: free days (reference: yes)	0.027	-0.008, 0.061	0.127	0.024	-0.012, 0.059	0.186

Note. CI: confidence intervals.

Table 43

Prediction of Waist to Height Ratios by Demographic and Behavioral Characteristics in Females (n = 78): Model 2, Phase I

Parameter	Unadjusted Model *b*	Unadjusted Model 95% CI	Unadjusted Model *p*	Model 2 *b*	Model 2 95% CI	Model 2 *p*
Age	-0.001	-0.003, 0.001	0.151	-0.001	-0.003, 0.001	0.316
Race/ethnicity (reference: Hispanic)			0.270			
Free/reduced lunch (reference: yes)	-0.032	-0.67, 0.003	0.071	-0.025	-0.060, 0.011	0.170
Eating Habits						
juice	0.012	-0.007, 0.031	0.199	0.005	-0.013, 0.024	0.574
fruit/vegetables	0.004	-0.004, 0.013	0.295			
soda	-0.007	-0.021, 0.008	0.353			
milk	0.009	-0.016, 0.033	0.480			
breakfast	-6×10^{-7}	-0.007, 0.007	1.000			
Physical Activity						
screen time	-8×10^{-5}	-0.007, 0.007	0.983			
days active	0.002	-0.006, 0.009	0.665			
sports	-0.010	-0.025, 0.004	0.158	-0.010	-0.025, 0.005	0.177
Sleep duration						
school nights	0.012	0.000, 0.024	0.054			
free nights	0.002	-0.007, 0.012	0.594			
total night	0.013	-0.001, 0.027	0.068	0.012	-0.002, 0.026	0.094
Naps: school days (reference: yes)	0.032	-0.002, 0.066	0.062	0.014	-0.022, 0.050	0.445
Naps: free days (reference: yes)	0.027	-0.008, 0.061	0.127	0.026	-0.010, 0.061	0.151

Note. CI: confidence intervals.

Table 44

Prediction of Waist to Height Ratios by Demographic and Behavioral Characteristics in Females (n = 51): Phase II

	Unadjusted Model			Adjusted Model		
Parameter	*b*	95% CI	*p*	*b*	(95% CI)	*p*
Age	0.000	-0.002, 0.002	0.875			
Race/ethnicity (reference: Hispanic)			0.338			
Free/reduced lunch (reference: yes)	-0.011	-0.048, 0.025	0.527			
Eating Habits						
juice	0.013	-0.004, 0.030	0.136	0.007	-0.010, 0.025	0.395
fruit/vegetables	0.009	0.002, 0.016	0.018	0.007	-0.001, 0.014	0.060
soda	-0.003	-0.018, 0.012	0.678			
milk	0.017	-0.006, 0.039	0.139	0.010	-0.012, 0.033	0.268
breakfast	0.001	-0.005, 0.008	0.678			
Physical Activity						
screen time	-0.001	-0.009, 0.006	0.698			
days active	0.004	-0.005, 0.012	0.389			
sports	-0.009	-0.024, 0.006	0.246			
Sleep duration						
school nights	0.003	-0.019, 0.025	0.799			
free nights	-0.004	-0.015, 0.007	0.483			
total night	-0.004	-0.027, 0.019	0.720			
Naps: school days (reference: yes)	0.028	-0.006, 0.063	0.105	0.013	-0.024, 0.050	0.357
Naps: free days (reference: yes)	0.046	-0.003, 0.095	0.066	0.034	-0.018, 0.086	0.237

Note. CI: confidence intervals.

Aim 3

The purpose of this aim was to determine if chronotype and social jet lag moderated the relationship between sleep duration and BMI z scores. Unadjusted general linear models were examined first. Variables associated with the dependent variable at the alpha level of 0.2 were selected for the adjusted general linear model as discussed in Chapter 3 to test the hypothesis that later chronotype and greater social jet lag would be associated with higher BMI z scores. Next, unadjusted general linear models for the interaction terms were examined with the significant threshold set at the alpha level of 0.05. Finally, separate general linear models for participants with the earliest and latest chronotypes were generated.

Chronotype Preference, Chronotype, Social Jet Lag and BMI z scores

Phase I. Younger ages ($F(1, 113) = 6.80$, $p = 0.01$), sex ($F(1, 113) = 2.70$, $p = 0.1$), reporting longer sleep on school nights ($F(1, 112) = 9.2$, $p = 0.003$) and total nights ($F(1, 112) = 4.34$, $p = 0.04$), and chronotype preference ($F(1, 113) = 2.8$, $p = 0.1$) were associated with higher BMI z scores in the unadjusted general linear models. Separate adjusted general linear models were created for school night sleep duration (model 1), and total night sleep duration (model 2). In both models, age and sleep duration (school night or total night) remained predictors of BMI z scores (model 1: $F(4, 109) = 4.7$, $p = 0.002$, adjusted $R^2 = 0.116$; model 2: $F(4, 109) = 3.5$, $p = 0.01$, adjusted $R^2 = 0.082$). The addition of chronotype preference to the model did not change the findings from aim 2. Similar to aim 2, for every one-month decrease in age, BMI z scores increased 0.03 ($p = 0.01$) and for every one-hour increase in sleep duration on school nights or total nights, BMI z scores increased 0.2 (model 1: $p = 0.003$; model 2: $p = 0.057$). See Tables 45 and 46.

Phase II. Sex ($F(1, 113) = 6.80$, $p = 0.01$), eating more fruit/vegetables ($F(1, 67) = 2.76$, $p = 0.10$), reporting more screen time ($F(1, 67) = 2.60$, $p = 0.11$), sleeping longer on school nights ($F(1, 67) = 2.75$, $p = 0.10$) and total nights ($F(1, 67) = 2.01$, $p = 0.16$), and napping on school days ($F(1, 67) = 5.03$, $p = 0.03$) and free days ($F(1, 67) = 8.14$, $p = 0.01$), and social jet lag ($F(1, 66) = 4.44$, $p = 0.04$) were associated with higher BMI z scores in the unadjusted general linear models. Separate adjusted general linear models were created for school night sleep duration (model 1) and total night sleep duration (model 2). Sex and social jet lag remained significant predictors of BMI z scores explaining approximately 21% of the variation (model 1: $F\ (7, 60) = 3.5$, p = 0.003, adjusted $R^2 = 0.208$; model 2: $F(7, 60) = 3.5$, p = 0.004, adjusted $R^2 = 0.205$). Compared to females, BMI z scores were 0.5 units higher in males ($p = 0.04$ for both models). For every one-hour increase in social jet lag, BMI z scores increase 0.3 units ($p = 0.01$ for both models). See Tables 47 and 48.

Table 45

Prediction of BMI z scores by Socio-demographic Characteristics, Behavioral Characteristics, Chronotype Preference, Chronotype, and Social Jet Lag, Model 1 Phase I (N = 115)

	Unadjusted Model			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.03	-0.05, -0.01	0.010	-0.03	-0.05, -0.01	**0.013**
Sex (reference: female)	0.35	-0.07, 0.76	0.103	0.25	-0.15, 0.65	0.225
Race/ethnicity (reference: Hispanic)			0.431			
Free/reduced lunch (reference: yes)	-0.26	-0.66, 0.15	0.213			
Pubertal category (reference: post)			0.212			
Eating Habits						
juice	0.04	-017, 0.25	0.710			
fruit/vegetables	0.04	-0.06, 0.14	0.449			
soda	-0.10	-0.28, 0.08	0.289			
milk	0.05	-0.19, 0.28	0.686			
breakfast	0.04	-0.04, 0.11	0.344			
Physical Activity						
screen time	-0.01	-0.09, 0.07	0.821			
days active	0.04	-0.04, 0.12	0.355			
sports	-0.02	-0.19, 0.14	0.781			
Sleep duration						
school nights	0.21	0.07, 0.34	0.003	0.20	0.07, 0.33	**0.003**
free nights	-0.04	-0.14, 0.06	0.440			
total night	0.17	0.01, 0.33	0.040			
Naps: school days (reference: yes)	0.18	-0.21, 0.57	0.356			
Naps: free days (reference: yes)	0.05	-0.34, 0.45	0.794			
Chronotype preference (M/E Q)	0.04	-0.01, 0.09	0.096	0.01	-0.04, 0.06	0.613
Chronotype (midpoint of sleep)	0.02	-0.11, 0.15	0.773			
Social jet lag	0.02	-0.12, 0.16	0.806			

Note. CI: confidence intervals.

Table 46

Prediction of BMI z scores by Socio-demographic Characteristics, Behavioral Characteristics, Chronotype Preference, Chronotype, and Social Jet Lag, Model 2: Phase I (N = 115)

	Unadjusted Model			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.03	-0.05, -0.01	0.010	-0.03	-0.05, -0.01	**0.018**
Sex (reference: female)	0.35	-0.07, 0.76	0.103	0.27	-0.14, 0.68	0.225
Race/ethnicity (reference: Hispanic)			0.431			
Free/reduced lunch (reference: yes)	-0.26	-0.66, 0.15	0.213			
Pubertal category (reference: post)			0.212			
Eating Habits						
juice	0.04	-017, 0.25	0.710			
fruit/vegetables	0.04	-0.06, 0.14	0.449			
soda	-0.10	-0.28, 0.08	0.289			
milk	0.05	-0.19, 0.28	0.686			
breakfast	0.04	-0.04, 0.11	0.344			
Physical Activity						
screen time	-0.01	-0.09, 0.07	0.821			
days active	0.04	-0.04, 0.12	0.355			
sports	-0.02	-0.19, 0.14	0.781			
Sleep duration						
school nights	0.21	0.07, 0.34	0.003			
free nights	-0.04	-0.14, 0.06	0.440			
total night	0.17	0.01, 0.33	0.040	0.15	-0.01, 0.31	0.057
Naps: school days (reference: yes)	0.18	-0.21, 0.57	0.356			
Naps: free days (reference: yes)	0.05	-0.34, 0.45	0.794			
Chronotype preference (M/E Q)	0.04	-0.01, 0.09	0.096	0.02	-0.03, 0.07	0.427
Chronotype (midpoint of sleep)	0.02	-0.11, 0.15	0.773			
Social jet lag	0.02	-0.12, 0.16	0.806			

Note. CI: confidence intervals.

Table 47

Prediction of BMI z scores by Socio-demographic Characteristics, Behavioral Characteristics, Chronotype Preference, Chronotype, and Social Jet Lag, Model 1: Phase II (N = 69)

	Unadjusted Model			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.04, 0.02	0.484			
Sex (reference: female)	0.36	-0.14, 0.86	0.157	0.49	0.01, 0.97	**0.044**
Race/ethnicity (reference: Hispanic)			0.749			
Free/reduced lunch (reference: yes)	-0.13	-0.60, 0.33	0.571			
Pubertal category (reference: post)			0.418			
Eating Habits						
juice	0.001	-0.24, 0.24	0.993			
fruit/vegetables	0.09	-0.02, 0.19	0.101	0.07	-0.02, 0.17	0.132
soda	-0.08	-0.28, 0.12	0.432			
milk	0.06	-0.19, 0.31	0.618			
breakfast	0.05	-0.04, 0.13	0.256			
Physical Activity						
screen time	-0.07	-0.16, 0.02	0.112	-0.05	-0.13, 0.04	0.297
days active	0.06	-0.04, 0.16	0.268			
sports	0.00	-0.19, 0.19	0.996			
Sleep duration						
school nights	0.23	-0.05, 0.51	0.102	0.09	-0.17, 0.36	0.500
free nights	0.05	-0.10, 0.20	0.501			
total night	0.21	-0.09, 0.50	0.161			
Naps: school days (reference: yes)	0.50	0.05, 0.94	0.028	0.28	-0.17, 0.73	0.221
Naps: free days (reference: yes)	0.95	0.28, 1.61	0.006	0.49	-0.22, 1.19	0.172
Chronotype preferences (M/E Q)	0.03	-0.02, 0.08	0.244			
Chronotype (midpoint of sleep)	0.11	-0.08, 0.31	0.238			
Social jet lag	0.26	0.01, 0.50	0.039	0.33	0.09, 0.57	**0.007**

Note. CI: confidence intervals.

Table 48

Prediction of BMI z scores by Socio-demographic Characteristics, Behavioral Characteristics, Chronotype Preference, Chronotype, and Social Jet Lag, Model 2: Phase II (N =69)

	Unadjusted Model			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.01	-0.04, 0.02	0.484			
Sex (reference: female)	0.36	-0.14, 0.86	0.157	0.50	0.02, 0.99	**0.042**
Race/ethnicity (reference: Hispanic)			0.749			
Free/reduced lunch (reference: yes)	-0.13	-0.60, 0.33	0.571			
Pubertal category (reference: post)			0.418			
Eating Habits						
juice	0.001	-0.24, 0.24	0.993			
fruit/vegetables	0.09	-0.02, 0.19	0.101	0.07	-0.02, 0.16	0.139
soda	-0.08	-0.28, 0.12	0.432			
milk	0.06	-0.19, 0.31	0.618			
breakfast	0.05	-0.04, 0.13	0.256			
Physical Activity						
screen time	-0.07	-0.16, 0.02	0.112	-0.05	-0.13, 0.04	0.287
days active	0.06	-0.04, 0.16	0.268			
sports	0.00	-0.19, 0.19	0.996			
Sleep duration						
school nights	0.23	-0.05, 0.51	0.102			
free nights	0.05	-0.10, 0.20	0.501			
total night	0.21	-0.09, 0.50	0.161	0.07	-0.23, 0.36	0.653
Naps: school days (reference: yes)	0.50	0.05, 0.94	0.028	0.28	-0.19, 0.75	0.234
Naps: free days (reference: yes)	0.95	0.28, 1.61	0.006	0.50	-0.21, 1.20	0.164
Chronotype preferences (M/E Q)	0.03	-0.02, 0.08	0.244			
Chronotype (midpoint of sleep)	0.11	-0.08, 0.31	0.238			
Social jet lag	0.26	0.01, 0.50	0.039	0.34	0.10, 0.58	**0.006**

Note. CI: confidence intervals.

The Moderating Effect of Chronotype Preference, Chronotype, Social Jet Lag on Sleep Duration and BMI z scores

Phase I. The interactions between chrontoype preference, chronotype, and social jet lag with sleep duration parameters on BMI z scores were not significant at the alpha level of 0.05. See Table 49.

Phase II. The interactions between chrontoype preference with sleep duration parameters on BMI z scores were not significant at the alpha level of 0.05. See Table 50.

Table 49

The Moderating Effect of Chronotype Preference, Chronotype, and Social Jet Lag on the Association between Sleep Duration and BMI z scores: Phase I (N =115)

	Unadjusted Model		
Parameter	*b*	95% CI	*p*
Interaction with school night sleep duration			
Chronotype preference (M/E Q)	-0.004	-0.042, 0.33	0.827
Chronotype (midpoint of sleep)	0.04	-0.05, 0.12	0.374
Social jet lag	0.04	-0.05, 0.13	0.369
Interaction with free night sleep duration			
Chronotype preference (M/E Q)	-0.02	-0.04, 0.01	0.258
Chronotype (midpoint of sleep)	0.02	-0.05, 0.09	0.563
Social jet lag	-0.02	-0.09, 0.04	0.496
Interaction with total night sleep duration			
Chronotype preference (M/E Q)	-0.01	-0.06, 0.04	0.661
Chronotype (midpoint of sleep)	0.08	-0.04, 0.19	0.172
Social jet lag	0.06	-0.06, 0.17	0.328

Note. CI: confidence intervals.

Table 50

The Moderating Effect of Chronotype Preference on Sleep Duration's association with BMI z scores: Phase II (N = 69)

	Unadjusted Model		
Parameter	*b*	95% CI	*p*
Interaction with school night sleep duration			
Chronotype preference (M/E Q)	0.03	-0.05, 0.11	0.479
Interaction with free night sleep duration			
Chronotype preference (M/E Q)	-0.01	-0.05, 0.02	0.391
Interaction with total night sleep duration			
Chronotype preference (M/E Q)	0.00	-0.08, 0.08	0.995

Note. CI: confidence intervals.

Sleep Duration and BMI z scores in Early Chronotypes

Phase I. Reporting more screen time was the only predictor of higher BMI z scores in participants with early chronotypes explaining 12.7% of the variation of BMI z scores **(**$F(1, 21) = 4.2$, p = 0.05, adjusted $R^2 = 0.127$). For every one hour increase in screen time, BMI z scores increased 0.14 in participants with early chronotypes (p = 0.05). See Table 51.

Table 51

Prediction of BMI z scores in Early Chronotypes (midpoint of sleep < 2:42): Phase I (n = 23)

Parameter	*b*	95% CI	*p*
Age	-0.02	-0.06, 0.02	0.280
Sex (reference: female)	0.43	-0.49, 1.35	0.340
Race/ethnicity (reference: Hispanic)			0.985
Free/reduced lunch (reference: yes)	-0.07	-0.84, 0.70	0.850
Pubertal category (reference: post)			0.369
Eating Habits			
juice	0.18	-0.18, 0.53	0.321
fruit/vegetables	0.02	-0.23, 0.26	0.890
soda	0.07	-0.34, 0.48	0.712
milk	0.20	-0.21, 0.61	0.315
breakfast	-0.07	-0.20, 0.06	0.284
Physical Activity			
screen time	0.14	0.00, 0.28	**0.053**
days active	0.06	-0.13, 0.24	0.527
sports	-0.06	-0.40, 0.28	0.708
Sleep duration			
school nights	-0.03	-0.33, 0.26	0.822
free nights	-0.04	-0.30, 0.22	0.771
total night	-0.06	-0.45, 0.32	0.739
Naps: school days (reference: yes)	0.42	-0.28, 1.13	0.225
Naps: free days (reference: yes)	-0.18	-0.89, 0.53	0.601
Chronotype preference (M/E Q)	-0.04	-0.15, 0.07	0.484
Social jet lag	0.13	-0.19, 0.45	0.409

Note. CI: confidence intervals.

Sleep Duration and BMI z scores in Late Chronotypes

Phase I. Younger ages (*F*(1, 22) = 3.51 *p* = 0.07), sleeping longer on school nights (*F*(1, 22) = 2.34, *p* = 0.08) and total nights (*F*(1, 22) = 2.6, *p* = 0.12), and reporting greater social jet lag (*F*(1, 22) = 5.81, *p* = 0.03) were associated with higher BMI z scores in participants with later chronotypes in the unadjusted general linear models. When these variables were included in separate adjusted general linear models for school night sleep duration (model 1) and total night sleep duration (model 2), none remained predictors of BMI z scores at the alpha level of 0.05 (see Tables 53 and 54).

Table 52

Prediction of BMI z scores in Late Chronotypes, (midpoint of sleep ≥ 5:06) Model 1: Phase I (n = 24)

	Unadjusted Model			Model 1		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.04	0.09, 0.01	0.074	-0.04	-0.09, 0.01	0.124
Sex (reference: female)	0.29	-0.57, 1.14	0.492			
Race/ethnicity (reference: Hispanic)			0.287			
Free/reduced lunch (reference: yes)	-0.20	-1.06, 0.66	0.639			
Pubertal stage (reference: post)			0.286			
Eating Habits						
juice	-0.21	-0.72, 0.29	0.392			
fruit/vegetables	0.06	-0.08, 0.21	0.384			
soda	-0.09	-0.48, 0.30	0.645			
milk	0.03	-0.36, 0.43	0.863			
breakfast	0.03	-0.15, 0.20	0.769			
Physical Activity						
screen time	-0.07	-0.28, 0.15	0.529			
days active	0.07	-0.10, 0.23	0.420			
sports	0.13	-0.24, 0.49	0.477			
Sleep duration						
school nights	0.22	-0.03, 0.47	0.081	0.20	-0.05, 0.45	0.115
free nights	-0.02	-0.22, 0.19	0.849			
total night	0.27	-0.07, 0.60	0.118			
Naps: school days (reference: yes)	-0.52	-1.37, 0.33	0.220			
Naps: free days (reference: yes)	-0.56	-1.52, 0.39	0.234			
Chronotype preference (M/E Q)	0.04	-0.08, 0.17	0.482			
Social jet lag	0.39	0.05, 0.72	0.025	0.19	-0.19, 0.57	0.308

Note. CI: confidence intervals.

Table 53

Prediction of BMI z scores in Late Chronotypes Prediction of BMI z scores in Late Chronotypes, (midpoint of sleep ≥ 5:06) Model 2: Phase I (n = 24)

	Unadjusted Model			Model 2		
Parameter	*b*	95% CI	*p*	*b*	95% CI	*p*
Age	-0.04	0.09, 0.01	0.074	-0.04	-0.09, 0.01	0.124
Sex (reference: female)	0.29	-0.57, 1.14	0.492			
Race/ethnicity (reference: Hispanic)			0.287			
Free/reduced lunch (reference: yes)	-0.20	-1.06, 0.66	0.639			
Pubertal stage (reference: post)			0.286			
Eating Habits						
juice	-0.21	-0.72, 0.29	0.392			
fruit/vegetables	0.06	-0.08, 0.21	0.384			
soda	-0.09	-0.48, 0.30	0.645			
milk	0.03	-0.36, 0.43	0.863			
breakfast	0.03	-0.15, 0.20	0.769			
Physical Activity						
screen time	-0.07	-0.28, 0.15	0.529			
days active	0.07	-0.10, 0.23	0.420			
sports	0.13	-0.24, 0.49	0.477			
Sleep duration						
school nights	0.22	-0.03, 0.47	0.081			
free nights	-0.02	-0.22, 0.19	0.849			
total night	0.27	-0.07, 0.60	0.118			
Naps: school days (reference: yes)	-0.52	-1.37, 0.33	0.220	0.19	-0.14, 0.53	0.242
Naps: free days (reference: yes)	-0.56	-1.52, 0.39	0.234			
Chronotype preference (M/E Q)	0.04	-0.08, 0.17	0.482			
Social jet lag	0.39	0.05, 0.72	0.025	0.19	-0.19, 0.57	0.308

Note. CI: confidence intervals.

In sum, chronotype preference, chronotype, and social jet lag did not have a moderating effect on the association between sleep duration and BMI z scores. However, social jet lag did have a main effect on BMI z scores, such that greater social jet lag, calculated from actigraphy-estimated sleep parameters, was associated with higher BMI z scores. When stratified by early and late chronotypes, only screen time remained a predictor of BMI z scores in early chronotypes. However, caution is warranted in interpreting the findings from these stratified samples due to the small sample sizes.

Aim 4

The purpose of this aim was to assess the validity of the Morningness/Eveningness Questionnaire, the Munich Chronotype Timing Questionnaire, and actigraphy measurements for estimating chronotype in 9th and 10th grade students. Associations between chronotype preference (Morningness/Eveningness Questionnaire) and chronotype (midpoint of sleep estimated from the Munich Timing Questionnaire and from actigraphy) were determined as described in Chapter 3.

The Morningness/Eveningness Questionnaire and Midpoints of Sleep. The Morningness/Eveningness Questionnaire was significantly associated with the midpoint of sleep estimated from the Munich Chronotype Timing Questionnaire ($r = -0.3$, $p < .001$) and the midpoint of sleep estimated from actigraphy ($r = -0.3$, $p < .05$). Correlation coefficients from the Pearson's product moment correlation and Spearman's rank order correlation were consistent. See Table 54.

Midpoints of sleep estimated by the Munich Chronotype Timing Questionnaire and actigraphy. Midpoints of sleep calculated from the Munich Chronotype Timing Questionnaire were not significantly associated with midpoints of sleep calculated from actigraphy ($r = 0.1$, $p = 0.4$). See Table 4.50. To estimate the level of agreement between these two methods, Bland Altman plots were generated (Bland & Altman, 1986). The midpoint of sleep calculated from the Munich Chronotype Timing Questionnaire was approximately 0.6 hours later than the midpoint of sleep calculated from actigraphy. The standard deviation of the mean differences was 1.83, hence, the lower 95% limit of agreement was -3.06 and the upper 95% limit of agreement was 4.27 (Bland 1995). Visual inspection of the plot suggests that the scatter of the differences increased as the midpoint of sleep increased, implying that the methods did not agree equally throughout the range (Bland 1986). Figure 4 plots the differences between the midpoints of sleep calculated from the Munich Chronotype Timing Questionnaire and from actigraphy against the average of these two values.

Table 54

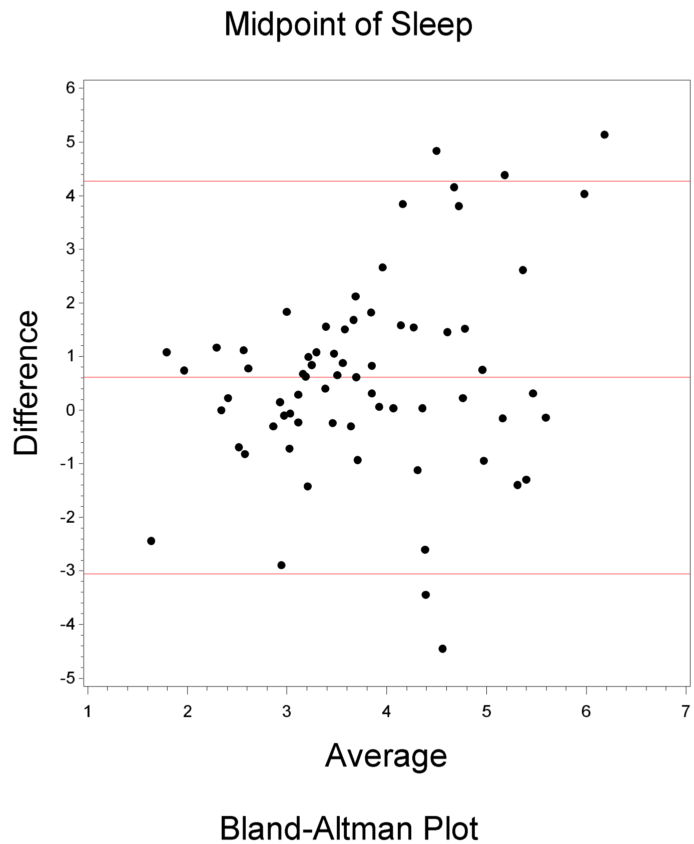
Correlation Coefficients between the Morningness/Eveningness Questionnaire and the Midpoints of Sleep Estimated from the Munich Chronotye Timing Questionnaire and Actigraphy

	M/E Q		MCTQ	
	Pearson's Correlation coefficient	*Spearman's Correlation Coefficient*	*Pearson's Correlation coefficient*	*Spearman's Correlation Coefficient*
Midpoint of sleep				
MCTQ[a]	-0.34***	-0.36***		
Actigraphy-estimated[b]	-0.28*	-0.27*	0.12	0.18

Note. * $p < .05$, ** $p < .01$, *** $p < .001$ [a] n = 115 [b] n = 68

Figure 4

Differences versus mean plot for Midpoint of Sleep Calculated from the Munich Chronotype Timing Questionnaire and Actigraphy



CHAPTER 5: DISCUSSION

There were several major findings from this study. First, racial/ethnic differences in free night sleep duration were identified. Second, there were demographic and behavioral differences between participants with different chronotypes. Finally, there was a positive association between sleep duration and BMI z scores as well as between social jet lag and BMI z scores. In this chapter, each major finding will be discussed within the context of the existing literature. Implications for practice and policy and recommendations for future research will follow.

Racial /Ethnic Differences in Sleep Duration

Black participants had significantly shorter self-reported and actigraphy-estimated sleep on free nights than Hispanic participants. To our knowledge, this is the first study to report racial/ethnic differences specifically for *free* night sleep in adolescents. Although not reaching statistical significance, there was a trend for Black participants to have shorter self-reported and actigraphy-estimated free night sleep than White participants. Differences in free night sleep duration between Black and White participants may not have reached statistical significance because of our small sample size. There were no significant racial/ethnic differences in self-reported or actigraphy-estimated for any other nocturnal sleep parameters.

Mixed evidence for racial/ethnic differences in adolescent self-reported school and total night sleep durations exist. Black adolescents have reported shorter school night sleep and less total sleep than White and Hispanic adolescents (Lowry et al., 2012; Maslowsky & Ozer, 2013; Organek et al., 2015; Williams, Zimmerman, & Bell, 2013). In other studies, White adolescents have reported less total sleep than Black, but more total sleep than Hispanic adolescents (Organek et al., 2015; Williams et al., 2013). Reasons for these disparate self-reported findings may stem from parent-reported versus self-reported sleep and total sleep (potentially including naps) versus nocturnal sleep. Our findings may portray self-reported sleep more accurately because parents often overestimated their teens sleep duration (Short, Gradisar, Lack, Wright, & Chatburn, 2013). Differences may also stem from whether participants were queried using one question about usual sleep duration or two questions about sleep duration on school nights and free nights. Blacks, but not Whites, have typically reported different sleep durations on weeknights and weekends (Lauderdale, 2014).

Shorter actigraphy-estimated sleep duration parameters have been reported in Black compared to White adolescents (particularly males) (M. H. Hall et al., 2014; Matthews, Hall, & Dahl, 2014; M. Moore et al., 2011). Together, this study contributes to the limited evidence of racial/ethnic differences in adolescent self-reported and actigraphy-estimated sleep duration.

Demographic Differences between Chronotype Preferences and Chronotypes

Age. Increasing age was associated with increasing lateness in chronotype preference, meaning a preference for later sleep times, but not chronotype, meaning later sleep onsets. This is consistent with extensive evidence of shifts towards lateness in chronotype preferences during adolescence (M. A. Carskadon et al., 1993; J. F. Diaz-Morales, Escribano, Jankowski, Vollmer, & Randler, 2014; J. F. Diaz-Morales, Sorroche, M.G., 2008; Hagenauer & Lee, 2012; Koscec, Radosevic-Vidacek, & Bakotic, 2014; Park et al., 2002; Randler, 2011c; Russo, Bruni, Lucici, Ferri, & Violani, 2007; Yang, Kim, Patel, & Lee, 2005). These findings also support evidence that shifts in chronotype lateness begin around the age of 14, *after* shifts in chronotype preference lateness have plateaued (Koscec et al., 2014).

Sex. No differences in chronotype preferences were detected between males and females, but males reported later chronotypes than females as has been reported by others (Borchers & Randler, 2012; Koscec et al., 2014; Randler, 2011b; Roenneberg et al., 2004). Despite conflicting evidence related to sex differences in chronotype preferences (Collado Mateo, Diaz-Morales, Escribano Barreno, Delgado Prieto, & Randler, 2012; J. F. Diaz-Morales, Sorroche, M.G., 2008; Gaina et al., 2006; Randler, 2011b), these data are consistent with most studies reporting no differences in chronotype preferences between adolescent males and females (S. F. Gau & Soong, 2003; Giannotti et al., 2002; Park et al., 2002; Russo et al., 2007).

Behavioral Differences between Chronotype Preferences and Chronotypes

There is limited evidence that adolescents with later chronotypes are more likely to engage in unhealthy behaviors than adolescents with earlier chronotypes (Fleig & Randler, 2009; Schaal et al., 2010; Urban, Magyarodi, & Rigo, 2011). These data extend this evidence to racially diverse high school students with regard to fruit, vegetable, and soda consumption, physical activity, and daytime napping. If these behavioral patterns persist over time, youth with later chronotypes may be at greater risk for obesity.

Fruit and vegetable consumption. Increasing lateness in chronotype preferences was associated with eating fewer fruits and vegetables. Few studies have reported fruit and vegetable intake in adolescents with different chronotypes and findings are inconsistent (Arora & Taheri, 2015; Fleig & Randler, 2009). However, both studies indicate that adolescents with later chronotypes have poorer dietary behaviors overall compared to their earlier counterparts (e.g. fewer fruits/vegetables, more unhealthy snacks, more fast food).

Soda consumption. Increasing lateness in chronotype preferences was associated with drinking more soda. This is consistent with previous reports that adolescents with later chronotypes drink more caffeinated beverages (including soda) than their earlier counterparts (Arora & Taheri, 2015; Fleig & Randler, 2009; Giannotti et al., 2002). Individuals with later chronotypes may drink more caffeinated beverages to adapt better to daytime hours (Giannotti et al., 2002).

Physical activity. Increasing lateness in chronotype preferences and later self-reported chronotypes were associated with less physical activity (days per week). This is consistent with previous findings in adolescents (Gaina et al., 2006; Schaal et al., 2010).

Daytime naps. Increasing lateness in chronotype preferences and chronotype were significantly associated with increases in self-reported free day naps and actigraphy-estimated school day naps respectively. This is consistent with findings that Tiawanese and Italian adolescents with later chronotype preferences are more likely to nap than their earlier counterparts (S. F. Gau & Soong, 2003; Giannotti et al., 2002). This suggests that adolescents with later chronotypes compensate for shorter nocturnal sleep by taking naps.

Sleep duration and BMI

The hypothesis that shorter sleep duration would be associated with higher BMI z scores was not supported. On the contrary, a positive association between sleep duration and BMI z scores was found. Although not reaching statistical significance, there was also a positive association between actigraphy-estimated sleep duration and BMI z scores. These unexpected findings are inconsistent with most studies that have reported an inverse relationship between self-reported and actigraphy-estimated sleep duration and BMI (Arora et al., 2013; Arora & Taheri, 2015; M. Y. Chen et al., 2006; Garaulet et al., 2011; Gupta et al., 2002; J. A. Lee & Park, 2014; M. Moore et al., 2011; Morley et al., 2012; Noland, Price, Dake, & Telljohann, 2009; Seicean et al., 2007; Wells et al., 2008). Possible reasons for disparate findings for the association between self-reported sleep duration and BMI include our small sample with a limited number of participants reporting very short sleep, our narrow age range, and our greater percentage of female participants.

Several studies found an inverse association only in adolescents reporting very short sleep (e.g. less than six hours) suggesting that a certain threshold for short sleep needs to be reached before an inverse association emerges (M. Y. Chen et al., 2006; J. A. Lee & Park, 2014; Lowry et al., 2012; Seicean et al., 2007). Our ability to detect an inverse relationship in a subgroup of very short sleepers may have been limited because few participants in our sample reported sleeping less than six hours per night, even on school nights (n = 18). Another reason for inconsistent findings is the narrow age range of our participants. Evidence of an inverse relationship between sleep duration and BMI is consistent in children, but less consistent in adults (Nielsen et al., 2011). Including children and adolescents in analyzing this relationship in other studies may have obfuscated differences in the relationship between sleep duration and BMI between these groups. Several studies reported an inverse relationship in adolescent males, but not females (Chaput, Brunet, & Tremblay, 2006; Eisenmann et al., 2006; Knutson, 2005; Ramos & Barros, 2007). The smaller percentage of males in our sample may have been another factor limiting our ability to detect an inverse relationship.

Additional reasons for disparate findings between actigraphy-estimated sleep duration and BMI include differences in the duration and type of actigraphy data collected. Gupta et al. (2002) collected actigraphy data for 24 hours, as opposed to seven continuous days, despite the low reliability of 24-hour actigraphy (Pearson's r = 0.25-0.37) (Acebo et al., 1999). Gupta et al. (2002) also estimated total sleep, including naps, whereas, our analysis included strictly nocturnal sleep. Analyzing total sleep may have differentiated adolescents with short nocturnal sleep who do take naps (longer total sleep) from those who do not take naps (shorter total sleep).

Nonetheless, the relationship between sleep duration and BMI in adolescents is inconclusive. Studies have also reported a U-shaped association in females (Lowry et al., 2012), no association in males or females (Calamaro et al., 2010; Gates, 2013; Kong et al., 2013), and a positive association between self-reported sleep duration and BMI (Biggs & Dollman, 2007; Lowry et al., 2012; Lytle et al., 2011; Sun et al., 2009). Our data are consistent with these latter reports.

Social Jet Lag and BMI

The regularity of sleep-wake timing can be estimated by differences in the midpoint of sleep on school days and free days, or social jet lag. Our most important finding was that greater social jet lag was associated with higher BMI z scores using actigraphy-estimated sleep parameters. These data are consistent with reports that greater social jet lag calculated from self-reported sleep parameters and BMI calculated from self-reported heights and weights is associated with higher BMI in adolescents and adults (Randler, Haun, & Schaal, 2013; Roenneberg et al., 2012). In our study, this association did not reach statistical significance when social jet lag was calculated from self-reported sleep parameters. These discrepancies may be attributed to greater precision of the actigraphy data collected. For example, the average midpoint of sleep was calculated from multiple nights of actigraphy-estimated sleep-wake times as opposed to one night of self-reported sleep-wake time. Another possible reason is seasonal differences in sleep duration and social jet lag. More social jet lag has been reported during daylight savings times (between March and October) (Allebrandt et al., 2014). Self-reported data was collected between October and January, whereas, actigraphy-estimated data was collected between late January and May in this study.

Other methods of calculating regular sleep-wake timing exist and have reported similar findings. For example, Moore et al. (2011) reported higher BMI in adolescents with greater actigraphy-estimated night-to-night variability in sleep-wake timing calculated using the coefficient of variation of total sleep time. Lytle et al. (2011) also found higher BMI z scores in adolescent females reporting the greatest differences in bed times and wake times between school nights and free nights.

Chronotype and BMI

The hypothesis that the relationship between sleep duration and higher BMI z scores would be stronger in adolescents with later chronotypes was not supported. There was no association between any chronotype parameter and BMI. Additionally, chronotype and social jet lag did not moderate the relationship between sleep duration and BMI. Existing evidence of associations between chronotype and BMI are limited and inconsistent (Arora & Taheri, 2015; Culnan, Kloss, & Grandner, 2013; Roenneberg et al., 2012). However, if obesity is impacted by the duration of exposure related to chronotype, differences in BMI may not yet be detectable in adolescents. Support for this theory is garnered from evidence that the risk of developing other chronic diseases depends on the duration of exposure to circadian misalignment (i.e. type 2 diabetes and shift work) (Pan, Schernhammer, Sun, & Hu, 2011).

Chronotype Measurements

Convergent validity between the Morningness/Eveningness Questionnaire and Midpoints of Sleep calculated from the Munich Chronotype Timing Questionnaire and from actigraphy. The hypothesis that the Morningness/Eveningness Questionnaire would be correlated with midpoints of sleep calculated from self-reported sleep parameters on the Munich Chronotype Timing Questionnaire and actigraphy-estimated sleep parameters was supported. The strength of this correlation was weak but closely aligned with correlations between these measures reported in Croatian adolescents ($r = -0.4$ for 13 to 15 year olds, $p < 0.001$) (Koscec et al., 2014).

These results extend convergent validity between the Morningness/Eveningness Questionnaire and the midpoints of sleep calculated from the Munich Chronotype Timing Questionnaire to racially/ethnically diverse US adolescents. Potential reasons for weak correlations stem from the narrow age range of participants in this study and the correction for oversleep on free nights applied to the midpoint of sleep estimate (Di Milia, Adan, Natale, & Randler, 2013). Additionally, the Morningness/Eveningness Questionnaire and midpoints of sleep measure different aspects of a common underlying phenomenon. The Morningness/Eveningness Questionnaire provides an estimate of psychological preferences for activity and rest. The midpoint of sleep provides a biomarker for sleep-wake behavior (Di Milia et al., 2013).

Concordance between the Midpoint of Sleep calculated from Self-reported versus Actigraphy-estimated Sleep Parameters. The hypothesis that the midpoint of sleep calculated from self-reported sleep parameters would be correlated with the midpoint of sleep calculated from actigraphy-estimated sleep parameters was not supported. Few studies have evaluated midpoints of sleep calculated from the Munich Chronotype Timing Questionnaire with actigraphy. High levels of concordance between the midpoints of sleep calculated from parent-reported and actigraphy-estimated sleep parameters were reported (Spearmans correlation = 0.70) (Werner et al., 2009). Differences may be explained by modifications of the questionnaire for parent responses about the sleep patterns of their child (4 to 11 years old) and by the participants' completion of the measurements within a closer time period than the current study (Werner et al., 2009).

Further evaluation for the level of agreement between these two measurement methods using the Bland-Altman approach identified discrepancies of up to four hours (Bland & Altman, 1986). This exceeds an a priori determined acceptable limit of 30 minutes suggesting that these two measures are not interchangeable. However, conclusions cannot be confirmed based on these findings because self-reported and actigraphy-estimated measurements were not concurrent. The lack of correlation and agreement could reflect true variation in sleep-wake timing due to differences in social commitments between these time periods. Sports team participation during one season, but not another, may have introduced considerable variability in weekend sleep-wake timing. Differences between other self-reported and actigraphy-estimated sleep parameters, such as sleep duration, have been reported previously in adolescents (Short et al., 2012).

Implications for Practice and Policy

Today's obese adolescents are tomorrow's obese adults (Gordon-Larsen et al., 2010). The high percentage of overweight youth in this sample and nationally bodes poorly for reversing obesity trends (Ogden, Carroll, Kit, & Flegal, 2014). High percentages of abdominal obesity in this sample and nationally raise further concerns for cardio-metabolic health (Caprio, 2012; Ford, Ajani, Mokdad, National, & Nutrition, 2005; Li, Ford, Mokdad, & Cook, 2006; Pi-Sunyer, 2006). Effective strategies using multi-factorial innovative approaches for preventing obesity are urgently needed.

The associations identified in this study between chronobiological factors and obesity, such as sleep-wake timing and chronotype, present novel opportunities for interventions. The overall goal of these interventions is to align the timing of specific behaviors (e.g. sleep-wake, activity-rest) with individual biological rhythms. This approach resonates with growing interest in personalized preventative care. Within this context, several interventions known to influence sleep-wake timing and chronotype are proposed.

Delaying school start times to align with developmental delays in sleep-wake timing is one promising intervention (Adolescent Sleep Working Group, 2014; M. A. Carskadon et al., 1998; Wahlstrom, 2002). Initial concerns that these delays would lead to further delays in bed times have not come to fruition (Owens et al., 2010; Wahlstrom, 2002). Rather, schools that have delayed start times by one hour report 45 to 60 minute increases in student's sleep duration, improved attendance, reduced tardiness, and less daytime sleepiness (Owens et al., 2010; Wahlstrom, 2002). This evidence has led to policy statements supporting the delay of middle school and high school start times until 8:30 (Adolescent Sleep Working Group, 2014). In 2011-2012, 86% of over 18,000 public high schools started school before 8:30 (US Department of Education & National Center for Education Statistics).

The Northeast coastal city school district where this study took place advanced school start times from 8:00 to 7:30 the year data were collected. Only nine percent of study participants reported the recommended number of hours sleep on school nights compared to 11% (10^{th} grade) and 17% (9^{th} grade) nationally. Reported wake times were 20 to 30 minute earlier than nationally representative samples (M. Carskadon & Acebo, 2002; National Sleep Foundation, 2006; US Department of Health and Human Services). Irregular sleep-wake times, an indicator of insufficient sleep, were also evident in study participants (Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009). There were two to four hour differences in wake times on average between school days and weekends. Forty percent to 68% had greater than or equal to two hours of social jet lag and over 40% reported school day naps.

Whether or not “sleeping in” on weekends and daytime naps are beneficial compensatory mechanisms for insufficient nocturnal sleep is undetermined (M. H. Hall, Lee, & Matthews, 2015; McDevitt, Alaynick, & Mednick, 2012; Pilcher, Michalowski, & Carrigan, 2001; Wing, Li, Li, Zhang, & Kong, 2009). These data do not support this because daytime naps lead to irregular sleep (Vela-Bueno et al., 2008) and greater social jet lag was associated with higher BMI z scores. Furthermore, “sleeping in” and taking naps would not be needed if adolescents had enough nocturnal sleep. Regular sleep-wake times during summer vacation indicate that adolescents can achieve regular sleep-wake times. Irregular sleep-wake times once school begins in September indicate that school schedules may be a critical factor contributing this irregularity (Hansen, Janssen, Schiff, Zee, & Dubocovich, 2005; Warner, Murray, & Meyer, 2008). Current recommendations for delaying school start times 30 to 60 minutes are a promising intervention for increasing school night sleep duration, but may fall short of achieving regular sleep-wake times, particularly in adolescents with later chronotypes (Owens et al., 2010; Wahlstrom, 2002).

Innovative approaches to flexibly configuring school days (e.g. start times, class schedules) are needed to accommodate these individual differences in chronotype. School nurses should work with health educators to help students determine their unique chronotype. This 10-item Morningness/Eveningness Questionnaire may be completed and scored briefly during health class. School nurses, together with health educators, can help students identify their chronotype preference relative to their peers. Students can use this information to determine times that they will feel and perform best for certain activities, including exercise. For example, youth with earlier chronotypes will be best suited for morning physical activity, whereas, youth with later chronotypes will be better suited for afternoon physical activity. This may influence adherence to regular physical activity regimes and attitudes towards participating in sports programs (Brown, 2008; J. F. Diaz-Morales, de Leon, & Sorroche, 2007; Sugawara, 2001; Tran et al., 2014; Vitale, 2013). Creating opportunities for students to attend morning or afternoon schools based on their individual chronotype is another possible approach. The option for morning or afternoon start times resembles summer schedule flexibility and can improve sleep regularity in youth with different chronotypes.. These changes will particularly benefit youth with later chronotypes who may be combating sleepiness by drinking caffeinated beverages, such as soda, and being less physically active.

School nurses should support current policy statements to delay school start times and should advocate for more flexible school start time options. This support will involve educating students, parents/guardian, teachers, school administrators and other key stakeholders about normal developmental changes in sleep patterns, individual variations within these patterns, and approaches for aligning school days according to these patterns. Information about sleep, particularly sleep-wake timing and chronotype, should be integrated throughout the health curriculum.

Changes in modern lifestyles are also contributing to greater shifts towards lateness at the population level (Roenneberg, Kumar, et al., 2007a). Greater time spent indoors has dampened the strength of light/dark stimuli critical to regulating sleep-wake timing. Increasing exposure to outdoor daylight and limiting exposure to night time light can help regulate sleep-wake timing and mitigate shifts towards lateness (Roenneberg & Merrow, 2007; Vollmer, Michel, & Randler, 2012; West et al., 2011). Two hours of outdoor light exposure per day is the minimum amount needed to shift sleep-wake timing one hour earlier (Roenneberg & Merrow, 2007). Strategies to increase outdoor light exposure for adolescents include scheduling weekend athletic events during the day, promoting short times between classes and during lunch to be outdoors during the school day (Harada, 2002), and designing school buildings that enhance light exposure and increase outdoor spaces.

These interventions must be combined with limiting light at night exposure. Community urban planning committees should seek innovative ways to reduce ambient light at night exposure, including the lighting of school athletic fields. School nurses should educate adolescents, parents/guardians, teachers, and school information technology personnel about strategies for reducing light exposure from electronic media. Although one study found that one-hour exposure to electronic media at night did not delay sleep-wake times in adolescents, most students report far greater media use (Heath et al., 2014). Sixty percent of study participants and 40% nationally representative samples of high school students report using a computer for non-related school activities greater than or equal to three hours per day (Centers for Disease Control and Prevention, 2014). Strategies for limiting electronic light exposure include installing software programs to adjust computer screen displays based on the time of day (f.lux). Adjusting screen settings to white text on black for night reading is another possible intervention. Parents/guardians should limit the electronic devices in adolescent's bedrooms, including cell phones (Calamaro, Mason, & Ratcliffe, 2009; Calamaro, Yang, Ratcliffe, & Chasens, 2012).

Parent/guardian monitoring over bedtimes, typically decline as adolescents progress through high school. Yet, adolescents who have parents/guardians who enforce bedtimes have earlier sleep-wake times during the week (Randler & Bilger, 2009). Nurses should educate and encourage parents/guardians to enforce bedtimes throughout high school, including weekends.

School nurses should routinely assess sleep in high school students. This can be accomplished through brief questionnaires, such as the Sleep Habits Survey, during health class, or through encounters with individual students during health visits. These data that Black adolescents slept less on free nights than their counterparts from other racial/ethnic groups identifies the importance of querying adolescents about school night and free night sleep. It also identifies a group of adolescents that may be at greater risk for the negative consequences associated with short sleep, particularly if these sleep disparities persist into adulthood (e.g. mortality) (Duggan, Reynolds, Kern, & Friedman, 2014; Grandner et al., 2013). Future research is needed to identify the most appropriate measurement method for detecting regular sleep-wake times that is sensitive to health outcomes and appropriate for school settings.

Recommendations for Future Research

As a cross-sectional study, the direction of the relationship between social jet lag and BMI z scores is uncertain and the mechanistic pathways underlying this association can only be speculated. Future studies with larger samples are needed to corroborate associations between social jet lag and BMI independent of sleep duration. Quantifying the intensity and duration of exposure to irregularity associated with unfavorable health behaviors and health outcomes are also needed, as well as factors that are associated with resiliency. These findings should be bolstered by experimental studies aimed at further elucidating the mechanistic pathways underlying this association, particularly in adolescents.

It is also possible that other factors are accounting for the association between sleep and obesity. Meal timing (Garaulet et al., 2013a; Spaeth, Dinges, & Goel, 2013), depressed mood (Mooreville et al., 2014), self-regulation (Verbeken, Braet, Bosmans, & Goossens, 2014) and eating in the absence of hunger (Reina et al., 2013) are important factors to consider. Several adult studies have reported that meals consumed after 22:00 are associated with obesity (Garaulet et al., 2013a; Spaeth et al., 2013). This raises the possibility that meal timing rather than sleep per se is the more important factor. Interestingly, resting energy expenditure has not been found to differ between adolescents reporting short versus long sleep (Hitze et al., 2009). Additionally, obese adolescents have similar total energy expenditure to lean adolescents when expressed per kg of lean body mass in response to a 12 week exercise regime (van der Heijden, Sauer, & Sunehag, 2010). Larger samples would permit modeling and testing of the relationships between these variable with BMI using different statistical methods, such as structural equation modeling.

More research is also need to determine the most appropriate measurement method for detecting relationships between sleep-wake timing and health outcomes, such as obesity. Detecting the association between social jet lag and BMI only when social jet lag is calculated from actigrapy-estimated sleep parameters may limit its use in clinic and school settings. Future research needs to establish the level of agreement between the self-reported calculation and the actigraphy-estimated calculation when the measurements are made concurrently. Nonetheless, the combination of measures used to estimate sleep-wake timing and chronotype preferences may contribute to a more comprehensive understanding of how individuals with different chronotypes adapt their sleep-wake behavior to various preferences and social demands along with the consequences of doing so.

Future research should also examine factors that contribute to racial/ethnic differences in nocturnal sleep duration. Possibilities include urban living environments

(Gamaldo, McNeely, Shah, Evans, & Zonderman, 2013), different circadian lengths (Eastman, Molina, Dziepak, & Smith, 2012), and different cultural practices (e.g. napping) (Jenni & O'Connor, 2005). National research agendas include expanding research to greater understand racial/ethnic and socio-economic disparities in sleep (US Department of Health and Human Services, National Institute of Health, & National Heart Lung and Blood Institute, 2011).

Limitations

There were more female participants (Davis, September 2013) and greater participation in the National School Lunch program (free/reduced lunch) among study participants compared to a nationally representative sample of students and a state-wide representative sample of students (Department of U.S. Department of Education, Institute of Education Sciences, & National Center for Education Statistics). In New Jersey, 30% of students report receiving free/reduced lunch compared to 65% of study participants (Department of U.S. Department of Education et al.). Hence, the generalizability of these findings to male adolescents and more affluent socio-economic groups may be limited.

There are other factors that may have biased our findings. Recruitment efforts were undertaken through the athletic department to increase male participation, specifically via the swim team and wrestling team. The need for parent/guardian consent may have limited participation from some students (Tigges, 2003). Lastly, the low reliability of the Pubertal Development Scale, especially in males, may have limited our ability to detect differences in sleep and BMI by pubertal category.

Conclusions

A chronobiological approach to accelerate progress in reducing obesity rates in adolescents is novel. The associations between social jet lag and BMI, as well as chronotype and health-related behaviors, in this study suggest that these approaches may be warranted. The overall goal should be to align daily schedules (e.g. school, physical activity, sleeping) with individual biological rhythms. Additional approaches to improve the regularity of sleep-wake timing may be needed, such as increasing exposure to outdoor light during the day and limiting exposure to artificial light at night. Shorter free night sleep duration in Black adolescents indicate that this group may be at greatest risk for the negative consequences of short sleep as well as the potential negative consequences of irregular sleep-wake timing.

LIST OF APPENDICES

APPENDIX A: STANDING HEIGHT PROTOCOL

Standing height is an assessment of maximum vertical size. Take this measure on all participants who are able to stand unassisted. Standing height is measured with a fixed stadiometer with a vertical backboard and a moveable headboard. Have the participant move or remove hair ornaments, jewelry, buns, braids, and corn rolls from the top of the head and remove their shoes in order to measure stature properly.

Have the participant stand on the floor (see image below) with the heels of both feet together and the toes pointed slightly outward at approximately a 60 degree angle. Make sure the body weight is evenly distributed and both feet are flat on the floor. Check the position of the heels, the buttocks, shoulder blades, and the back of the head for contact with the vertical backboard. Depending on the overall body conformation of the individual, all points may not touch. In such case, make sure the participant's trunk is vertical above the waist, and the arms and shoulders are relaxed.

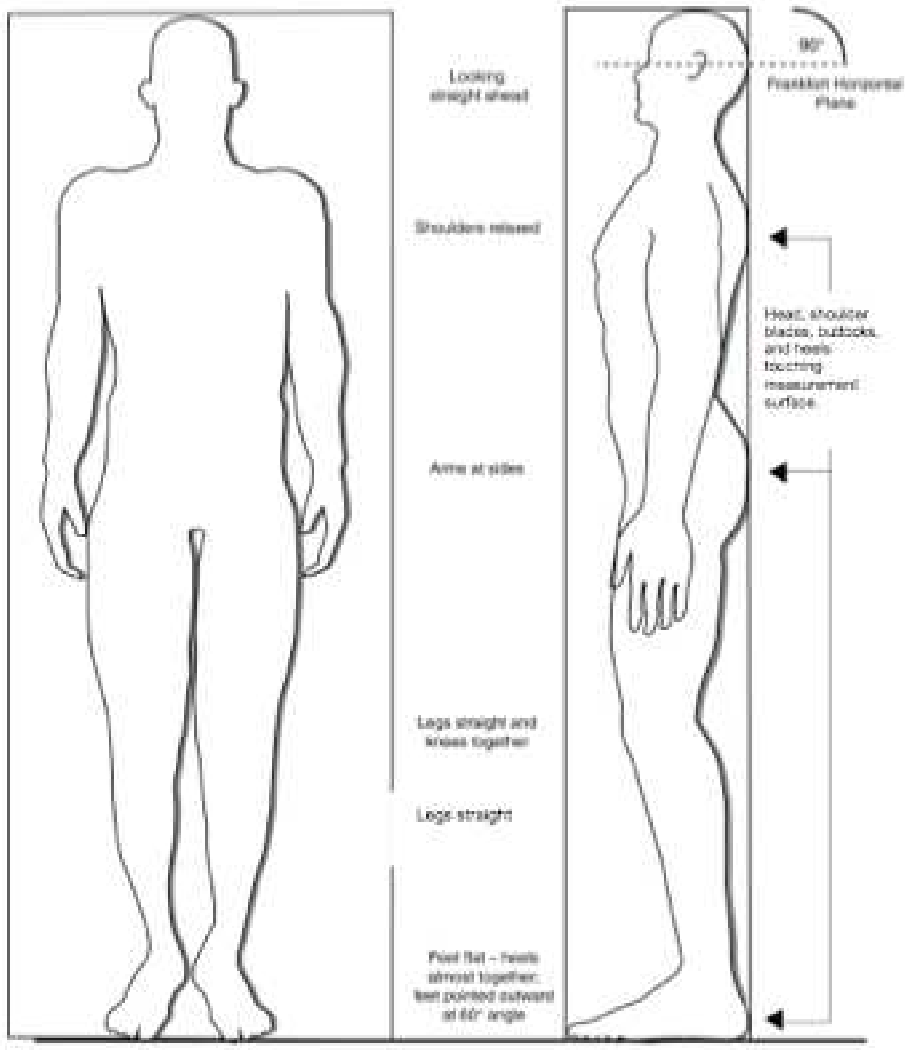
Align the head in the Frankfort horizontal plane. The head is in the Frankfort plane when the horizontal line from the ear canal to the lower border of the orbit of the eye is parallel to the floor and perpendicular to the vertical backboard. Many people will assume this position naturally, but for some it may be necessary to make a minor adjustment. If required, gently tilt the head up or down until proper alignment is achieved with eyes looking straight ahead. Once correctly positioned, lower the headboard and instruct the participant to take a deep breath and stand as tall as possible. A deep breath will allow the spine to straighten, yielding a more consistent and reproducible stature measurement. Position the headboard firmly on top of the head with sufficient pressure to compress the hair. When the participant is properly positioned, record the height. Hold the headpiece in position until the height is verified. Then have the participant relax and step away from the stadiometer. Repeat the height measurement two more times following this protocol. Between each reading, have the participant step away from the stadiometer.

Some participant's may have conditions that interfere with the specific procedures for measuring stature. One of the more common conditions is kyphosis. Kyphosis is a forward curvature of the spine that appears as a hump or crooked back condition. Kyphosis most frequently occurs in the elderly, and in women the condition is commonly referred to as dowager's hump. In these cases it is important to get the best measure possible according to the protocol. Then make a note coded "NS" (not straight) on the participant's height record.

Adapted from:

(National Health Nutrition Examination Survey, 2004 pp. 3-21 to 3-23)

Figure A1



(National Health Nutrition Examination Survey, 2004 p. 3-23)

APPENDIX B: WEIGHT PROTOCOL

The participant's weight will be taken on a digital scale. Weight will be measured in pounds or kilograms. Participants may be wearing light indoor clothing (excluding shoes and sweaters) (Gordon, 1988). Instruct participants to stand still in the center of the scale platform facing the recorder, hands at side, and looking straight ahead. When the participant is properly positioned and the digital readout is stable, record the measurement. Do not weigh participants wearing casts. Ask the participant to step off the scale and repeat this measurement following the same protocol two more times.

Adapted from: (National Health Nutrition Examination Survey, 2004)

APPENDIX C: WAIST CIRCUMFERENCE PROTOCOL

The participant stands with arms by the sides, feet together, and abdomen relaxed. The investigator faces the participant and places the inelastic tape around the subject in a horizontal plane (a wall mirror can be used to ensure that the horizontal plane of the tape is maintained around the participant). The tape is placed around the participant at the level of the greatest anterior extension of the abdomen in a horizontal plane. This level is usually, but not always at the level of the umbilicus (See Figure D1). If possible, have an assistant position the tape behind the participant. The tape is held snug against the skin without compressing the tissues and with its zero end below the value to be recorded. The measurement is made at the end of a normal expiration to the nearest 0.1 cm. Record the measurement. Follow the above protocol two more times.

Figure D1

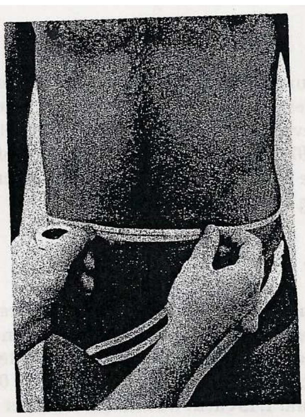


Figure 8 Measurement of abdominal circumference.

Adapted from:

(Callaway, 1988 pp. 45-46)

APPENDIX D: SLEEP HABITS SURVEY

There are no right or wrong answers. Be careful to choose the one answer that best describes the way your sleep has been in the **last two school weeks.**

The next set of questions has to do with your usual schedule on days when you have school.

1. What time do you **usually** go to bed on school days?
   List ONE time, not a range.

   (time) ___________ (circle one) AM PM

2. What time do you **usually** wake up on school days?

   (time) ___________

3. Figure out how long you usually sleep on a normal school night and fill it in here. (Do not include the time you spend awake in bed. Remember to mark hours and minutes, even if minutes are zero.)

   ______________ hours ________________ minutes

The next set of questions has to do with your usual schedule on days when you do not have school, such as on the weekend.

4. What time do you **usually** go to bed on weekends?

   (time) ___________ (circle one) AM PM

5. What time do you **usually** wake up on weekends?

   (time) ___________ (circle one) AM PM

6. Figure out how long you usually sleep on a night when you do not have school the next day (such as a weekend night) and fill it in here. (Do not include the time you spend awake in bed. Remember to mark hours and minutes, even if minutes are zero.)

   ______________ hours ________________ minutes

During the past 2 weeks, have you slept during the day on weekends? (please circle)

yes no

If yes, how many days on the weekend did you sleep during the day? ______

If yes, about how long did you sleep during the day? __________ hours __________minutes

During the past 2 weeks, have you slept during the day on school days? (please circle)

yes   no

If yes, how many days during the week did you sleep during the day (school days only)? _________

If yes, about how long did you sleep during the day? __________ hours __________minutes

APPENDIX E: MORNINGNESS EVENINGNESS QUESTIONNAIRE

1.* Imagine: School is cancelled! You can get up whenever you want to. When would you get out of bed? Between…

a. 5:00 and 6:30 am
b. 6:30 and 7:45 am
c. 7:45 and 9:45 am
d. 9:45 and 11:00 am
e. 11:00 am and noon

2. Is it easy for you to get up in the morning?

a. No way!
b. Sort of
c. Pretty easy
d. It's a cinch

3* Gym class is set for 7 in the morning. How do you think you'll do?

a. My best!
b. Okay
c. Worse than usual
d. Awful

4.* The bad news: You have to take a two hour test. The good news: You can take it when you think you'll do your best. What time is that?

a. 8:00 to 10:00 am
b. 11:00 am to 1:00 pm
c. 3:00 to 5:00 pm
d. 7:00 to 9:00 pm

5.* When do you have the most energy to do your favorite things?

a. Morning! I'm tired in the evening
b. Morning more than evening
c. Evening more than morning
d. Evening! I'm tired in the morning

6. Guess what? Your parents have decided to let you set your own bedtime. What time would you pick? Between…

a. 8:00 and 9:00 pm
b. 9:00 and 10:15 pm
c. 10:15 and 12:30 am
d. 12:30 and 1:45 am
e. 1:45 and 3:00 am

7. How alert are you in the first half hour you're up?

a. Out of it
b. A little dazed
c. Okay
d. Ready to take on the world

8.* When does your body start to tell you it's time for bed (even if you ignore it)? Between…

a. 8:00 and 9:00 pm
b. 9:00 and 10:15 pm
c. 10:15 and 12:30 am
d. 12:30 and 1:45 am
e. 1:45 and 3:00 am

9. Say you had to get up at 6:00 am every morning: What would it be like?

a. Awful!
b. Not so great
c. (Okay (if I have to)
d. Fine. no problem

10.* When you wake up in the morning how long does it take you to be totally "with it"?

a. 0 to 10 minutes
b. 11 to 20 minutes
c. 21 to 40 minutes
d. More than 40 minutes

*Items are reverse scored.

APPENDIX F: MUNICH CHRONOTYPE TIMING QUESTIONNAIRE

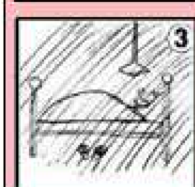
Instructions: The following questionnaire will ask you questions in regards to your sleep and wake behaviour. Please respond to the questions according to your perception of a standard week, based on your most current living conditions. All fields are required unless otherwise specified. This questionnaire is separated to several pages.

Please complete all the following questions. Use the 24 hours scale. For example, 23:00 instead of 11:00 pm.

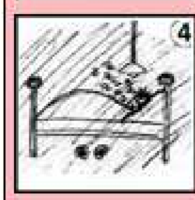
School Days

I go to bed at ___ : ___ o'clock.

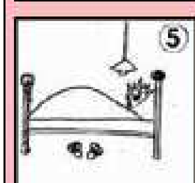
Please note! Some people stay awake for some time when in bed!



I actually get ready to fall asleep at ___ : ___ o'clock.



I need ___ minutes to fall asleep.



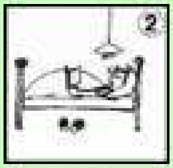
I wake up at ___ : ___ o'clock.,

- ○ I am woken by an alarm clock or my parents
- ○ I wake up by myself

After ___ minutes, I get up.

Free Days

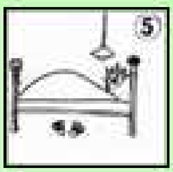
I go to bed at ____ : ____ o'clock.



Please note! Some people stay awake for some time when in bed!

I actually get ready to fall asleep at ____ : ____ o'clock.

I need ____ minutes to fall asleep.



I wake up at ____ : ____ o'clock.

- ○ I am woken by an alarm clock or my parents
- ○ I wake up by myself

After ____ minutes, I get up.

Please use the blank field below to leave a comment if you currently have NO possibility of freely choosing your sleep times (e.g. because of pet(s), parents that might wake you up etc.). Use this field also to provide additional information, if the system asks for it:

Daylight Exposure

On average, how long per day, do you spend outside exposed to daylight (without a roof above your head)?

On days I visit School/Play-or Kindergarten	____	hours	____	minutes
On Free-Days	____	hours	____	minutes

APPENDIX G: MCTQ MIDPOINT OF SLEEP CALCULATION

Evaluation of the MCTQ

The basic evaluation of the MCTQ comprises many different, interrelated variables. In the MCTQshift, these variables are calculated separately for each shift (e.g., morning, evening and night shift). Asterisks indicate variables that are computed from the direct answers in the MCTQ.

1. **Basic Variables**

BTw Local time of going to bed on work days;
SPrepw Local time of preparing to sleep on workdays;
SLatw Sleep latency on workdays "I need __ min to fall asleep";
* SOw Sleep onset on workdays = SPrepw + SLatw;
SEw Sleep end on workdays;
SIw Sleep inertia on workdays "after __ min, I get up"
* GUw Local time of getting out of bed on workdays = SEw + SIw;
* SDw Sleep duration on workdays = SEw – SOw;
* TBTw total time in bed on workdays = GUw – BTw;
BTf Local time of going to bed on free days;
SPrepf Local time of preparing to sleep on free days;
SLatf Sleep latency on free days "I need __ min to fall asleep";
* SOf Sleep onset on free days = SPrepf + SLatf;
SEf Sleep end on free days;
SIf Sleep inertia on free days "after __ min, I get up"
* GUf Local time of getting out of bed on free days;
* SDf Sleep duration on free days = SEf – SOf;
* TBTf total time in bed on free days = GUf – BTf;
WD = number of workdays;
* SDweek (Average SD across the week) = (SDw x WD + SDf x (7-WD))/7;
* SLOSSweek (Sleep loss across the week):
if SDweek > SDw: SLOSSweek = (SDweek – SDw) x WD;
if SDweek ≤ SDw: SLOSSweek = (SDweek – SDf) x (7 – WD);

2. **Chronotype**

The basis for estimating chronotype is the Mid-Sleep Time on Free days (MSF) MSF = SOf + (SDf)/2; MSF is then corrected for "oversleep" on free days that subjects use to compensates the sleep debt accumulated during the workweek: MSFsc = MSF - (SDf - SDw)/2;

This correction is only applied to individuals who sleep longer on free days than on workdays. For all others: MSFsc = MSF; MSFsc is the basic assessment for chronotype for an individual under the current circumstances; (MSFsc depends on developmental and environmental conditions, e.g., age and light exposure). For epidemiological and genetic studies, MSFsc is normalised for age and sex to make populations of different age and sex compositions comparable.

3. **Social Jetlag**

The relative social jetlag (SJLrel) is the difference between the Mid-Sleep on work- and on free days: MSW = SOw + (SDw)/2; SJLrel = MSF – MSW;

The absolute social jetlag (SJL) is used for most assessments of the consequences of social jetlag: SJL = abs(SJLrel);

Roenneberg, T., Allebrandt, K. V., Merrow, M., & Vetter, C. (2012). Social jetlag and obesity. Curr Biol, 22(10), 939-943. doi: 10.1016/j.cub.2012.03.038

APPENDIX H: ACTIGRAPH DATA COLLECTION, PROOFING, AND SCORING PROCEDURES AW2*

*This protocol was modified by the investigator for this study. Modifications are indicated in red text.

Actigraph Documentation Procedures

Any and all action on an actigraph should be recorded on them. Each actigraph has it's own tab in the binder.

Each time an actigraph is initialized, put to sleep, downloaded, or internally tested, record the date, participant's ID number if applicable, and comments (i.e., initialized OK, downloaded OK, low sensitivity etc) with your initials. *Careful documentation of all procedures is extremely helpful in the event that the actigraph needs to be sent out for service. It will also help to ensure that we only use the most accurate devices with our participants*.

In each of the following sections there is information on specific procedures to be followed along with information on how to document these procedures on the actigraph communication sheets in the white actigraph binder for the study. Please be sure to follow the documentation procedures noted below, and be as clear as possible in the notes that you make. Oftentimes it will be months or even years before we will go back & review notes; the clearer they are, the more helpful they will be if the device needs service.

Charging an AW2 Actigraph

All actigraphs need to be charged prior to configuring them for use by participants. Follow the directions below to charge actigraphs.

<u>All actigraphs MUST charge for AT LEAST 24 hours prior to sending them home with participants; this will ensure ample battery life for the one-week assessment period.</u>

1. Turn on your computer & log-in with your user name & password.

2. Ensure that the Actiwatch 2 docking station is connected to either of the computer's two USB ports. The **red** light on the front of the docking station will light up when it is connected.

3. Place the Actiwatch 2 in the docking station. The button should fit nicely into the indentation in the docking station with the metal nodes of the docking station contacting the medal on the AW2. You will know that it is properly connected when the **red** light on the docking station turns **green**. It will likely also begin to flash.

4. Leave the Actiwatch 2 in the docking station until the flashing **green** light becomes a constant **green** light **<u>AND the actigraph is charged for at least 24 hours</u>**. *Please note that the computer needs to be turned on for the Actiwatch 2 to be charged so do not turn off the computer until charging is complete.*

5. Document in the Actigraph binder the date of charging as follows:

Date	ID #	Comments	Initials
05/03/09	----	Connected to dock to charge	CH

6. Once the Actiwatch 2 has fully charged, either configure the device for a participant (see p. 8 for directions) or put it to sleep (see p. 6 for directions) for future use.

Actigraph Testing Procedure

Actigraphs should be tested on three separate occasions: 1) If it is the first time that the actigraph is being used, 2) If the actigraph was sent out for repair & we just got it back, and 3) On a quarterly basis to ensure that it is working appropriately. Follow the Procedures below to test actigraphs.

For New Actigraphs & Quarterly Testing

1. Configure the actigraph (using procedures on the following page).
   - *Please Note: When configuring the Actigraph, use the "Test" database located* on *the server under T:\Studies\Sleep\Data\Actiwatch Test Database.AW5*
   - Use the next available idno in the test database for configuring the device.
   - Document in the Actigraph binder that the AW2 was configured & is being tested; indicate why the testing is being completed; document the idno that was used for the test:

Date	ID #	Comments	Initials
05/03/09	Test004	Configuration OK-Testing AW2 due to receiving message, "error reading AW2"	CH

2. Wear the actigraph & complete the "Sleep Diary for Actigraph Test" located on the server under: *T:\Studies\SLEEP\Actigraphs*, for each of the days that you wear the device. *For most test periods, wear the device for 24 hours (& complete two test sleep diaries), and then leave it by a windowsill (so that it can pick up the variation in light/darkness) for the next 120 hours (i.e., 5 days), and wear it for one more 24-hour period. This will provide ample information on the device's performance over a 1-week assessment period*. EACH WAS WORN FOR 24 HOURs IN THIS STUDY.

3. After wearing it and completing sleep diaries, download the actigraph (using procedures on the following pages)
   - *Please Note: When downloading the Actigraph, use the "Test" database located on the server under T:\Studies\Sleep\Data\Actiwatch Test Database.AW5*
   - Document in the Actigraph binder that the AW2 was downloaded & write down the results of testing, noting any discrepancies between diary & actigraph. Please note, there may be times when you will be required to test the device against another actigraph (i.e., when it comes back from being repaired-see below). Information regarding the performance of both devices will need to be clearly documented.

Date	ID #	Comments	Initials
05/04/09	Test004	AW2 downloaded-Consistent with sleep diary	CH

4. If there are any discrepancies between the sleep diary and the actigraph, Respironics may be contacted for technical support.

5. If the Actigraph passed the test, ensure that it is fully charged and then either configure it for a participant or put it to “sleep” for later use. Document either of these procedures in the Actigraph binder.

<u>For An Actigraph Returned After Repair</u>
Follow all of the above procedures except instead of just wearing the repaired actiwatch, also wear a 2^{nd} actiwatch that is believed to work well. Download both Actigraphs, and compare both to the Sleep Diary that was recorded.

Configuring a New AW2 with Respironics Actiware 5 Software

1. Turn on your computer & log-in.

2. Ensure that the Actiwatch 2 docking station is connected to either of the computer's two USB ports. The **red** light on the front of the docking station will light up when it is connected.

3. Place the Actiwatch 2 in the docking station. You will know that it is properly connected when the **red** light on the docking station turns **green** (& is typically flashing).

4. On the desktop, double click on the Respironics Actiware 5 icon. The actiware screen will come up & should have available in the Database Viewer (top, left-hand column) the correct database, "Project Sleep-Study 2.AW5".
   - If the database is not in the viewer, go to File, Database, Open & select the database from the following location on the T: drive: T:\Studies\SLEEP\Study 2\Data.

5. When you select the Respironics Actiware 5 icon, another screen should appear, "Actiwatch Communications Console".
   a. The "Actiwatch 2" box should indicate that it is "Connected"
   b. Click on the "Actiwatch 2" box. It should indicate that the Actiwatch 2 is ready to be configured & should also say that the battery is fully charged. If the battery is not fully charged, remove the actiwatch from the docking station & configure a new actiwatch.

6. Click on the "Configure" button in the lower right of the "Actiwatch Communications Console" box.

7. Another box should appear, "Configure Actiwatch-Select Subject".
   a. For a <u>new participant</u>, select the "New Subject" button.
      i. The "new subject" screen will appear. The ONLY information that should be entered into this screen is the participant's idno, and gender. No additional identifying information should be entered. For date of birth, always select a January 1st birth date that will reflect the participant's age. For example, if today's date is 05/07/09 and you know the participant is 9 years old, choose January 1, 2000 as the DOB. In this way, the participant's age will be reflected on printouts, but identifying information will not.
      ii. Select the "OK" button.
   b. For <u>returning participants</u> (i.e., who already have idnos), select their study idno from the drop down menu in the middle of the "Configure Actiwatch-Select Subject" screen.
   c. Select the "next" button at the bottom of the box.

8. The box should now be titled, “Configure Actiwatch-Data Collection Setup”. Select the following options:
    a. Epoch Length: 1 minute
    b. Logging Mode: Activity and Photopic Light
    c. Click on the “Next” button

9. The box should now be titled, “Configure Actiwatch-Start Time and Duration”. Select the following options:
    a. <u>Start Time</u>: configure the watch to start collecting data on the day and time of the participant’s scheduled visit (i.e., make sure the box next to “Start collecting data as soon as possible” is NOT selected.)
    b. <u>Data Collection Duration</u>: Log Until Full
    c. Click on <u>Time Zone</u> to ensure it is collecting data for the Eastern Time Zone.
    d. Click on the Configure button

10. A new box should appear, “Configure now?” Select the “Configure” button to proceed.

11. The actiwatch will be configured by the software. Once it is complete, the “Completed” box will appear.
    a. Remove the Actiwatch from the docking station.
    b. Click on the “OK” button.

12. Close out of the Actiwatch Communication Console screen.

13. Close out of the Respironics Actiware Software program by selecting “File” and “Exit”

Downloading Data from an AW2 Actigraph

1. Turn on your computer & log-in.

2. Ensure that the Actiwatch 2 docking station is connected to either of the computer's two USB ports. The **red** light on the front of the docking station will light up when it is connected.

3. Place the Actiwatch 2 in the docking station. You will know that it is properly connected when the **red** light on the docking station turns **green**.

4. On the desktop. Double click on the Respironics Actiware 5 icon. The actiware screen will come up & should have available in the Database Viewer (top, left-hand column) the correct database, "Project Sleep-Study 2.AW5".
   - If the database is not in the viewer, go to File, Database, Open & select the database from the following location on the T: drive: T:\Studies\SLEEP\Study 2\Data\Actiware Database

5. To download data, click on "Communications" and then "Actiwatch Console" in the upper left portion of the screen.
   a. The "Actiwatch Communications" box should appear
   b. Click on the "Actiwatch 2" box (the 2nd box). It should indicate that the Actiwatch 2 is connected, and collecting data.

6. Select the "Retrieve" button on the lower right side of the communications box.

7. A "Retrieve Data" box will be launched and the software will begin to retrieve data from the actigraph.

8. When it is done, the software will indicate that Data was retrieved successfully.

9. Click on the "Save Data" button.

10. An "Auto Intervals" box will appear. Click "OK".

11. The box will now say, "Retrieve Data-Reconfigure Actiwatch".

12. Close out of the "Actiwatch Communication Console" screen.

13. Close out of the Respironics Actiware Software program by selecting "File" and "Exit"

14. Leave the Actiwatch connected to the Computer for the remainder of the assessment so that the Actiwatch battery can be recharged.

Actigraphy and Sleep Diary Proofing Procedures

Materials: diary, actigraphy printout (on computer screen), red pen for questions, black/blue pen (for participant answers), and an actigraph question form.

1. Check that the diary is complete.
    a. Make sure that there is an answer to every question on each page of the Sleep Diary.
    b. Circle in **red ink** (or flag with a sticky note) any missing answers or questionable responses (e.g., circled both "no caffeine" and then wrote in that caffeine was consumed; or you cannot read what time they went to bed). These will need to be reviewed with families when you query actigraph data.

2. Download Actigraph & Print copies of Actogram: Download the Actigraph using the procedures on the previous pages.
    a. The actogram associated with the participant should automatically appear on the screen. If it does not, in the Database Viewer, double-click on the participant's idno & date that the actigraph was configured. Double click on "New Analysis" to be able to view the actigraph data.
    b. To make it easier to view the data, on the right hand side, under the heading, "Visibility", de-select the "White Illuminance Data" button-it's the 2nd button from the left with a sun up top & orange vertical lines on the bottom.
    c. Print two copies of the actogram-one for yourself & one for the participant. Retrieve the printouts from the printer.
    d. Using a red pen, box and write "off" on the actogram when the diary says that the actigraph was taken off.
    e. Inspect for periods of low activity (i.e., any break in the red line), and circle these times if they are not accounted for in the diary by some quiet activity.

3. Obtain Actigraph Scored Sleep Onset & Wake Time:
    a. Each night's sleep will appear on a separate line on the actogram. The date on the left-hand side corresponds to the date when the child fell asleep. Black lines with a red bar beneath them indicate activity. **For our purposes, sleep onset is defined as the first of 3 consecutive Ss.**
    b. To determine **SLEEP ONSET**: Use the participant button press (blue downward arrow on the actogram) as a guide. Place the cursor on the blue downward arrow.
    (*Note: If this is in an area on the actogram followed by a lot of activity, move the cursor to a later time that seems to correspond more closely to bedtime; conversely, it it appears that there was low activity prior to the button press or self-reported sleep time move the cursor to an earlier time*).

If the participant did not press the button, use self-reported data on the sleep diary (and if that's not available, use the call-in log) as an indication of sleep onset.

i. When you click on the actogram a small box will appear that indicates the date, time, activity count (labeled "ac"), and either a W ("wake") or a S ("sleep") in the right corner. Use the left & right arrows to move the cursor back and forth to determine sleep onset.

ii. **SLEEP ONSET** is defined as *the first out of* 3 consecutive Ss that occur after the participant reports sleep (via diary, button press or call-in).

c. To determine **WAKE TIME**: As indicated above, use the participant button press (blue downward arrow on the actogram) as a guide. Follow the above instructions for sleep onset with the following exceptions: **WAKE TIME** is defined as the last of 5 consecutive Ss. Thus, place the cursor on the blue downward arrow, and count backwards until you achieve 5 consecutive Ss-sleep onset will be the last (i.e., latest wake time) of these. Again, if there is no button press, refer to self-reported wake time from the diary, and if not available, from the call-in log.

4. Transfer Sleep Onset and Wake Time for each night's sleep onto the "Sleep Validity Check" form. If you notice the following discrepancies, put a ✓ in the box indicating that you need to speak with the participant, clearly write out the question that needs to be asked on the "Actigraph Question Form" & then speak with them to ensure accurate assessment of sleep/wake times (*see the querying section that follows for details regarding how best to query participants*):
   a. If the **SLEEP ONSET** time occurs > 15 minutes before the diary, speak to the participant to get an explanation for the discrepancy.
   b. If the **WAKE TIME** occurs > 15 minutes before the diary, then speak to the participant to get an explanation for the discrepancy.
   c. *Please make notes of discrepancies & associated participant explanations on the "Actigraph Question Form"*

5. When you are done documenting sleep onset and wake times, close out of the software program. All data will automatically be saved.

6. Bring the "Sleep Validity Check" and the "Actigraph Question Form" along with the Sleep Diaries and Call-In logs into the room with participant. Clearly document on the "Actigraph Question Form" the participant's response to each question. Provide as much information as possible in the response section so that we can determine whether or not to use the night's sleep.

Querying Discrepancies between the Sleep Diary, Call-Ins, Button Press, & Actogram

It is extremely important to thoroughly document questions and participant answers on the Actigraph Question Form. These are often not reviewed for some time so clarity is key to ensure appropriate scoring. Examples are provided below regarding common discrepancies that might arise, and appropriate questions/documentation of responses. *Please note, for EVERY query it is important that you also circle whether or not the participant fell asleep*.

Questions Related to Sleep Onset

Example 1: Participant reports bedtime at 9:30PM, but activity on the actigraph printout continues until 10:15PM.

DATE	Questions	Answers
Fri, 03/03/13	*Diary BT = 9:30PM; CI BT = 9:25PM; no BP; Actigraph shows activity until 10:15PM.* *Why is there continued activity?*	*Ppt got into bed @ 9:30pm, but he then got up to use the bathroom & brush teeth; didn't settle back into bed with lights out/trying to sleep until approx. 10:00pm.*

Example 2: Participant reported bedtime at 9PM, but the activity on the actigraph printout appears to stop at 8:15PM.

DATE	Questions	Answers
Mon, 03/06/13	*Diary BT = 9:00PM; CI BT = 8:50PM; BP @ 8:15PM & 8:51PM; Actigraph shows very low activity starting at 8:15PM* *What were you (the child) doing?*	*Participant was in bed reading from 8-9PM. She pushed button at 8:15PM because she got into bed then; pressed it again at 8:51pm because that was when she turned lights out/tried to fall asleep.*

Questions Related to Wake Time

Example 3: Participant reported that he/she woke at 6:30AM, but activity on the actigraph printout does NOT start until 8:00AM.

DATE	Questions	Answers
Fri, 03/10/13	*Diary WT = 6:30AM; CI WT = 6:30AM, but not received on VM until 8:15AM; BP = 6:30AM; Actigraph shows little activity at 6:30AM, but then very low*	*Participant woke at 6:30AM to use bathroom, but went back into bed to try to fall back asleep. Participant reported that he/she DID fall back asleep until 8:00AM.*

	activity until 8:00AM *Why doesn't activity begin until 8AM?*	

Example 4: Participant reports waking at 6:00AM, and actigraph shows activity at this time. However, there is then very low activity from 7:00-8:00AM.

DATE	Questions	Answers
Sat, 03/11/13	*Diary WT = 6:00AM; CI WT = 6:00AM,; BP = 6:00AM; Actigraph = 6:00AM, but then low activity from 7-8:00AM.* *What happened that morning?*	*Participant woke at 6:00AM & got out of bed. She had breakfast & then reported watching television. She did NOT fall back asleep.*

Key Pieces of Information to Keep in Mind When Querying

1. This is a data gathering expedition so it is important to ask open-ended questions that do NOT lead the participant in any way.

    a. Examples of Open-Ended Questions:
        i. What happened?
        ii. Why was there low/high activity?
        iii. Tell me about this morning/night.

    b. Examples of Leading Questions that Should **NOT** be asked:
        i. Should we go with the actigraph time?
        ii. Is the button press time the best one to use?

2. You do NOT need to make final decisions about whether or not the participant was awake or asleep. It is your job to get as much information as possible about the discrepancy that occurred so that someone else could make this decision later on. There will be times when particpants cannot report clear recounting of what transpired. This is OK. You just need to document EXACTLY what the participant reported to your open-ended questions, and you need to make sure that you get responses that help us to determine whether a participant was asleep or not.

    a. Examples of Unacceptable answers:
        i. Participant reports going to bed around 10:00PM, but the actigraph does not show low activity until 11:15PM.
        Q: Why was there high activity from 10:00PM to 11:15PM
        A: Dog on bed

-This answer tells us what the dog was doing but does not tell us what the participant was doing. Was the participant asleep? Was he petting/playing with the dog?

ii. Participant reports going to bed at 9PM, but the actigraph shows low
activity starting at 8PM.
Q: What was going on between 8PM & 9PM?
A: The ppt was really tired.
-This answer does not provide any additional information about when the participant actually fell asleep.

3. Every query should end with a question regarding whether or not the participant was asleep/feel back asleep.

4. Try to jog the family's memory by providing information about the day of the week, and what "interesting event" the child noted about that day in their sleep diary.

Putting an AW2 Actigraph to Sleep

If an actigraph is not going to be used immediately by a participant, it is important to put the actigraph to "sleep" after charging it. This will help to protect the life of the charge. Follow the directions below to put the actigraph to "sleep".

1. Follow directions on the previous page for charging an AW2 Actigraph.

2. Once the AW2 Actigraph is charged, on your desktop, double click on the Respironics Actiware 5 icon. The actiware screen will come up.

3. In the upper left-hand side, select "Communications" and then "Actiwatch Console".

4. The "Actiwatch Communications Console" screen will appear.
    a. On this screen will be The "Actiwatch 2" box (2nd box down), which should indicate that the AW2 is "Connected"

5. Click on the "Actiwatch 2" box. It should indicate that the Actiwatch 2 is ready to be configured & should also say that the battery is fully charged.

6. On the bottom left-hand side of the "Actiwatch Communications Console" screen is a button labeled, "Sleep". Click this button.

7. The "Put to Sleep?" screen will appear; the screen also notes "Caution!"because the actigraph will no longer be able to collect data in this mode. Ignore this "Caution" and select "Put Actiwatch to Sleep".

8. A new screen will appear during which the Actigraph will be configured to go to "sleep"; this process may take a few seconds to complete.

9. A new screen, "Completed!" will appear, stating that the Actigraph was successfully put to sleep. Click "OK" and remove Actigraph from docking station.

10. Document in the Actigraph binder the date the Actigraph was put to "sleep":

Date	ID #	Comments	Initials
05/03/09	----	Actigraph put to sleep.	CH

11. Store the actigraph device in one of the drawers in the gray actigraph storage box that are labeled "Charged AW2 Sleeping".

Actigraphy Scoring Guidelines

Materials needed for each participant:

- Diary
- Actigraphy printout
- Actigraph Question (Query) Form
- Actigraphy Scoring Form
- Actigraphy digital file (opened in Actiware)

Definitions

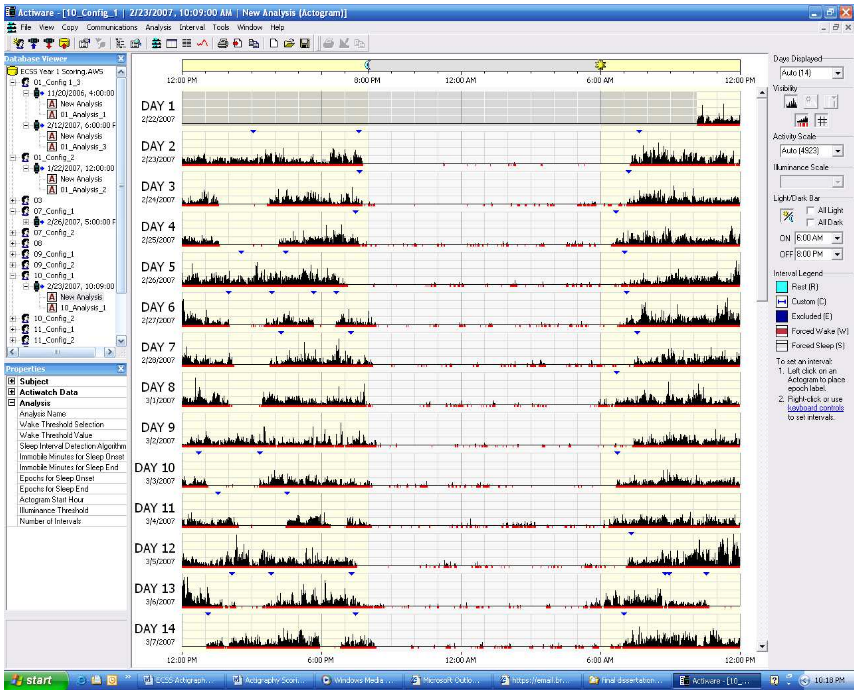
Sleep Period = Interval from sleep start to sleep end.

Time in Bed = Interval from lights-out to lights-on

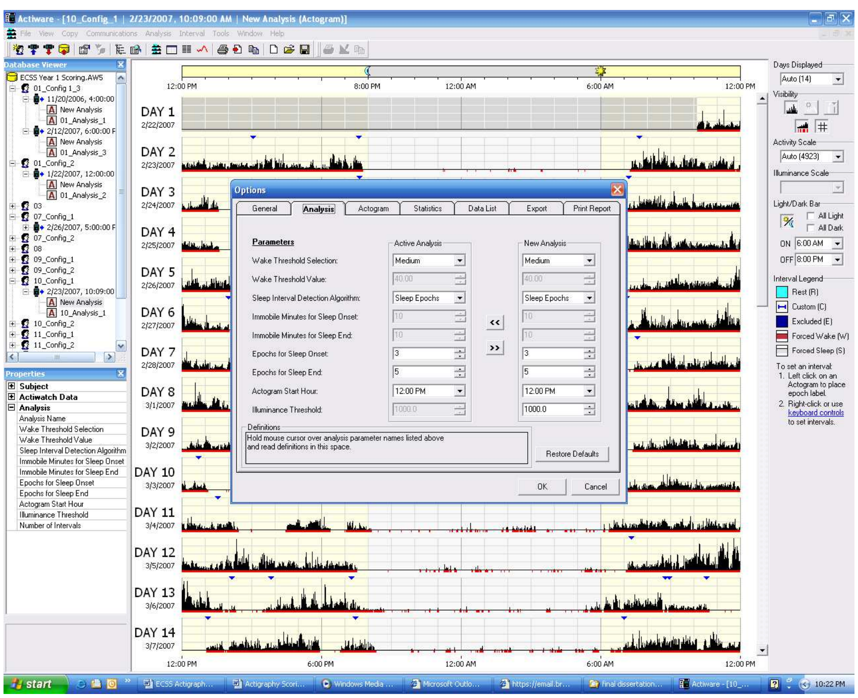
Getting Familiar with the Actiware Software (see Chapter 2 of Manual)

Opening the Digital Actigraphy File

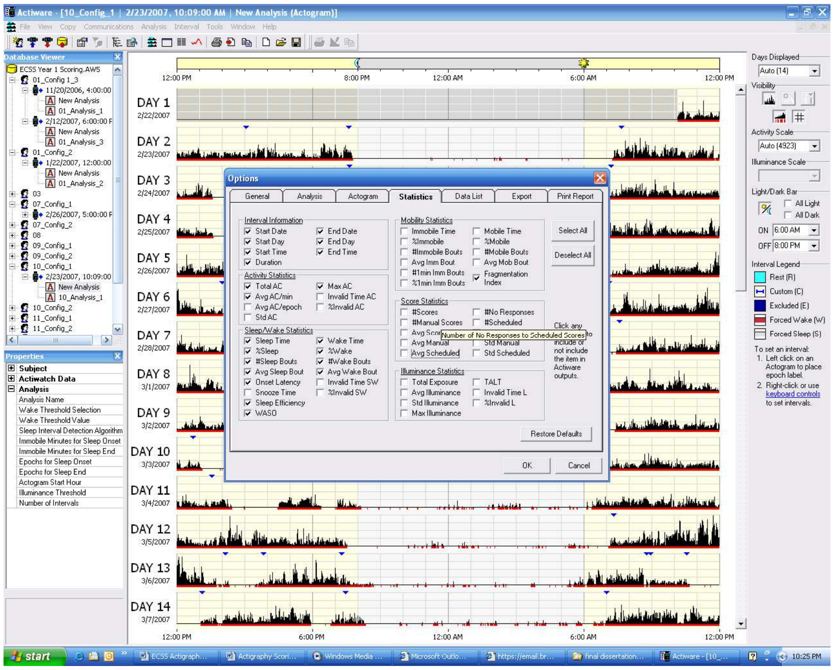
A. Open the Actiware 5.0 software located on the desktop or start menu
B. Once program is open, it should automatically open "ADA Project Sleep.AW5" in the database viewer
C. Note that Participant ID's should be listed on the left hand side of the screen
D. Each participant ID has a face and a "+". If you click on the "+" all data (of which we have three sleep assessments) for that participant will be shown.
E. Click on an ID of interest, so that all the data for that ID is displayed. Each individual sleep assessment (-) will be entitled with the date of download.
F. Select ***New Analysis*** under the date of interest. An actogram will appear. You will use data from this actogram to complete the Actigraphy Scoring Form and to score the data.



G. Go to Tools – Options – Analysis and make the following settings (make sure that sleep epochs are used with sleep onset at 3 minutes and sleep offset at 5 minutes).



H. Go to Tools – Options – the Statistics and make sure the following are selected.



Complete Actigraphy Scoring Form (Analysis 1: Nighttime Sleep Period)

A. Ultimately, you want to determine whether the sleep interval is usable or not. All nights are scored individually and are defined as usable if
   - No technical failures occurred
   - The child was not sick
   - The participant reported no day time or nighttime atypical events (e.g., resistance to wearing watch, spending the night with friends)
   - No part of the sleep period was influenced by extreme external motion (e.g., sleeping in a car)
   - The actigraph was attached to the participant during the entire scoring period
   - The actigraphic data corresponded with the participant's sleep diary
   - The diary was appropriately completed

B. If a period is usable, mark YES in the status window; if a period is not usable, mark NO; if you are unsure, mark "consensus." All periods marked consensus should be discussed at a meeting with multiple people who understand actigraphic scoring rules and issues.

C. This analysis will involve using set scoring rules to define sleep start and sleep end periods.

D. Fill in header information. Date range can be determined from the actogram / diary

E. Select whether this is a self-selected or a scheduled week

F. For each 24-hour period (start with Bedtime Data), use the sleep diary and the digital actogram to complete the scoring form.

G. Fill in the Day # (1, 2, 3, 4…), day of the week (M, TU, WE, TH, FR, SA, SU), and date. **Note** if the child was sick, bathed near sleep intervals, or napped.

H. Complete the following for Nighttime Sleep
   1. Diary BT (bedtime): lights-out time in sleep diary (# 8)
   2. ACT BT (bedtime): time from event marker (scroll over blue marker on actogram to see this time)
   3. Diary WT (wake time): time child awakened in sleep diary (# 16)
   4. ACT WT (wake time): time from event marker (scroll over blue marker on actogram to see this time)

I. Fill in the Sleep Start and Sleep End (Analysis 1 – Sleep Period) times using the following rules:
   - **SLEEP START**: The ***first of 3 epochs*** of consecutive sleep that occurs after bedtime (diary/event marker). If sleep start appears to happen BEFORE reported bedtime (with no documentation of why), you must bring this issue to consensus.
   - **SLEEP END**: The ***last of 5 consecutive epochs*** of sleep that occurs before wake time (diary/event marker). If sleep end appears to happen AFTER reported wake time (with no documentation of why), you must bring this issue to consensus.

Create Rest Intervals for Nighttime Sleep Period

A. Use the Sleep START/END times to mark intervals.

B. To set the interval **START**, place the mouse as close to the time on the actogram and click (pink arrow will appear). Use the L/R arrow buttons to move the cursor to the exact location. Press R.

C. To set the interval **END**, repeat the above procedure and then press shift + R at the same time.

D. To insert the rest interval press ctrl + R. The interval should now be highlighted in cyan blue.

E. Create Rest Intervals for all <u>usable</u> sleep periods.

F. Press the X to close the window. You will be prompted to save the analysis. Save as ID#_date of scoring _your initials_, e.g.: 07_091210_AC.

Actigraph Failure Procedure

If there is a problem with an actigraph such that data is lost or distorted in any way, immediately call XX and review the situation with her. We will need to determine whether the data can be saved or whether the family will need to be sent home, and instructed to continue with the previous week's instructions for sleep.

Clearly document in the Actigraph binder what happened with the Actigraph & leave the Actigraph on Chantelle's desk so that she can follow-up with Respironics technical support.

Phillips Respironics Contact
Philips Respironics

20300 Empire Avenue, Bldg. B-3
Bend OR 97701 USA

Phone: 800-685-2999

Tech support is available by phone, Steve - ext. 83837 or Jake at ext. 83813, email: steve.edwards@philips.com or philip.covert@philips.com.

APPENDIX I: SLEEP VALIDITY CHECK

IDno__________
Date_________
Reviewer's initials:________

Day	Dat e		Participant-Report		Actigraph	
			Sleep Onset [a]	Wake Time [b]	Sleep Onset [c]	Wake Time [d]
M T W T F S S		Night 1				
M T W T F S S		Night 2				
M T W T F S S		Night 3				
M T W T F S S		Night 4				
M T W T F S S		Night 5				
M T W T F S S		Night 6				
M T W T F S S		Night 7				

[a] Take from Sleep Diary, Right Box, Question #21.
[b] Take from Sleep Diary, Left Box, Question #6.
[c] Take from Actigraph Program; Sleep Onset is the <u>first of 3 consecutive minutes</u> of sleep ('s').
[d] Take from Actigraph Program; Wake Time is the <u>last of 5 consecutive minutes</u> of sleep ('s').

*adapted from Chantelle Hart

Notes:

APPENDIX J: ACTIGRAPH COMMUNICATION SHEET

Date	Activity		Comments	Initials
	☐ Internal Test ☐ Initializing	☐ Downloading ☐ Put to Sleep	Participant Idno: _____	
	☐ Internal Test ☐ Initializing	☐ Downloading ☐ Put to Sleep	Participant Idno: _____	
	☐ Internal Test ☐ Initializing	☐ Downloading ☐ Put to Sleep	Participant Idno: _____	
	☐ Internal Test ☐ Initializing	☐ Downloading ☐ Put to Sleep	Participant Idno: _____	
	☐ Internal Test ☐ Initializing	☐ Downloading ☐ Put to Sleep	Participant Idno: _____	
	☐ Internal Test ☐ Initializing	☐ Downloading ☐ Put to Sleep	Participant Idno: _____	
	☐ Internal Test ☐ Initializing	☐ Downloading ☐ Put to Sleep	Participant Idno: _____	

*from Project Sleep (Chantelle Hart)

APPENDIX K: CONSENSUS SLEEP DIARY

Sleep Diary Instructions What is a Sleep Diary? A sleep diary is designed to gather information about your daily sleep pattern.
How often and when do I fill out the sleep diary? It is necessary for you to complete your sleep diary every day. Ideally, the sleep diary should be completed within one hour of getting out of bed in the morning.
What should I do if I miss a day? If you forget to fill in the diary or are unable to finish it, leave the diary blank for that day.
What if something unusual affects my sleep or how I feel in the daytime? If your sleep or daytime functioning is affected by some unusual event (such as an illness, or an emergency) you may make brief notes on your diary.
What do the words "bed" and "day" mean on the diary? This diary can be used for people who are awake or asleep at unusual times. In the sleep diary, the word "day" is the time when you choose or are required to be awake. The term "bed" means the place where you usually sleep.
Will answering these questions about my sleep keep me awake? This is not usually a problem. You should not worry about giving exact times, and you should not watch the clock. Just give your best estimate.
Item Instructions
Use the guide below to clarify what is being asked for each item of the Sleep Diary.
Date: Write the date of the morning you are filling out the diary
In total, how long did you nap or doze? Estimate the total amount of time you spent napping or dozing, specifying if you are referring to hours or minutes. For instance, if you napped twice, once for 30 minutes and once for 60 minutes, and dozed for 10 minutes, you would answer "1 hour 40 minutes." If you did not nap or doze, write "N/A" (not applicable). *1. What time did you get into bed?* Write the time that you got into bed. This may not be the time that you began "trying" to fall asleep.
2. What time did you try to go to sleep? Record the time that you began "trying" to fall asleep. *3. How long did it take you to fall asleep?* Beginning at the time you wrote in question 2, how long did it
take you to fall asleep.
4. How many times did you wake up, not counting your final awakening? How many times did you wake up between the time you first fell asleep and your final awakening?
5. In total, how long did these awakenings last? What was the total time you were awake between the time you first fell asleep and your final awakening. For example, if you woke 3 times for 20 minutes, 35 minutes, and 15 minutes, add them all up (20+35+15= 70 min or 1 hr and 10 min).
6a. What time was your final awakening? Record the last time you woke up in the morning. *6b. Did you wake up earlier than you planned?* If you woke up or were awakened earlier than you
planned, check yes. If you woke up at your planned time, check no.
6c. If yes, how much earlier? If you answered "yes" to question 6c, write the number of minutes you woke up earlier than you had planned on waking up. For example, if you woke up 15 minutes before the alarm went off, record 15 minutes here.
7. How would you rate the quality of your sleep? "Sleep Quality" is your sense of

whether your sleep was good or poor.
8. *Comments* Feel free to write anything that you would like to say that is relevant to your sleep

Sleep Diary Name:______________________________

	Sample							
Today's date	4/5/08							
In total, how long did you nap or doze yesterday?	n/a							
1. What time did you get into bed?	10:15 p.m							
2. What time did you try to go to sleep?	11:30 p.m							
3. How long did it take you to fall asleep?	1 hour 15 min.							
4. How many times did you wake up, not counting your final awakening?	3 times							
5. In total, how long did these awakenings last?	1 hour 10 min.							
6a. What time was your final awakening? 6b. Did you wake up earlier than you desired? 6c. If yes, how many minutes earlier?	6:35 a.m. ☑ Yes ☐ No 30 min.							
7. What time did you get out of bed for the day?	7:20 a.m							
8. How would you rate the quality of your sleep?	☐ Very poor ☑ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good
9. Comments (if applicable)	I have a cold							

APPENDIX L: SCRIPT FOR INITIATING ACTIGRPAHY

** Script should be presented to only 1-2 participants at a time for focused and individual attention if possible.*

Your actigraph monitor needs to be worn everyday until I collect it on ______________.

Are you going to be here next week?

[Make arrangements to come back at a later date for participants who are going to be away on vacation or absent during the measurement period.

Let's go through the instructions for wearing the monitor and keeping the sleep log: It's VERY important that you pay attention right now. Wearing the monitor is THE MOST important part of this study – and I need you to pay attention and understand what is involved.

The monitor is attached to wrist strap that will be worn on your wrist. This is YOUR monitor – meaning that this particular monitor has been set up so that ONLY you should be wearing it this week.

Please wear the monitor all day while you are awake and during the night while you are asleep.

If you take it off for any reason that means that the monitor is not getting the important information that is needed for this study.

ask if there is are anyone participating in extra curricular sports/activities where they may be asked to remove the monitor. If there are, ask them to stay behind at the end of the presentation to discuss how to deal with this or tell them we will talk about this at the end.

You can wear the monitor when you shower, bathe, or swim, but if you do remove the monitor, it is really important to always put it back on as soon as you can so you are wearing it as much time as possible.

Sweating will not hurt the monitor, so you *should* wear it when you play sports or games, as long as this is OK with your coach and/or the referees.

If you do need to take the monitor off put it somewhere that it will not be bumped, dropped, or broken. AND it is very important that you put the monitor back on your wrist as soon as you can. Write down in your sleep log when you took it off and put it back on.

[show participants how to use the sleep log]

Like I said before, we need to have you wear the monitor for as much as you can. It is important that you help us out by wearing the monitor the way we are asking you to.

[Show the diagrams of a day of activity and explain that the higher the spikes, the more active the girl was at that time, and where there is nothing on the chart, she wasn't wearing the monitor as instructed.]

[demonstrate while saying] **It is VERY important that you always wear the monitor in the same location on your non-dominant wrist.**

[Give monitor to participant. Have the participants demonstrate to you that they know where the monitor is supposed to be worn. Adjust length of watch as needed so it is snug.]

You can wear the monitor over or under your clothes, whichever you prefer.

You'll get a five dollar gift certificate between day three and five if you have been wearing the monitor as we discussed. On the seventh day, you will return the monitor to me.

Once I make sure that everything is OK with the data on your monitor (usually takes about a week), you will get a ten dollar gift certificate and a print out of your results. If, when I get the monitor back from you, I find out something was wrong with the monitor (like if it got broken or damaged) or it was not worn the entire time that you agreed to wear it (the whole week), I will ask you to wear it again (for another week).

Here are three things to remember about wearing the monitor.

Keep the wrist watch snug

If you take it off for any reason, put it back on as soon as you can.

Make sure to ID label the monitor and write the serial # on the participant's informed consent form.

[Each student should be given the following sheets to take home: 1) Three (3) copies of the
student instruction sheets, 2) the parent information sheet]

In your packet, I am giving you some papers to take with you. The first sheet is a letter to your parents. This letter explains to your parents what you need to do while you are wearing the monitor. Make sure you give this letter to your parents tonight so that they can help you to remember to wear the monitor each day.

The second sheet reminds you how and when to wear the activity monitor. Please post this sheet in an area where it will help you remember to wear your monitor, for example, your bathroom mirror or on the fridge. I have given you 3 copies so that you can post it in three different places.

Each of these sheets also contains my phone number and my email address. Please feel free to call or email her if you have any questions while you are wearing the monitor.

Next ______________ I will pick up the monitors.

I may come back to your during the week to make sure everyone who should be wearing monitors has his/hers on. I will also text or call you at home during the between 8pm and 9 pm to remind you about wearing the monitor and to see if you have any questions then.

[check if this is OK and note preferences for calls or texts and that the time of day is OK]

Do you have any questions about wearing the monitor?

Review:

> **When are you supposed to wear the monitor?**
>
> **Where on your body does the monitor go?**
>
> **How many days are you going to be wearing the monitor?**
>
> **When am I collecting it?**
>
> **When are the only times the monitor should be taken off?**

Do you participate in any organized sport or physical activity outside of school time where you're not sure if you will be able to wear the activity monitor (or think you won't be able to)

[review individually as needed]

[If NO, say]: **"Thank you! I'll see you next ________!"**

Adapted from:

(Trial of Activity for Adolescent Girls (TAAG), 2005)

APPENDIX M: ACTIGRAPH MONITOR INSTRUCTIONS

Monitor Instructions

Wear the monitor

All Day and Night – Every Day and Night

The monitor should always be worn on the same wrist: ID sticker facing your body.

Do not take the monitor apart – that will ruin the data and we won't be able to use it.

I will call or text you during the week to see how you are doing.

I will pick up the monitor at school on ________.

If you have any questions, please call me at

_______________ or email me at

_____________________________.

Thank you for helping with this important research

APPENDIX N: PARENT INFORMATION MEMO

TO: Parents/Guardians

FROM:

DATE:

As you know, your child was invited to participate in a study about sleeping and waking patterns. The purpose of this memo is to inform you of the details of this study, and the importance of your child wearing the monitor assigned to your him/her.

The monitor (attached to a wrist strap) must be worn on the same wrist. The monitor is very small, is hardly noticeable, and will not interfere with your child's normal, everyday activities.

Your child also has a sleep log to write in everyday their sleep times, wake times, and if the times that the monitor was taken for things like bathing.

The monitor must be worn all day and night, every day and night. It should be removed for purposes of showering, bathing, or swimming, but should be put back on immediately afterwards.
The monitor should be worn for one week, seven consecutive days - from __________, [date]_____________________ through ____________ [date]_________________ .

I will return to **Long Branch High School** on _________________ to pick-up the monitor assigned to your child.

PLEASE remind your child to wear the monitor all day and night, every day and night. ***It is crucial to the integrity of the study that the monitor is worn as instructed, for the next7 days.***

We have given your child three signs to remind him/her to put the monitor on if it has been removed. (It will be helpful if these are placed in obvious places, such as the refrigerator and on the bathroom mirror). If you or your daughter has *any* questions, comments, or concerns regarding the study, please do not hesitate to call me at my office (insert # here). If I am not there, please leave a message and I will promptly return your call.

Thank you for giving your child the opportunity to participate in this important sleep study.

Sincerely,

APPENDIX O: ACTIGRAPH SCORING FORM

*from Project Sleep (Chantelle Hart)

ID: _____ **Date Range:** _________ to ________ **Scorer Initials**_________ **Date Scored**____________

( ) BL: BT_______ WT_________
( ) INC: BT_______ WT_________
( ) DEC: BT_______ WT_________

						Nighttime Sleep											
												Analysis 1: Night Sleep Period			Analysis 2: Night Time in Bed		
# /day	Date	Sick (Y/N)	School? (Y/N)	Any Naps? (Y/N)	Bath Near Slp (Y/N)	Diary BT #8	ACT BT Button press	Call-In BT	Diary WT #16 Next Day	ACTWT Buttonpress Next Day	Call-In WT Next Day	Sleep Start	Sleep End Next Day	Score Y/N/C	TIB Start	TIB End Next Day	Score? Y/N

Sleep Period filename: ____
Time in Bed filename:______________________________

Comments and Problems:

APPENDIX P: ACTIGRAPH QUESTION FORM

Date	Question	Response
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a
		Fall asleep? yes no don't know don't remember n/a

ID#___________________ Date: ________________Reviewer's initials:_________

Questions: Note all appropriate times (e.g., diary get into bed, minutes to fall asleep, approximate sleep time on the actigraph printout). **<u>Ask whether they fell asleep</u>**.

Answers: Please be clear!!! Find out what the subject was doing during the time in question. Record their answer in detail. If they aren't sure, then record that (note if they thought they were awake or asleep).
*from Project Sleep (Chantelle Hart)

APPENDIX Q: DEMOGRAPHIC INFORMATION

ID Number:

Today's Date (month/date/year): __________

Your date of birth (month/date/year): __________

Please circle one of the following:

Male Female

How would you identify your ethnicity? (Choose one)

_____ Hispanic or Latino

_____ Not Hispanic or Latino

How would you identify your race? (Check all that apply)

________ American Indian/Alaska Native

________ Asian

________ Native Hawaiian or Other Pacific Islander

________ Black or African American

________ White

________ Other

APPENDIX R: YRBS EATING HABITS AND PHYSICAL ACTIVITY

The next 9 questions ask about food you ate or drank during the past 7 days. Think about all the meals and snacks you had from the time you got up until you went to bed. Be sure to include food you ate at home, at school, at restaurants, or anywhere else.

72. During the past 7 days, how many times did you drink100% fruit juices such as orange juice, apple juice, or grape juice? (Do not count punch, Kool-Aid, sports drinks, or other fruit flavored drinks.)
    A. I did not drink 100% fruit juice during the past 7 days
    B. 1 to 3 times during the past 7 days
    C. 4 to 6 times during the past 7 days
    D. 1 time per day
    E. 2 times per day
    F. 3 times per day
    G. 4 or more times per day

73. During the past 7 days, how many times did you eat fruit? (Do not count fruit juice.)
    A. I did not eat fruit during the past 7 days
    B. 1 to 3 times during the past 7 days
    C. 4 to 6 times during the past 7 days
    D. 1 time per day
    E. 2 times per day
    F. 3 times per day
    G. 4 or more times per day

74. During the past 7 days, how many times did you eat green salad?
    A. I did not eat green salad during the past 7 days
    B. 1 to 3 times during the past 7 days
    C. 4 to 6 times during the past 7 days
    D. 1 time per day
    E. 2 times per day
    F. 3 times per day
    G. 4 or more times per day

75. During the past 7 days, how many times did you eat potatoes? (Do not count French fries, fried potatoes, or potato chips.)
    A. I did not eat potatoes during the past 7 days
    B. 1 to 3 times during the past 7 days
    C. 4 to 6 times during the past 7 days
    D. 1 time per day
    E. 2 times per day
    F. 3 times per day
    G. 4 or more times per day

76. During the past 7 days, how many times did you eat carrots?
    A. I did not eat carrots during the past 7 days
    B. 1 to 3 times during the past 7 days
    C. 4 to 6 times during the past 7 days

D. 1 time per day
E. 2 times per day
F. 3 times per day
G. 4 or more times per day

77. During the past 7 days, how many times did you eat other vegetables? (Do not count green salad, potatoes, or carrots.)

A. I did not eat other vegetables during the past 7 days
B. 1 to 3 times during the past 7 days
C. 4 to 6 times during the past 7 days
D. 1 time per day
E. 2 times per day
F. 3 times per day
G. 4 or more times per day

78. During the past 7 days, how many times did you drink a can, bottle, or glass of soda or pop, such as Coke, Pepsi, or Sprite? (Do not count diet soda or diet pop.)

A. I did not drink soda or pop during the past 7 days
B. 1 to 3 times during the past 7 days
C. 4 to 6 times during the past 7 days
D. 1 time per day
E. 2 times per day
F. 3 times per day
G. 4 or more times per day

79. During the past 7 days, how many glasses of milk did you drink? (Count the milk you drank in a glass or cup, from a carton, or with cereal. Count the half pint of milk served at school as equal to one glass.)

A. I did not drink milk during the past 7 days
B. 1 to 3 glasses during the past 7 days
C. 4 to 6 glasses during the past 7 days
D. 1 glass per day
E. 2 glasses per day
F. 3 glasses per day
G. 4 or more glasses per day

80. During the past 7 days, on how many days did you eat breakfast?

A. 0 days
B. 1 day
C. 2 days
D. 3 days
E. 4 days
F. 5 days
G. 6 days
H. 7 days

The next 4 questions ask about physical activity.

81. During the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day? (Add up all the time you spent in any kind of physical activity that increased your heart rate and made you breathe hard some of the time.)

A. 0 days
B. 1 day
C. 2 days
D. 3 days
E. 4 days
F. 5 days
G. 6 days
H. 7 days

83. On an average school day, how many hours do you watch TV?

A. I do not watch TV on an average school day
B. Less than 1 hour per day
C. 1 hour per day
D. 2 hours per day
E. 3 hours per day
F. 4 hours per day
G. 5 or more hours per day

84. On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work? (Count the time spent on things such as Xbox, PlayStation, and iPod, an iPad or other tablet, a smartphone, YouTube, Facebook or other social networking tools, and the Internet.)

A. I do not play video or computer games or use a computer for something that is not school work
B. Less than 1 hour per day
C. 1 hour per day
D. 2 hours per day
E. 3 hours per day
F. 4 hours per day
G. 5 or more hours per day

86. During the past 12 months, on how many sports teams did you play? (Count any teams run by your school or community groups.)

A. 0 teams
B. 1 team
C. 2 teams
D. 3 or more teams

APPENDIX S: COMPARISON OF SLECTED YOUTH RISK BEHAVIOR SURVEY RESPONSES TO STATE AND NATIONAL RESPONSES

Eating Habit and Physical Activity

Behavior	Overall Sample *n* (%)	New Jersey %	National Sample %
Did not eat fruit or drink juice on any day^	17 (14.78)	3.9	5.0
Did not eat vegetables on any day^	9 (7.83)	5.2	6.6
Did not drink milk on any day^	64 (55.65)	24.9	19.4
Drank soda ≥ once a day^	19 (16.52)	12.2	27.0
Did not eat breakfast on all 7 days^	80 (69.57)	59.7	61.9
Did not participate in 60 minutes of physical activity on any day^	13 (11.30)	11.6	15.2
Watched TV ≥ 3 hours /day^^	35 (30.70)	25.5	32.5
Used computer ≥ 3 hours/day^^^	69 (60.00)	36.6	41.3
Played on at least 1 sports team	75 (67.39)	-	54

Note. ^ during the 7 days preceeding the survey.
^^on an average school day.
^^^video or computer time not related to school work on an average school day.

APPENDIX T: PUBERTAL SELF-RATING SCALE FOR BOYS

Introduction: The next questions are about changes that may be happening to your body. These changes normally happen to different young people at different ages. Since they may have something to do with your sleep patterns, do your best to answer carefully. If you do not understand a question or do not know the answer, just mark “I don’t know”.

1. Would you say that your growth in height:
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don’t know

2. And how about the growth of you body hair (“Body hair” means hair in any place other than your head, such as under your arms.) Would you say that your body hair growth:
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don’t know

3. Have you started to notice any skin changes, especially pimples?
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don’t know

4. Have you noticed a deepening of your voice?
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don’t know

5. Have you begun to grow hair on your face?
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don’t know

APPENDIX U: PUBERTAL SELF RATING SCALE FOR GIRLS

Introduction: The next questions are about changes that may be happening to your body. These changes normally happen to different young people at different ages. Since they may have something to do with your sleep patterns, do your best to answer carefully. If you do not understand a question or do not know the answer, just mark "I don't know".

1. Would you say that your growth in height:
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don't know

2. And how about the growth of you body hair ("Body hair" means hair in any place other than your head, such as under your arms.) Would you say that your body hair growth:
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don't know

3. Have you started to notice any skin changes, especially pimples?
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don't know

4. Have you noticed that your breasts have begun to grow?
    a) not yet started
    b) barely started
    c) definitely started
    d) seems complete
    e) I don't know

5. Have you begun to menstruate (started to have your period)?
    a) yes
    b) no

6. If yes, how old were you when you started to menstruate? _________
7. If yes, what was the first day of your last period?
   month: _______ day: ______ year: _____

APPENDIX V: PARENT / GUARDIAN INFORMED CONSENT – PHASE ONE

Title of the Research Study: Does chronotype modify the relationship between sleep duration and body mass index in adolescents?

Protocol Number:

Principal Investigator:
Dr. Terri Lipman
University of Pennsylvania School of Nursing
Room 224 Fagin Hall 418 Curie Blvd.
Philadelphia, Pennsylvania 19104-4217
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Susan Kohl Malone
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Your child is being asked to take part in a research study. This is not a form of treatment or therapy. It is not supposed to detect a disease or find something wrong. Your child's participation is voluntary which means you can choose whether on not to participate. If you decide to allow your child to participate or not to participate there will be no loss of benefits to which you are otherwise entitled. Before you make a decision you will need to know the purpose of the study, the possible risks and benefits of being in the study and what your child will have to do if decide to allow your child to participate. The research team is going to talk with your child about the study and give you this consent document to read. You do not have to make a decision now; you can take the consent document home and share it with friends, family doctor and family.

If you do not understand what you are reading, do not sign it. Please ask the researcher to explain anything you do not understand, including any language contained in this form. If you decide to allow your child to participate, you will be asked to sign this form and return it to the school with your child or in the envelope provided. A copy will be returned to you. You may ask to have this form read to you

Dear Parent/Guardian

You child is being asked to be in a research study.

What is the purpose of this study?

In this study, we want to know how sleep is related to weight in high school students. We would like to know so that we can learn how to prevent obesity or treat obesity in children. Your child is being asked to be in this study because during high school many children do not get enough sleep.

Where and when will the study take place?

This study will take place between September 2013 and June 2014 at the Long Branch High School during health class, physical education class, or study hall. Your child will be one of 200 students in this study.

What will your child be asked to do?

Your child will:

- Take 6 short surveys that ask about their sleep, morning or evening activities, physical changes, eating habits and physical activity.
- Permit me to measure their height, weight, and waist in a private place in the school health office or school based health clinic.
- Miss one or two classes (health, physical education classes, or study hall).

Also, we will want to know if your child gets a free or reduced lunch at school from their school record.

What are the risks for my child?

Your child may become upset about how they look or about their sleep habits. If others find out information about your child, your child may be embarrassed. If your child is upset, we will have your child talk to the school counselor. If we feel that your child is upset with being in the study, we will stop.

How will my child benefit from the study?

There are no direct benefits for being in this study.

What other choices does my child have?

You may choose to allow your child to be in the study or to not to be in the study.

What happens if I do not choose to allow my child to join the research study?

Whether or not your child is in the study is voluntary, meaning that your child does not have to be in the study and that you may have them leave the study at any time. Being in the study or not being in the study will not affect their care at school or their progress in school.

When is the study over for my child?

The study will end after your child has finished all visits.

Can my child leave the study before it ends?

You have the right to have your child leave the study at anytime. There is no penalty if you decide to do so. Leaving the study will not affect your child's care or progress in school.

If you do not want your child to be in the study, please call Susan Malone, at (732) 212-1889.

How will confidentiality be maintained and my child's privacy be protected?

We will do our best to make sure that the personal information about your child from this study is kept private. If information from this study is published or presented at scientific meetings, your child's name and other personal information will not be used.

During the study, only the principal investigator and the investigator will have access to your child's information. Information will be kept in a locked file cabinet and stored in a password-protected computer.

Who can I call with questions, complaints or if I'm concerned about my child's rights as a research subject?

If you have questions, concerns, or complaints about your child being in this study or if you have any questions about your child's rights as a participant, you should speak with the Principal Investigator listed on page one of this form. If a member of the research team cannot be reached or you want to talk to someone other than those working on the study, you may contact the Office of Regulatory Affairs with any question, concerns or complaints at the University of Pennsylvania by calling (215) 898-2614.

Will my child be paid?

Your child will receive a five-dollar gift certificate.

When you sign this form, you are permitting your child to take part in this research study. If you have any questions or there is something you do not understand, contact the principal investigator or co-investigator on the front of this form. Please return this form to your child's teacher, the school health office, or mail it in the enclosed, stamped envelope. I will mail you a copy of this form.

____
Signature of Parent/guardian

____ __________
Print Name of Student Date

There is a second part to this study. In the second part of this study, your child will wear a wristwatch device that records sleeping and waking. May I contact you at a later date to see if you would like your child to be in this part of the study?

Please circle: YES NO MAYBE

APPENDIX W: STUDENT ASSENT – PHASE ONE

Title of the Research Study: Does chronotype modify the relationship between sleep duration and body mass index in adolescents?

Protocol Number:

Principal Investigator:
Dr. Terri Lipman
University of Pennsylvania School of Nursing
Room 224 Fagin Hall 418 Curie Blvd.
Philadelphia, Pennsylvania 19104-4217
tel: (215) 898-2259
email: lipman@nursing.upenn.edu

Co-investigator: (name, address, phone and email)
Susan Kohl Malone
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Emergency Contact: (name, address, phone and email)
Susan Kohl Malone
University of Pennsylvania School of Nursing
Room 360 Fagin Hall 418 Curie Blvd.
Philadelphia, Pennsylvania 19104-4217
tel: (732) 212-1889
email: malones@nursing.upenn.edu

You are being asked to take part in a research study. This is not a form of treatment or therapy. It is not supposed to detect a disease or find something wrong. Your participation is voluntary which means you can choose whether on not to participate. If you decide to participate or not to participate there will be no loss of benefits to which you are otherwise entitled. Before you make a decision you will need to know the purpose of the study, the possible risks and benefits of being in the study and what you will have to do if decide to participate. The research team is going to talk with you about the study and give you this consent document to read. You do not have to make a decision now; you can take the consent document home and share it with friends, family doctor and family.

If you do not understand what you are reading, do not sign it. Please ask the researcher to explain anything you do not understand, including any language contained in this form. If you decide to participate, you will be asked to sign this form and a copy will be given to you. Keep this form, in it you will find contact information and answers to questions about the study. You may ask to have this form read to you.

Dear Student,

You are being asked to be in a research study.

What is the purpose of this study?

In this study, we want to know how sleep is related to weight in high school students. We would like to know so that we can learn how to prevent obesity or treat obesity in children. You are being asked to be in this study because during high school many students do not get enough sleep.

Where and when will the study take place?

This study will take place between September 2013 and June 2014 at the Long Branch High School during one or two classes (health, physical education, or study hall). You will be one of 200 students in this study.

What will you be asked to do?

You will be asked to:

- Allow me to measure your height, weight, and waist in a private place in the school nurse's office or school based health clinic
- Complete 6 surveys during one or two classes (health, physical education, or study hall). These surveys will ask about your sleep habits, physical activity, eating habits, and physical changes.
- Miss one or two classes.

Also, whether or not you get a free or reduced lunch at school will be gotten from your school record.

What are the risks?

You may become upset about your height, weight, waist size, eating, activity, sleep, and/or physical changes. If this happens, we will have you talk to your school counselor for support.

How will I benefit?

There are no direct benefits for being in this study.

What other choices do I have?

You may choose to be in the study or to not to be in the study.

What happens if I do not choose to join the research study?

Being in this study is completely voluntary, meaning that you do not have to be in the study. Being in this study or not does not affect your care at school or your progress in school.

When is the study over?

The study will end after you have finished all visits.

Can I leave the study before it ends?

You may stop being in this study at any time. This will not affect with your care at school or your progress in school.

How will confidentiality be maintained and my privacy be protected?

All information that is gathered will remain confidential.

During the study, only the principal investigator and the co-investigator will have access to your information. This information will be kept in a locked file cabinet or stored in a password-protected computer.

Who can I call with questions, complaints or if I'm concerned about my rights as a research subject?

If you have any questions about the study, you may call the researchers at 732 212-1889. If you ever have any questions about your rights as a research participant, you may call the Institutional Review Board at the University of Pennsylvania by calling (215) 898-2614.

Will I be paid?

You will get a $5 gift certificate at the end of the study.

Thank you so much for considering being in this study,

Susan Kohl Malone

When you sign this document, you are agreeing to take part in this research study. If you have any questions or there is something you do not understand, please ask. You will receive a copy of this consent document.

____

Signature

____ ______________

Print Name of Student Date

There is a second part to this study. In the second part of this study, you will wear a wristwatch device that records sleeping and waking. May I contact you at a later date to see if you would like to be in this part of the study?

Please circle: YES NO MAYBE

APPENDIX X: PARENT/GUARDIAN CONSENT –PHASE TWO

Title of the Research Study: Does chronotype modify the relationship between sleep duration and body mass index in adolescents?

Protocol Number:

Principal Investigator:
Dr. Terri Lipman
University of Pennsylvania School of Nursing
Room 224 Fagin Hall 418 Curie Blvd.
Philadelphia, Pennsylvania 19104-4217
tel: (215) 898-2259
email: lipman@nursing.upenn.edu

Co-investigator: (name, address, phone and email)
Susan Kohl Malone
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Emergency Contact: (name, address, phone and email)
Susan Kohl Malone
University of Pennsylvania School of Nursing
Room 360 Fagin Hall 418 Curie Blvd.
Philadelphia, Pennsylvania 19104-4217
tel: (732) 212-1889
email: malones@nursing.upenn.edu

Your child is being asked to take part in a research study. This is not a form of treatment or therapy. It is not supposed to detect a disease or find something wrong. Your child's participation is voluntary which means you can choose whether on not to participate. If you decide to allow your child to participate or not to participate there will be no loss of benefits to which you are otherwise entitled. Before you make a decision you will need to know the purpose of the study, the possible risks and benefits of being in the study and what your child will have to do if decide to allow your child to participate. The research team is going to talk with your child about the study and give you this consent document to read. You do not have to make a decision now; you can take the consent document home and share it with friends, family doctor and family.
If you do not understand what you are reading, do not sign it. Please ask the researcher to explain anything you do not understand, including any language contained in this form. If you decide to allow your child to participate, you will be asked to sign this form and return it to the school with your child or in the envelope provided. A copy will be returned to you. You may ask to have this form read to you.

Dear Parent/Guardian

Thank you for letting your child be in Part 1 of this study. You are getting this form because you said we could ask you if your child could be in Part 2.

What is the purpose of this study?

You child is being asked to be in a study about sleep and weight. We want to know more about your child's rest and activity over one week.

Where and when will the study take place?

Over the next few months, your child will be asked to come to the health office to learn how to use a small watch like devise, called an actigraph. This device measures rest and activity. Your child will wear this device all the time during the next week when they are at home, at school, and while they are sleeping. Your child will be one of 80 students in this part of the study.

What will your child be asked to do?

Your child will:

- Come to the health office to learn how to use the device that will measure their rest and activity,
- Wear this device on their wrist, called an actigraph, for one week. This watch should be worn all the time but can be taken off for showers/bathing, swimming, and physical activities where the monitor might get bumped or hit, such as playing soccer.
- Keep a log of the times that they fall asleep and wake up each day, along with any daytime naps.
- Return the device and the log to me at the end of the 7 days.
- Allow me to measure their height, weight, and waist in a private place in the school health office or school based health clinic.
- Miss one class or two classes (health, physical education classes, or study hall).

What are the risks for my child?

Your child may become upset about how they look or about their sleep habits. If others find out information about your child, your child may be embarrassed. If your child is upset, we will have your child talk to the school counselor. If we feel that your child is upset with being in the study, we will stop.

How will my child benefit from the study?

Your child will not directly benefit from being in this study.

What other choices does my child have?

You may choose to allow your child to be in the study or to not to be in the study.

What happens if I do not choose to allow my child to join the research study?

Whether or not your child is in the study is voluntary, meaning that your child does not have to be in the study and that you may have them leave the study at any time. Whether or not your child is in the study, it will not affect their care at school or their progress in school.

When is the study over for my child?

The study will end after your child has worn the device for 7 days.

Can my child leave the study before it ends?

You have the right to have your child drop out of the study at anytime. There is no penalty if you decide to do so. It will not affect with your child's care or progress at school.

If you no longer want for your child to be in the study, please contact Susan Malone, at (732) 212-1889.

How will confidentiality be maintained and my child's privacy be protected?

We will do our best to make sure that the personal information obtained during the course of this research study will be kept private. If information from this study is published or presented at scientific meetings, your child's name and other personal information will not be used.

During the study, only the principal investigator and the co-investigator will have access to your child's information. Information will be kept in a locked file cabinet or stored in a password-protected computer.

Who can I call with questions, complaints or if I'm concerned about my child's rights as a research subject?

If you have questions, concerns or complaints regarding your child's participation in this research study or if you have any questions about your child's rights as a participant, you should speak with the Principal Investigator listed on page one of this form. If a member of the research team cannot be reached or you want to talk to someone other than those working on the study, you may contact the Office of Regulatory Affairs with any question, concerns or complaints at the University of Pennsylvania by calling (215) 898-2614.

Will my child be paid?

Your child will receive a $15 gift certificate when they return the actigraph and their log.

When you sign this form, you are permitting your child to be in this study. If you have any questions or there is something you do not understand, contact the principal investigator or co-investigator on the front of this form. Please return this form to the school health office or mail it in the enclosed, stamped envelope. I will mail you a copy of this consent form.

____
Signature of Parent/guardian

____ ____________
Print Name of Student Date

APPENDIX Y: STUDENT ASSENT - PHASE TWO

Title of the Research Study: Does chronotype modify the relationship between sleep duration and body mass index in adolescents?

Protocol Number:

Principal Investigator:
Dr. Terri Lipman
University of Pennsylvania School of Nursing
Room 224 Fagin Hall 418 Curie Blvd.
Philadelphia, Pennsylvania 19104-4217
tel: (215) 898-2259
email: lipman@nursing.upenn.edu

Co-investigator: (name, address, phone and email)
Susan Kohl Malone
University of Pennsylvania School of Nursing
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Philadelphia, Pennsylvania 19104-4217
tel: (732) 212-1889
email: malones@nursing.upenn.edu

Emergency Contact: (name, address, phone and email)
Susan Kohl Malone
University of Pennsylvania School of Nursing
Room 360 Fagin Hall 418 Curie Blvd.
Philadelphia, Pennsylvania 19104-4217
tel: (732) 212-1889
email: malones@nursing.upenn.edu

You are being asked to take part in a research study. This is not a form of treatment or therapy. It is not supposed to detect a disease or find something wrong. Your participation is voluntary which means you can choose whether on not to participate. If you decide to participate or not to participate there will be no loss of benefits to which you are otherwise entitled. Before you make a decision you will need to know the purpose of the study, the possible risks and benefits of being in the study and what you will have to do if decide to participate. The research team is going to talk with you about the study and give you this consent document to read. You do not have to make a decision now; you can take the consent document home and share it with friends, family doctor and family.

If you do not understand what you are reading, do not sign it. Please ask the researcher to explain anything you do not understand, including any language contained in this form. If you decide to participate, you will be asked to sign this form and a copy will be given to you. Keep this form, in it you will find contact information and answers to questions about the study. You may ask to have this form read to you.

Dear Student,

Thank you for being in Part 1 of this study. You are getting this form because you said it would be OK to ask you to be in Part 2.

What is the purpose of this study?

You are being asked to be in a study about sleep and weight. We would like to know more about your rest and activity over one week.

Where and when will the study take place?

Over the next few months, you will be asked to come to the health office to learn how to use a small watch like devise, called an actigraph. This devise will measure your rest and activity. You will need to wear this device all the time during the next week when you are at home, at school, and while you are sleeping. You will be one of 80 students in this part of the study.

What will you be asked to do?

You will:

- Come to the health office or school based health clinic to learn how to use the device that will measure your rest and activity.
- Wear a small watch like device on your wrist, called an actigraph, for one week. This watch should be worn all the time. You can remove it for showers/bathing, swimming or any time the device might get bumper or hit, such as when playing soccer.
- Keep a log of the times that you fall asleep and wake up each day and any daytime naps.
- Return the device and the log to me at the end of the 7 days.
- Allow me to measure your height, weight, and waist in a private place in the school health office or school based health clinic.
- Miss one or two class (health, physical education classes, or study hall) to learn how to use the device and have your height, weight and waist measured.

What are the risks?

You may become upset about your height, weight, waist size, and/or sleep habits. If this happens, we will have you talk to your school counselor.

How will I benefit?

There are no direct benefits for being in this study.

What other choices do I have?

You may choose to be in the study or to not to be in the study.

What happens if I do not choose to join the research study?

Whether or not you are in this study is voluntary, meaning that you do not have to be in the study. Whether or not you are in the study, your care at school or your progress in school will not be affected.

When is the study over?

The study will end after you have worn the device for one week.

Can I leave the study before it ends?

You may leave this study at any time. This will not affect with your care at school or your progress at school.

How will confidentiality be maintained and my privacy be protected?

All information that is gathered will be kept private.

During the study, only the principal investigator and the co-investigator will have access to your information. Paper and pencil information will be kept in a locked file cabinet or stored in a password-protected computer.

Who can I call with questions, complaints or if I'm concerned about my rights as a research subject?

If you have any questions about the study, you may call the researchers at (732) 212-1889. If you ever have any questions about your rights as a research participant, you may call the Institutional Review Board at (215) 898-2614.

Will I be paid?

You will receive a $15 gift certificate at the end of this study.

Thank you so much for considering being in this study,

Susan Kohl Malone

When you sign this form, you are agreeing to be in this research study. If you have any questions or there is something you do not understand, please ask. You will receive a copy of this form.

____
Signature

____________________________________ ____________
Print Name of Student Date

APPENDIX Z: RESOLVING PARENT/GUARDIAN AND STUDENT PARTICIPATION DISAGREEMENTS

The investigator will resolve dissent between parent/guardian and student as follows:

1. In situations where the student assents to participate but the parent/guardian has refused consent; the parent/guardian refusal will supercede the student's assent.
2. In situations where the student does not assent, but the parent/guardian has consented, the student's refusal will supercede the parent/guardian consent.

APPENDIX AA: RESULTS OF BIVARIATE ANALYSES FOR AIM 1

School Night Sleep Duration: Socio-demographic and Behavioral Characteristics

Phase I. Taking naps on school days (t (112) = 2.0, p = 0.05), drinking soda (r^s = -0.3, p = 0.001), and having a later chronotype preference (lower M/E Q scores; r = 0.3, p = 0.01) were associated with shorter self-reported school night sleep in the bivariate analyses (see Table 55 and Table 56)

Phase II. Taking naps on school days (t (67) = 2.4, p = 0.02) and free days (t (67) = 2.4. p = 0.02) was associated with shorter actigraphy-estimated school night sleep in the bivariate analyses (see Table 55 and 56).

Table 55

Differences in School Night Sleep Duration

Characteristic	Phase I (N = 115) *M (SD)*	*p*	Phase II (N = 69) *M (SD)*	*p*
Sex		0.246		0.982
female (reference)	7.2 (1.5)		7.1 (0.8)	
male	7.5 (1.3)		7.1 (0.8)	
Race/ethnicity		0.416		0.350
Hispanic (reference)	7.6 (1.0)		7.0 (0.8)	
White	7.2 (1.5)		7.2 (0.8)	
Black	7.2 (1.7)		7.1 (0.8)	
Asian	6.9 (1.3)		6.4 (0.4)	
Free/reduced lunch		0.164		0.892
yes (reference)	7.5 (1.5)		7.1 (0.8)	
no	7.1 (1.1)		7.1 (0.8)	
Pubertal category		0.497		0.731
mid	7.3 (1.3)		7.0 (0.9)	
late	7.7 (1.3)		6.9 (0.7)	
post (reference)	7.3 (1.5)		7.1 (0.8)	
Naps: school days		**0.053**		**0.021**
no	7.5 (1.1)		7.3 (0.8)	
yes	7.0 (1.7)		6.8 (0.7)	
Naps: free days		0.141		**0.019**
no	7.6 (1.4)		7.2 (0.8)	
yes	7.2 (1.4)		6.5 (0.8)	

Note. *M* = mean *SD* = standard deviation

Table 56

Correlations between School Night Sleep Duration and Age, Eating Habits, and Physical Activity

Characteristic	Phase I (N= 115) *Correlation coefficients*	Phase II (N =69) *Correlation coefficients*
Age	0.02	-0.04
Eating Habits		
juice^	0.06	-0.09
fruit/vegetables^	0.15	-0.003
soda^	-0.31**	-0.14
milk^	-0.03	-0.05
breakfast^	0.04	0.03

Characteristic	Phase I (N= 115) *Correlation coefficients*	Phase II (N =69) *Correlation coefficients*
Physical Activity		
screen time^	-0.11	-0.13
days active^	0.10	0.03
sports^	0.16	0.13
Chronotype		
M/EQ	0.23**	0.16
Midpoint of sleep	-0.13	-
Social jet lag	-0.03	-

Note. * $p \leq 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified. ^ Spearman's correlations were performed because these variables are nonparametric.

Free Night Sleep Duration: Demographic and Behavioral Characteristics

Phase I. Race/ethnicity (F (3,110) = 3.7, p = 0.01), free/reduced lunch participation (t (112) = 2.1, p = 0.04), and eating breakfast less frequently ($r^s = 0.2$, p = 0.05) were significantly associated with shorter free night sleep duration in the bivariate analyses (see Table 57 and Table 58).

Phase II. There were no significant bivariate associations for actigraphy-estimated free night sleep duration. See Table 57 and Table 58).

Table 57

Differences in Free Night Sleep Duration

Characteristic	Phase I (N =114) *M (SD)*	*p*	Phase II (N = 68) *M (SD)*	*p*
Sex		0.738		0.160
female (reference)	9.4 (1.9)		8.3 (1.5)	
male	9.3 (2.3)		7.7 (1.4)	
Race/ethnicity		**0.014**		0.128
Hispanic (reference)	9.8 (1.5)		8.4 (1.7)	
White	9.8 (2.0)		8.2 (1.2)	
Black	8.5 (2.4)		7.4 (1.5)	
Asian	9.0 (1.4)		9.1 (1.0)	
Free/reduced lunch		**0.037**		0.667
yes (reference)	9.1 (2.2)		8.1 (1.7)	

Characteristic	Phase I (N =114) M (SD)	p	Phase II (N = 68) M (SD)	p
no	9.9 (1.4)		8.2 (1.7)	
Pubertal category		0.237		0.805
mid	9.5 (1.5)		7.9 (1.6)	
late	8.6 (2.4)		8.0 (1.4)	
post (reference)	9.5 (2.0)		8.2 (1.6)	
Naps: school days		0.127		0.072
no (0)	9.6 (1.7)		8.4 (1.5)	
yes (1)	9.1 (2.3)		7.7 (1.6)	
Naps: free days		0.093		0.193
no (0)	9.6 (2.0)		8.2 (1.6)	
yes (1)	9.0 (1.9)		7.5 (1.2)	

Note. *M* = mean *SD* = standard deviation

Table 58

Correlations between Free Night Sleep Duration and Age, Eating Habits, and Physical Activity

Characteristic	Phase I (N = 114) *Correlation coefficients*	Phase II (N = 68) *Correlation coefficients*
Age	0.02	-0.06
Eating Habits		
juice^	0.10	-0.18
fruit/vegetables^	-0.12	-0.04
soda^	-0.003	-0.17
milk^	0.01	-0.07
breakfast^	0.18*	0.05
Physical Activity		
screen time^	0.02	0.02
days active^	0.13	-0.03
sports^	0.11	0.11
Chronotype		
M/EQ	-0.02	0.12
Midpoint of sleep	-0.07	-
Social jet lag	0.13	-

Note. * $p \leq 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified. ^ Spearman's correlations were performed because these variables are nonparametric.

Total Night Sleep Duration: Demographic and Behavioral Characteristics

Phase I. Taking naps on school days (t (112) = 2.4, p = 0.02), not participating in sports (r^s = 0.2, p =0.04), drinking more soda (r^s = -0.3, p = 0.01), and having a later chronotype preference (lower M/E Q scores; r = 0.2, p = 0.05) were associated with shorter total night sleep durations in the bivariate analyses (see Table 59 and Table 60).

Phase II. Napping on school days (t (67) = 3.3, p = 0.002) and napping on free days (t (67) = 2.6, p = 0.012) were associated with shorter total night sleep duration in the bivariate analyses (see Table 59 and Table 60).

Table 59

Differences in Total Night Sleep Duration

	Phase I (N = 114)		Phase II (N = 69)	
Characteristic	*M (SD)*	*p*	*M (SD)*	*p*
Sex		0.424		0.582
female (reference)	7.8 (1.3)		7.3 (0.8)	
male	8.0 (1.1)		7.2 (0.7)	
Race/ethnicity		0.080		0.580
Hispanic (reference)	8.2 (0.9)		7.3 (0.2)	
White	7.9 (1.3)		7.4 (0.7)	
Black	7.5 (1.5)		7.2 (0.9)	
Asian	7.5 (1.2)		6.9 (0.3)	
Free/reduced lunch		0.860		0.691
yes (reference)	7.9 (1.4)		7.3 (0.8)	
no	7.9 (0.9)		7.3 (0.7)	
Pubertal category		0.978		0.669
mid	7.9 (1.0)		7.2 (0.8)	
late	8.0 (1.0)		7.1 (0.7)	
post (reference)	7.9 (1.3)		7.3 (0.1)	
Naps: school days		**0.020**		**0.002**
no	8.1 (1.0)		7.5 (0.8)	
yes	7.6 (1.4)		6.9 (0.6)	
Naps: free days		0.670		**0.012**
no	7.9 (1.1)		7.4 (0.7)	
yes	7.9 (1.3)		6.5 (0.6)	

Note. M = mean SD = standard deviation

Table 60

Correlations between Total Night-time Sleep Duration and Age, Eating Habits, and Physical Activity

Characteristic	Phase I (N = 114) *Correlation coefficients*	Phase II (N = 69) *Correlation coefficients*
Age	0.03	-0.06
Eating Habits		
juice^	0.12	-0.10
fruit/vegetables^	0.07	-0.08
soda^	-0.26**	-0.20
milk^	-0.03	-0.07
breakfast^	0.10	0.10
Physical Activity		
screen time^	-0.09	-0.11
days active^	0.13	-0.01
sports^	0.16*	0.13
Chronotype		
M/EQ	0.20*	0.20
Midpoint of sleep	-0.001	-
Social jet lag	0.09	-

Note. * $p \leq 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified. ^ Spearman's correlations were performed because these variables are nonparametric.

Morningness /Eveningness Questionnaire (M/E Q): Demographic and Behavioral Characteristics

Phase I. Taking naps on school days (t (113) = 5.5, p = 0.000), eating fewer fruits/vegetables (r^s = 0.2, p = 0.01), drinking more soda (r^s = -0.3, p = 0.000), watching more TV and playing more computer/video games (r^s = -0.2, p = 0.03), being less physically active (r^s = 0.3, p = 0.002), and participating on fewer sports teams (r^s = 0.2, p = 0.03) were associated with later chronotype preferences (lower M/E Q scores) in the bivariate analyses (see Table 61 and Table 62).

Phase II. Taking naps on school day (t (67) = 2.6, p = 0.01), being less physical activity (r = 0.3, p = 0.01), eating fewer fruits/vegetables (r = 0.3, p = 0.01), drinking more soda (r = -0.5 p < 0.00), and spending more TV/computer time per day (r = -0.3, p = 0.01) were significantly associated with a lower M/E Q scores, indicating a preference for a later chronotype in the bivariate analyses (see Table 61 and Table 62).

Table 61

Differences in the Morningness/Eveningness Questionnaire

Characteristic	Phase I (N = 115) *M (SD)*	*p*	Phase II (N = 69) *M (SD)*	*p*
Sex		0.179		0.302
female (reference)	26.2 (4.2)		27 (5)	
male	27.2 (2.9)		28 (3)	
Race/ethnicity		0.802		0.777
Hispanic (reference)	26.7 (3.7)		27 (4)	
White	26.9 (4.0)		27 (4)	
Black	26.0 (4.0)		26 (5)	
Asian	26.5 (4.9)		28 (4)	
Free/reduced lunch		0.313		0.731
yes (reference)	26.3 (3.9)		27 (4)	
no	27.1 (3.9)		27 (4)	
Pubertal category		0.134		0.141
mid	27.4 (3.1)		28 (4)	
late	27.9 (3.2)		29 (3)	
post	26.1 (4.1)		26 (4)	
Naps: school days		0.112		**0.012**
yes (reference)	25.9 (3.9)		25 (4)	
no	27.1 (3.8)		28 (4)	
Naps: free days		**0.000**		0.535
yes (reference)	25.1 (3.7)		26 (5)	
no	28.7 (3.1)		27 (4)	

Note. M = mean. *SD* = standard deviation

Table 62

Correlations between the Morningness/Eveningness Questionnaire with Age, Eating Habits, and Physical Activity

Characteristic	Phase I (N = 115) *Correlation coefficients*	Phase II (N = 69) *Correlation coefficients*
Age	-0.15	-0.13

Eating Habits		
juice^	0.07	0.06
fruit/vegetables^	0.24**	0.34**
soda^	-0.33***	-0.46***
milk^	0.15	0.18
breakfast^	0.14	0.21
Physical Activity		
screen time^	-0.20*	-0.33**
days active^	0.29**	0.33**
sports^	0.20*	0.20

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified. ^ Spearman's correlations were performed because these variables are nonparametric.

Midpoint of Sleep: Demographic and Behavioral Characteristics

Phase 1. Drinking more soda ($r^s = 0.2$, $p = 0.04$) and being less physically active ($r^s = -0.2$, $p = .03$) were associated with later chronotypes (later midpoints of sleep) in the bivariate analyses (see Table 64).

Phase II. Taking naps on school days ($t\ (66) = -2.8$, $p = 0.01$), and spending more TV/computer time per day ($r^s = 0.3$ $p = 0.01$) were significantly associated with later midpoints of sleep, indicating later chronotypes in the bivariate analyses. See Tables 63 and 64.

Table 63

Differences in the Midpoint of Sleep

Characteristic	Phase I (N = 115) *M (SD)*	*p*	Phase II (N = 68)	
Sex		0.167		0.325
female (reference)	3:49 (1:25)		3:36 (1:12)	
male	4:14 (1:32)		3:18 (1:00)	
Race/ethnicity		0.560		0.588
Hispanic (reference)	3:44 (1:37)		3:18 (1:18)	
White	4:05 (1:13)		3:42 (1:06)	
Black	4:00 (1:31)		3:36 (1:18)	
Asian	4:36 (1:15)		3:06 (0:18)	

Free/reduced lunch		0.536		0.740
yes (reference)	3:53 (1:27)		3:30 (1:18)	
no	4:03 (1:28)		3:24 (0:54)	
Pubertal category		0.431		0.179
mid	4:22 (1:41)		3:24 (0:48)	
late	3:59 (1:31)		2:42 (0:18)	
post (reference)	3:51 (1:24)		3:36 (1:18)	
Naps: school days		0.754		**0.006**
yes (reference)	3:59 (1:20)		3:54 (1:18)	
no	3:54 (1:34)		3:12 (1:00)	
Naps: free days		0.172		0.394
yes (reference)	4:06 (1:36)		3:48 (1:00)	
no	3:43 (1:13)		3:24 (1:00)	

Note. M = mean. *SD* = standard deviation

Table 64

Correlations between the Midpoint of Sleep with Age, Eating Habits, and Physical Activity

Characteristic	Phase I (N = 115) *Correlation coefficients*	Phase II (N =68) *Correlation coefficients*
Age	0.02	-0.07
Eating Habits		
juice^	0.01	-0.15
fruit/vegetables^	0.02	-0.17
soda^	0.19*	0.22
milk^	-0.01	-0.21
breakfast^	-0.04	-0.03
Physical Activity		
screen time^	0.12	0.30*
days active^	-0.21*	-0.21
sports^	-0.01	-0.23

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified. ^ Spearman's correlations were performed because these variables are nonparametric.

Social Jet Lag: Demographic and Behavioral Characteristics

Phase 1. Drinking more soda ($r^s = 0 .2$, $p = 0.04$) was associated with greater social jet lag in the bivariate analyses. See Table 66.

Phase II. Females (t (66) = -2.4, p = 0.01), greater juice intake (r = 0.3 p = 0.04), and pubertal category (F (2, 63) = 4.9, p = 0.01) were associated with greater social jet lag in the bivariate analyses. See Tables 65 and 66.

Table 65

Differences in Social Jet Lag

Characteristic	Phase I (N = 115) *M (SD)*	*p*	Phase II (N = 68) *M (SD)*	*p*
Sex		0.765		**0.019**
female (reference)	2.5 (1.3)		1.5 (0.9)	
male	2.6 (1.7)		0.9 (0.8)	
Race/ethnicity		0.743		0.723
Hispanic (reference)	2.4 (1.4)		1.4 (0.9)	
White	2.7 (1.2)		1.3 (0.9)	
Black	2.6 (1.7)		1.1 (1.1)	
Asian	2.5 (1.1)		1.6 (0.5)	
Free/reduced lunch		0.145		0.824
yes (reference)	2.4 (1.4)		1.3 (1)	
no	2.8 (1.4)		1.3 (0.7)	
Pubertal category		0.940		**0.011**
mid	2.7 (1.4)		1 (0.8)	
late	2.6 (1.9)		0.5 (0.4)	
post	2.5 (1.3)		1.5 (0.9)	
Naps: school days		0.699		0.553
yes (reference)	2.5 (1.4)		1.4 (1)	
no	2.6 (1.4)		1.3 (0.9)	
Naps: free days		0.103		0.567
yes (reference)	2.7 (1.5)		1.3 (0.9)	
no	2.3 (1.2)		1.1 (1.3)	

Note. M = mean. *SD* = standard deviation

Table 66

Correlations between Social Jet Lag with Age, Eating Habits, and Physical Activity

Characteristic	Phase I (N = 115) *Correlation coefficients*	Phase II (N = 68) *Correlation coefficients*
Age	-0.04	-0.11
Eating Habits		
juice^	0.06	-0.26*

fruit/vegetables^	0.12	0.07
soda^	0.20*	-0.07
milk^	0.03	-0.22
breakfast^	-0.10	-0.13
Physical Activity		
screen time^	0.10	0.15
days active^	-0.15	-0.09
sports^	0.01	-0.14

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified. ^ Spearman's correlations were performed because these variables are nonparametric.

APPENDIX BB: RESULTS OF BIVARIATE ANALYSES FOR AIM 2

Sleep Duration and BMI z scores (Tables BB.1, BB.2)

Phase I. Longer school night sleep duration ($r = 0.3$, $p = 0.003$), longer total night-time sleep duration ($r = 0.193$, $p = 0.04$), less soda intake ($r^s = -0.2$ $p = 0.3$), and younger ages ($r = -0.2$, $p = 0.01$) were associated with higher BMI z scores in the bivariate analyses (see Table 67 and Table 68).

Phase II. Not napping on school days (t (67) = 2.2, $p = 0.03$) and free days (t (67) = 2.9, $p = 0.01$) were significantly associated with higher BMI z scores in the bivariate analyses. See Table 67 and 68.

Table 67

Differences in BMI z scores

	Phase I (N = 115)		Phase II (N = 69)	
Characteristic	*M (SD)*	*p*	*M (SD)*	*p*
Sex		0.103		0.157
female (reference)	0.5 (1.0)		0.6 (0.9)	
male	0.9 (1.2)		0.9 (0.9)	
Race/ethnicity		0.731		0.406
Hispanic (reference)	0.7 (1.1)		0.7 (1.0)	
White	0.5 (1.0)		0.7 (0.8)	
Black	0.7 (1.1)		0.5 (1.2)	
Asian	0.1 (0.5)		0.2 (0.5)	
Free/reduced lunch		0.213		0.571
yes (reference)	0.7 (1.1)		0.7 (1)	
no	0.4 (1.0)		0.6 (0.9)	
Pubertal category		0.212		0.660
mid	1.0 (1.2)		0.9 (1.1)	
late	0.6 (1.1)		0.7 (0.7)	
post (reference)	0.5 (1.0)		0.6 (0.9)	
Naps: school days		0.356		0.028
yes (reference)	0.5 (1.1)		0.4 (1.1)	
no	0.7 (1.0)		0.9 (0.7)	
Naps: free days		0.794		0.006

Characteristic	Phase I (N = 115) M (SD)	p	Phase II (N = 69) M (SD)	p
yes (reference)	0.6 (1.0)		-0.2 (1.2)	
no	0.6 (1.1)		0.8 (0.8)	

Note. *M* = mean. *SD* = standard deviation.

Table 68

Correlations between BMI z scores with Age, Eating Habits, Physical Activity, and Sleep Duration

Characteristic	Phase I (N = 115) *Correlation coefficients*	Phase I (N = 69) *Correlation coefficients*
Age	-0.24**	-0.09
Eating Habits		
juice^	-0.07	-0.05
fruit and vegetables^	0.02	0.15
soda^	-0.20*	-0.19
milk^	-0.01	-0.002
breakfast^	0.10	0.18
Physical Activity		
screen time^	0.02	-0.08
days active^	0.09	0.14
sports^	-0.02	0.01
Sleep duration		
school nights	0.28**	0.20
free nights	-0.07	0.08
total night	0.19*	0.17

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified.^ Spearman's correlations were performed because these variables are nonparametric.

Sleep Duration and BMI z scores in Males

Phase I. Younger ages were associated with higher BMI z scores in males ($r = -0.3$, $p = 0.05$) in the bivariate analyses. See Table 70.

Phase II. Drinking less juice per day was significantly associated with higher BMI z scores in males ($r = -0.6$, $p = 0.01$) in the bivariate analyses See Table 69.

Table 69

Differences in BMI z scores in Males

	Phase I (*n* = 35)		Phase II (*n* = 18)	
Characteristic	*M (SD)*	*p*	*M (SD)*	*p*
Race/ethnicity		0.785		0.904
Hispanic (reference)	1.2 (0.3)		0.8 (1.1)	
White	1.1 (0.3)		1.0 (0.7)	
Black	1.2 (0.4)		1.4 (0.9)	
Free/reduced lunch		0.850		0.672
yes (reference)	0.8 (1.2)		1.0 (1.1)	
no	0.9 (1.1)		0.8 (0.3)	
Pubertal category		0.443		0.767
mid	1.1 (1.1)		1.0 (1.0)	
late	0.6 (1.1)		0.7 (0.7)	
post	1.1 (0.8)		1.2 (1.2)	
Naps: school days		0.418		0.727
yes (reference)	1.0 (1.1)		0.8 (1.1)	
no	0.7 (1.1)		1.0 (0.8)	
Naps: free days		0.262		0.740
yes (reference)	1.1 (1.1)		-	-
no	0.6 (1.2)		0.9 (0.9)	

Note. *M* = mean. *SD* = standard deviation

Table 70

Correlations between BMI z scores with Age, Eating Habits, Physical Activity, and Sleep Duration in Males

	Phase I (n = 35)	Phase II (n = 18)
Characteristic	*Correlation coefficients*	*Correlation coefficients*
Age	-0.34*	0.11
Eating Habits		
juice^	-0.28	-0.62**
fruit/vegetables^	-0.09	-0.10
soda^	-0.30	-0.26
milk^	0.01	-0.36
breakfast^	0.14	0.22
Physical Activity		
screen time^	0.17	0.02
days active^	-0.12	-0.06
sports^	-0.10	-0.01
Sleep duration		

Characteristic	Phase I (n = 35) *Correlation coefficients*	Phase II (n = 18) *Correlation coefficients*
school nights	0.25	0.03
free nights	-0.15	0.34
total night	0.12	0.19

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified.^ Spearman's correlations were performed because these variables are nonparametric.

Sleep Duration and BMI z scores in Females

Phase I. Longer school night sleep duration was associated with higher BMI z scores in females ($r = 0.3$, $p = 0.02$) in the bivariate analyses. See Table 72.

Phase II. Not napping on school days (t (49) = 2.4, $p = 0.02$) and free days (t (49) = 2.8, $p = 0.01$) were significantly associated with higher BMI z scores in females in the bivariate analyses See Table 71.

Table 71

Differences in BMI z scores in Females

	Phase I (n = 80)		Phase II (n = 51)	
Characteristic	*M (SD)*	*p*	*M (SD)*	*p*
Race/ethnicity		0.704		0.664
Hispanic (reference)	0.6 (1.1)		0.7 (0.9)	
White	0.5 (0.9)		0.6 (0.8)	
Black	0.5 (1.0)		0.4 (1.2)	
Asian	-0.1 (0.3)		-0.04 (0.3)	
Free/reduced lunch		0.088		0.726
yes (reference)	0.7 (1.0)		0.6 (1.0)	
no	0.3 (0.9)		0.5 (0.9)	
Naps: school days		0.081		0.021
yes (reference)	0.3 (1.0)		0.2 (1.1)	
no	0.7 (1.0)		0.8 (0.7)	
Naps: free days		0.287		0.007
yes (reference)	0.4 (1.0)		-0.3 (1.2)	
no	0.7 (1.0)		0.7 (0.8)	

Note. *M* = mean. *SD* = standard deviation

Table 72

Correlations between BMI z scores with Age, Eating Habits, Physical Activity, and Sleep Duration in Females

Characteristic	Phase I (n = 80) *Correlation coefficients*	Phase II (n = 51) *Correlation coefficients*
Age	-0.19	-0.14
Eating Habits		
juice^	0.03	0.11
fruit/vegetables^	0.07	0.24
soda^	-0.13	-0.17
milk^	-0.09	0.05
breakfast^	0.002	0.11
Physical Activity		
screen time^	-0.03	-0.11
days active^	0.13	0.16
sports^	0.004	-0.03
Sleep duration		
school nights	0.27*	0.26
free nights	-0.22	0.05
total night	0.22	0.18

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified.^ Spearman's correlations were performed because these variables are nonparametric.

Sleep duration and Waist to Height Ratios

Phase I. Younger ages (r = 0.2, p = .01), longer school night sleep durations (r = 0.2, p = 0.02), and longer total night time sleep durations (r = 0.2, p = 0.04) were associated with a higher WHtR in the bivariate analyses. See Tables 73 and 74.

Phase II. There were no significant associations between sleep duration and WHtR in the bivariate analysis.

Table 73

Differences in Waist to Height Ratio

	Phase I (N = 113)		Phase II (N = 69)	
Characteristic	*M (SD)*	*p*	*M (SD)*	*p*
Sex		0.616		0.292
female (reference)	0.50 (0.08)		0.51 (0.06)	
male	0.49 (0.08)		0.49 (0.07)	
Race/ethnicity		0.409		0.370
Hispanic (reference)	0.51 (0.09)		0.51 (0.07)	
White	0.49 (0.06)		0.51(0.06)	
Black	0.49 (0.08)		0.49 (0.07)	
Asian	0.46 (0.02)		0.46 (0.02)	
Free/reduced lunch		0.149		0.271
yes (reference)	0.50 (0.08)		0.51 (0.07)	
no	0.48 (0.06)		0.49 (0.05)	
Pubertal category		0.342		0.270
mid	0.51(0.09)		0.49 (0.08)	
late	0.47 (0.07)		0.47 (0.05)	
post (reference)	0.50 (0.08)		0.51 (0.06)	
Naps: school days		0.112		0.307
yes (reference)	0.48 (0.07)		0.49 (0.07)	
no	0.51 (0.08)		0.51 (0.06)	
Naps: free days		0.538		0.150
yes (reference)	0.49 (0.07)		0.50 (0.06)	
no	0.50 (0.09)		0.47 (0.04)	

Note. *M* = mean. *SD* = standard deviation

Table 74

Correlations between Waist to Height Ratio and Age, Eating Habits, Physical Activity, and Night-time Sleep Duration

Characteristic	Phase I (N = 113) *Correlation coefficients*	Phase II (N = 69) *Correlation coefficients*
Age	-0.24*	0.04
Eating Habits		
juice^	-0.02	-0.05
fruit and vegetables^	0.01	0.15
soda^	-0.16	-0.14
milk^	-0.07	-0.07
breakfast^	0.02	0.07

Characteristic	Phase I (N = 113) *Correlation coefficients*	Phase II (N = 69) *Correlation coefficients*
Physical Activity		
screen time^	0.08	0.01
days active^	-0.04	-0.07
sports^	-0.14	-0.17
Sleep duration		
school nights	0.21*	0.004
free nights	0.04	0.05
total night	0.19*	-0.004

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified.^ Spearman's correlations were performed because these variables are nonparametric.

Sleep duration and Waist to Height Ratios in Males

Phase I. Younger ages were associated with higher WHtRs in males in the bivariate analyses ($r = -0.4$, $p = 0.01$). See Table 76.

Phase II. Drinking less juice per day was significantly associated with higher WHtRs in males in the bivariate analyses ($r = -0.6$ $p = 0.02$). See Table 76.

Table 75

Differences in Waist to Height Ratio in Males

Characteristic	Phase I (n = 35) *M (SD)*	*p*	Phase II (n = 18) *M (SD)*	*p*
Race/ethnicity		0.902		0.859
Hispanic (reference)	0.49 (0.09)		0.50 (0.08)	
White	0.49 (0.07)		0.48 (0.06)	
Black	0.50 (0.11)		0.49 (0.09)	
Free/reduced lunch		0.992		0.271
yes (reference)	0.49 (0.08)		0.50 (0.08)	
no	0.49 (0.08)		0.46 (0.04)	
Pubertal category		0.390		0.604
mid	0.51 (1.00)		0.50 (0.08)	
late	0.47 (0.07)		0.47 (0.05)	
post (reference)	0.49 (0.08)		0.50 (0.10)	
Naps: school days		0.882		0.586
yes (reference)	0.49 (0.07)		0.50 (0.09)	

Characteristic	Phase I (n = 35) *M (SD)*	*p*	Phase II (n = 18) *M (SD)*	*p*
no	0.49 (0.09)		0.48 (0.06)	
Naps: free days		0.346		0.837
yes (reference)	0.50 (0.09)		-	
no	0.48 (0.07)		0.49 (0.07)	

Note. SD: standard deviation

Table 76

Correlations between Waist to Height Ratio and Age, Eating Habits, Physical Activity, and Sleep Duration in Males

Characteristic	Phase I (n = 35) *Correlation coefficients*	Phase II (n = 18) *Correlation coefficients*
Age	-0.43	0.06
Eating Habits		
juice^	-0.21	-0.56*
fruit and vegetables^	-0.11	-0.19
soda^	-0.32	-0.29
milk^	-0.08	-0.31
breakfast^	0.08	0.15
Physical Activity		
screen time^	0.02	-0.16
days active^	-0.12	-0.18
sports^	-0.07	-0.07
Sleep duration		
school nights	0.22	-0.08
free nights	-0.01	0.40
total night	0.17	0.10

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified.^ Spearman's correlations were performed because these variables are nonparametric.

Sleep duration and Waist to Height Ratios in Females

Phase I. There were no associations between the independent variables and WHtR in females in the bivariate analyses.

Phase II. Eating more fruits/vegetables was significantly associated with higher WHtRs in females in the bivariate analyses (r = 0.3, p = 0.03). See Table 78.

Table 77

Differences in Waist to Height Ratio in Females

	Phase I (n = 78)		Phase II (n = 51)	
Characteristic	*M (SD)*	*p*	*M (SD)*	*p*
Race/ethnicity		0.270		0.338
Hispanic (reference)	0.52 (0.09)		0.52 (0.06)	
White	0.50 (0.06)		0.51 (0.06)	
Black	0.48 (0.07)		0.48 (0.07)	
Asian	0.47 (0.003)		0.47 (0.01)	
Free/reduced lunch		0.071		0.527
yes (reference)	0.51 (0.08)		0.51 (0.06)	
no	0.48 (0.06)		0.50 (0.06)	
Naps: school days		0.062		0.105
yes (reference)	0.48 (0.06)		0.49 (0.06)	
no	0.51 (0.08)		0.52 (0.06)	
Naps: free days		0.127		0.066
yes (reference)	0.49 (0.06)		0.47 (0.04)	
no	0.52 (0.09)		0.51 (0.06)	

Note. SD: standard deviation

Table 78

Correlations between Waist to Height Ratio and Age, Eating Habits, Physical Activity, and Sleep Duration in Females

	Phase I (n = 78)	Phase II (n = 51)
Characteristic	*Correlation coefficients*	*Correlation coefficients*
Age	-0.16	0.02
Eating Habits		
juice^	0.13	0.16
fruit and vegetables^	0.11	0.30*
soda^	-0.10	-0.08
milk^	-0.06	0.10
breakfast^	-0.01	0.08
Physical Activity		
screen time^	0.06	0.04
days active^	0.06	0.05
sports^	-0.13	-0.13
Sleep duration		
school nights	0.22	0.04
free nights	0.06	-0.10

Characteristic	Phase I (n = 78) *Correlation coefficients*	Phase II (n = 51) *Correlation coefficients*
total night	0.21	-0.05

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified.^ Spearman's correlations were performed because these variables are nonparametric.

APPENDIX CC: RESULTS OF BIVARIATE ANALYSES FOR AIM 3

Phase I. The M/E Q, midpoint of sleep, and social jet lag were not significantly associated with BMI z scores in the bivariate analyses (see Table 79).

Phase II. Greater social jet lag was associated with higher BMI z scores ($r = 0.3$, $p = 0.04$). See Table 79.

Table 79

Pearson Correlations between BMI z scores, the Morningness/Eveningness Questionanire, the Midpoint of Sleep, and Social Jet Lag

Characteristic	Phase I (N = 115) *Correlation coefficients*	Phase II (N = 68) *Correlation coefficients*
Morningness/Eveningness Questionanire	0.16	0.14^
Midpoint of sleep	0.03	0.15
early chronotype^^	0.22	
late chronotype^^^	0.25	
Social jet lag	0.02	0.25*

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. ^ $n = 69$, ^^ $n = 23$, ^^^$n = 24$

Sleep Duration and BMI z scores in Early Chronotypes (Phase I: midpoint of sleep ≤ 2:42) (Table CC.2)

Phase I. There were no significant associations in early chronotypes and no predictors of BMI z scores at the alpha level of 0.05 in the general linear models (see Tables 80 and 81).

Table 80

Differences in BMI z scores in Early Chronotypes: Phase I (n = 23)

Characteristic	*M (SD)*	*p*
Sex		0.340
Female (reference)	0.7 (0.8)	
Male	1.1 (0.9)	
Race/ethnicity		0.985
Hispanic (reference)	0.8 (0.8)	

Characteristic	*M (SD)*	*p*
White	0.8 (0.7)	
Black	0.8 (1.0)	
Pubertal category		0.369
Late	1.1 (0.9)	
Post (reference)	0.8 (0.8)	
Free/reduced lunch		0.850
yes (reference)	0.8 (0.9)	
no	0.7 (0.6)	
Naps: school days		0.225
yes (reference)	0.5 (0.7)	
no	0.9 (0.8)	
Naps: free days		0.601
yes (reference)	0.9 (0.7)	
no	0.7 (1.0)	

Note. *M* = mean. *SD* = standard deviation

Table 81

Correlations between BMI z scores with Age, Eating Habits, Physical Activity, and Sleep Duration in Early Chronotypes: Phase I (n = 23)

Characteristic	*Correlation coefficients*
Age	-0.26
Eating Habits	
juice^	0.32
fruit/vegetables^	0.05
soda^	0.05
milk^	0.09
breakfast^	-0.24
Physical Activity	
screen time^	0.36
days active^	0.05
sports^	-0.06
Sleep duration	
school nights	-0.05
free nights	-0.07
total night	-0.08

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified.^ Spearman's correlations were performed because these variables are nonparametric.

Sleep Duration and BMI z scores in Late Chronotypes (Phase I: midpoint of sleep ≥

5:06).

Phase I. There were no significant bivariate associations in later chronotypes.

Table 82

Differences in BMI z scores in Late Chronotypes: Phase I (n = 24)

Characteristic	*M (SD)*	*p*
Sex		0.492
Females (reference)	0.8 (1.2)	
Males	0.5 (0.8)	
Race/ethnicity		0.287
Hispanic (reference)	1.2 (0.8)	
White	0.3 (0.6)	
Black	0.6 (1.2)	
Pubertal category		0.286
Mid	1.4 (0.9)	
Late	0.4 (1.4)	
Post (reference)	0.5 (0.8)	
Free/reduced lunch		0.639
yes (reference)	0.7 (1.0)	
no	0.5 (1.0)	
Naps: school days		0.220
yes (reference)	1.0 (0.8)	
no	0.4 (1.0)	
Naps: free days		0.234
yes (reference)	0.8 (0.9)	
no	0.2 (1.1)	

Note. *M* = mean. *SD* = standard deviation

Table 83

Correlations between BMI z scores with Age, Eating Habits, Physical Activity, and Sleep Duration in Late Chronotypes: Phase I (n = 24)

Characteristic	*Correlation coefficients*
Age	-0.37
Eating Habits	
juice^	-0.24
fruit/vegetables^	0.13
soda^	-0.15
milk^	0.03
breakfast^	0.01

Characteristic	*Correlation coefficients*
Physical Activity	
screen time^	-0.15
days active^	0.26
sports^	0.16
Sleep duration	
school nights	0.36
free nights	-0.04
total night	0.33

Note. * $p < 0.05$,** $p < 0.01$, ***$p < 0.001$. Pearson's correlations were generated unless otherwise specified.^ Spearman's correlations were performed because these variables are nonparametric.

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