Published in final edited form as:
Chronobiol Int. 2016 ; 33(9): 1255–1266. doi:10.1080/07420528.2016.1196697.

Social jetlag, chronotype, and body mass index in 14 to 17 year old adolescents

Susan Kohl Malone, PhD, RN,NCSN[a,d], **Babette Zemel, PhD**[b,c], **Charlene Compher, PhD, RD, CNSC, LDN, FADA**[a], **Margaret Souders, PhD, CRNP**[a,c], **Jesse Chittams, MS**[a], **Aleda Leis Thompson, MS**[a], **Allan Pack, M.B.Ch.B., Ph.D., FRCP**[d], and **Terri H. Lipman, PhD, CRNP, FAAN**[a,c]

[a]University of Pennsylvania School of Nursing

[b]Department of Pediatrics, Perelman School of Medicine, University of Pennsylvania

[c]The Children's Hospital of Philadelphia, Philadelphia, PA

[d]Center for Sleep and Circadian Neurobiology, Perelman School of Medicine, University of Pennsylvania

Abstract

The relationship between sleep duration and obesity in adolescents is inconclusive. This may stem from a more complex relationship between sleep and obesity than previously considered. Shifts towards evening preferences, later sleep-wake times, and irregular sleep-wake patterns are typical during adolescence but their relationship to body mass index has been relatively unexplored. This cross sectional study examined associations between sleep duration, midpoint of sleep, and social jetlag (estimated from seven days of continuous actigraphy monitoring) and morningness/eveningness with body mass indexes (BMI z scores) and waist to height ratios in 14 to 17 year old adolescents. Seventy participants were recruited from 9th and 10th grades at a public high school. Participant characteristics were as follows: 74% female, 75% post-pubertal, 36% Hispanic, 38% White, 22% Black, 4% Asian, and 64% free/reduced lunch participants with a mean age of 15.5 (SD, 0.7). Forty one percent of the participants were obese (BMI ≥ 95th percentile); 54% were abdominally obese (waist to height ratio ≥ 0.5). Multivariable general linear models were used to estimate the association between the independent variables (school night sleep duration, free night sleep duration, midpoint of sleep (corrected), social jetlag, and morningness/eveningness) and the dependent variables (BMI z scores and waist to height ratios). Social jetlag positively associated with BMI z scores ($p < 0.01$) and waist to height ratios ($p = 0.01$). Midpoint of sleep (corrected) positively associated with waist to height ratios ($p = 0.01$). After adjusting for social jetlag, school night sleep duration was not associated with waist to height ratios or BMI z scores. Morningness/eveningness did not moderate the association between sleep duration and BMI z scores. Findings

Declaration of Interest Statement
The author(s) disclosed the following financial support for the research, authorship, and/or publication of this article: This work was made possible through generous support from the National Association of School Nurses, Ruth L. Kirschstein National Research Service Award (F31NR014603), The Rockefeller University Heilbrunn Nurse Scholar Award, University of Pennsylvania School of Nursing Biobehavioral Research Center, University of Pennsylvania Office of Nursing Research and the National Institute of Health (T32 HL 7953-16). This funding source did not influence the study design, the collection, analysis or interpretation of data, the writing of the report, nor the decision to submit the article for publication.

from this study suggest that chronobiological approaches to preventing and treating obesity may be important for accelerating progress in reducing obesity rates in adolescents.

Introduction

Obesity has a profound impact on the quality of life of adolescents (12–19 years) (Schwimmer, Burwinkle, & Varni, 2003; Taras & Potts-Datema, 2005). Obesity during adolescence forebodes a lifetime burden of obesity and increased risk for several chronic diseases (Gordon-Larsen, The, & Adair, 2010; Skinner, Perrin, Moss, & Skelton, 2015). Despite recent plateaus in adolescent obesity rates, these rates remain unacceptably high and there is a disturbing increase in obesity trends among Black and Hispanic adolescents and White adolescents from lower socioeconomic groups (Freedman, 2011). Furthermore, abdominal obesity (waist to height ratio ≥ 0.5) is increasing to a greater extent than generalized obesity (body mass index (BMI) ≥ 95th percentile) in youth (Li, Ford, Mokdad, & Cook, 2006; McCarthy, Jarrett, Emmett, & Rogers, 2005). Accelerating progress in reducing adolescent obesity rates requires a multifactorial approach that extends beyond diet and exercise (Chaput et al., 2010). Within this broader context, sleep has emerged as a potentially modifiable risk factor for obesity.

Several studies have reported an inverse relationship between self-reported sleep duration and obesity in adolescents, whereby shorter sleep duration is associated with a higher BMI (Guidolin & Gradisar, 2012). Plausible pathways for this association include altered appetite regulatory hormones and increased snacking (Al-Disi et al., 2010; Nedeltcheva et al., 2009; Spiegel, Tasali, Penev, & Van Cauter, 2004). However, adolescent 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, Pasch, & Farbakhsh, 2011; Sun, Sekine, & Kagamimori, 2009). Few studies have estimated sleep duration using actigraphy (Gupta, Mueller, Chan, & Meininger, 2002; Moore et al., 2011). In sum, research supporting an association between short sleep and obesity in adolescence is inconclusive and findings are limited by the self-reported nature of sleep duration data in most studies (Guidolin & Gradisar, 2012).

Inconclusive evidence for the relationship between sleep duration and obesity in adolescents may also stem from a more complex relationship between sleep and obesity. During adolescence, there is a shift in sleep-wake timing towards later sleep onsets and sleep offsets and eveningness (Carskadon, Vieira, & Acebo, 1993). These development shifts are at odds with early waking required by high school start times (Carskadon, Acebo, & Jenni, 2004). On school days, adolescents with evening preferences go to bed late but are required to rise early. On free days, adolescents with evening preferences go to bed late and rise late (National Sleep Foundation, 2006). These chronic weekly shifts in sleep-wake times, coined social jetlag (Wittmann, Dinich, Merrow, & Roenneberg, 2006), resemble larger shifts in sleep-wake times typical of shift workers, a group known to suffer disproportionately from obesity (Suwazono et al., 2008). Social jetlag is greatest in individuals with evening preferences (Roenneberg, Allebrandt, Merrow, & Vetter, 2012). Yet associations between morningness/eveningness, social jetlag, and BMI have been relatively unexplored in adolescents.

This cross-sectional study examined the associations between actigraphy estimated sleep parameters (duration, midpoint of sleep, social jetlag), as well as, morningness/eveningness with BMI z scores and waist to height ratios in 9th and 10th grade students. We hypothesized that shorter sleep, later midpoints of sleep, greater social jetlag, and eveningness would be associated with higher BMI z scores and waist to height ratios. We also hypothesized that the association between short sleep and higher BMI z scores would be stronger in adolescents with evening preferences and greater social jetlag.

Materials and Methods

Participants were recruited from a coastal city public high school in New Jersey during 9th and 10th grade health and physical education classes, back-to-school night, and selected winter sports practices. Seventy 9th and 10th grade students, representing 13% of the 9th and 10th grade class, volunteered and provided written parent/guardian consent and written student assent. To be eligible to participate, individuals had to be full time 9th or 10th grade students with non-restricted participation in physical education class. Individuals were excluded for 1) self-reported pregnancy; 2) self-reported acute illness (defined as seven days prior to actigraphy monitoring); 3) self-reported diagnosis of a sleep disorder; 4) diagnosed medical condition affecting growth or development; or 5) diagnosed physical condition affecting diet and activity. Participants were compensated with a $15 gift card. The University of Pennsylvania Institutional Review Board approved this study.

Physical Characteristics

Anthropometric Measures—Standing height was measured with a portable stadiometer (Weigh and Measure LLC, ShorrBoard) on non-carpeted flooring to the nearest 0.1 cm following a standard protocol (Lipman et al., 2000; Lipman et al., 2004). Weight was measured on a calibrated digital scale (Health o meter 498 KL) to the nearest 0.1 kg with the participant wearing light indoor clothing (excluding shoes) (Gordon, 1988). As described by others, waist circumference (WC) was measured by the investigator (SKM) after students exposed their waist at the level of the umbilicus (Nambiar, Truby, Abbott, & Davies, 2009). Each measure was obtained three times. Means were used for calculating BMI and waist to height ratios ((Himes & Bouchard, 1989). A standardized z-score for BMI, adjusted for age and sex, was computed using the CDC 2000 BMI charts with the SAS software application and is presented as BMI z.(Control & Prevention, 2009). Waist to height ratio was calculated as waist circumference (cm)/height (cm).

Puberty—Pubertal development is associated with a shift towards later chronotypes (Carskadon et al., 1993). The 5 to 6 item Pubertal Self Rating Scale was used to assess pubertal development (Petersen, L, M, & A, 1988). Participants self-reported secondary sexual characteristics such as growth, body hair, and skin changes were anchored by the responses “not yet started” and “seems complete”. “Do not know” was also a response option. Responses were used to estimate pubertal categories (pre-puberty early puberty, mid-puberty, late puberty, post puberty) (Carskadon & Acebo, 1993). Pre-puberty is comparable to Tanner Stage 1 and post-puberty is comparable to Tanner Stage 5 (Brooks-Gunn, Warren, Rosso, & Gargiulo, 1987; Carskadon & Acebo, 1993). The Cronbach's alpha, used to determine the internal consistency of this scale in our sample was 0.3 (females) and 0.6 (males). This is lower than the Cronbach's alpha reported by others for this scale in largely Caucasian younger adolescent samples (Carskadon & Acebo, 1993; Petersen et al., 1988) The low Cronbach's alpha in our sample may reflect the narrow range in data (Streiner, 2003) because the majority of the females selected post pubertal response options. This would be an expected stage of pubertal development in 9th and 10th grade females. The Cronbach's alpha reported by others represented younger females where greater variability in pubertal development would be expected. Mean values of non-missing items were used to replace missing values on the Pubertal Self Rating Scale at the individual level (Olinsky, Chen, & Harlow, 2003).

Morningness/eveningness

The 10-item Morningness/Eveningness Scale provided an estimate of participant's morning or evening preferences for activity and rest (Carskadon et al., 1993). Scores range from 10 to 43 with lower scores indicating greater eveningness (Carskadon et al., 1993; Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002). The Morningness/Eveningness Scale has been validated with adolescents' self-reported bed times and wake times (Carskadon et al., 1993; Giannotti et al., 2002). The Cronbach's alpha for our sample was 0.6, which is slightly lower than that reported by others for this scale (Giannotti et al., 2002).

Sleep Measures

Participants wore actigraphs on their non-dominant wrist and maintained a sleep diary for seven continuous days (see Table 1) (Acebo et al., 1999; Sadeh, Sharkey, & Carskadon, 1994). Actigraphy data were collected at 1-min epochs in the proportional integration mode using Actiwatch 2 devices (Philips Respironics). Analyses were based on medium threshold for sleep/wake detection in Actiware 5.70 from the manufacturer (Cole-Kripke formula). Sleep diary responses were used as a cross reference for actigraphy-estimated sleep onset, sleep offset and daytime naps. Discrepancies between actigraphy-estimated and diary-reported sleep onset, sleep offset, and naps were reconciled with participants on an individual basis. Wrist actigraphy has been validated with polysomnography in adolescents (Johnson et al., 2007).

Sleep duration—The formula ((sleep onset – sleep offset) – sleep onset latency) was used to calculate sleep duration for school nights (Sunday through Thursday nights) and free nights (Friday and Saturday nights). Total night sleep was calculated as ((mean school night sleep duration × 5) + (mean free night sleep duration × 2)/7). Mean school night, mean free night, and total night sleep durations were used in the analyses.

Midpoint of sleep (corrected)—The midpoint of sleep was computed from the mean sleep onset and the mean sleep offset on free nights. For individuals who slept *longer* on free nights than school nights, the midpoint of sleep on free nights was corrected to account for this oversleep using the formula described by others (Roenneberg et al., 2012). The unit of measurement for sleep duration was hours so any individual whose average free night sleep was 0.1 hours (or 10 minutes) longer on free nights than school nights had their midpoint of sleep corrected. As described by Roenneberg et al. (2012), this correction formula is not applicable for individuals who sleep shorter on free days. In these cases the midpoint of sleep on free days is used (Roenneberg et al., 2012). Midpoints of sleep are significantly correlated with dim light melatonin onset phase in adolescents indicating that the midpoint of sleep may be a useful circadian phase marker (Crowley, Acebo, Fallone, & Carskadon, 2006).

Social jetlag—Social jetlag was computed from the absolute difference between the mean midpoint of sleep on school nights and the mean midpoint of sleep on free nights (not corrected) (Wittmann et al., 2006).

Daytime naps—Actigraphy-estimated periods of inactivity between 6am and 6pm were cross referenced with diary reports and/or verified with individual participants to determine the presence/absence of daytime napping (yes/no).

Health Behaviors

The Youth Risk Behavior Survey (YRBS), established by the CDC, is a widely used instrument for monitoring self-reported health behaviors in 9th through 12th grade students across the US. Selected questions about eating habits, physical activity, and screen time from the 2013 YRBS were used in these analyses. The following behaviors were assessed: fruits and vegetables (servings per day comprised of fruit, green salad, carrots, potatoes, and other vegetables), fruit juice (servings per day), soda (servings per day), milk (servings per day), breakfast (days per week), moderate/vigorous physical activity (days per week in which 60 minutes of activity per day was done), sports team participation (number per year), and screen time (hours per day watching TV, playing video/computer games, and using a computer for non-school related activities).

Socio-demographics

Participants self-reported as male or female. Race/ethnicity and free/reduced lunch participation were gathered from official school records. Race/ethnicity was reported as White, Black, Hispanic, or Asian by parents/guardians. Free/reduced lunch participation was used as a proxy measure for poverty (US Department of Agriculture Food and Nutrition Services, 2012). Non-participants included those recorded as “did not apply”.

Procedures

Anthropometric and actigraphy measurements took place between February 2014 and June 2014. Actigraphy and sleep diary instruction took place in small groups during the school day and data collection began at 3pm on the instruction day. The investigator called participants daily at a pre-determined time to troubleshoot problems and encourage adherence to the study protocol. On the seventh day, participants returned actiwatches and sleep diaries to the investigator and the investigator performed all anthropometric measurements. Individual appointments to resolve discrepancies between diary and actigraphy data were arranged within one week of completing data collection. These appointments were scheduled to minimize disruption to students' academic schedules and followed an established protocol for resolving discrepancies.

Data Analysis

Means and standard deviations were calculated for continuous variables; frequencies and percentages for categorical variables. Bivariate associations and correlations between the independent variables (e.g. social jetlag, race/ethnicity) and the dependent variables of interest (BMI z-scores, waist to height ratios) were examined using independent sample *t* tests, ANOVAs, and Pearson's product correlations or Spearman's rho correlations, as appropriate. Multivariable models for the dependent variables were constructed using general linear modeling. To maximize statistical power, the final adjusted models only included variables significant at alpha level of 0.2 from the univariate analysis. An alpha level of 0.05 based on the two-tailed test was set for statistical significance. The moderating effect of morningness/eveningness on BMI z-score was tested using the interaction terms morningness/eveningness*school night sleep duration and morningness/eveningness*free night sleep duration. SPSS version 22 was used for statistical analysis.

Results

Participant Characteristics

Of the 70 participants recruited, one student diagnosed with type 2 diabetes was excluded leaving 69 participants. Of the remaining 69 participants, one did not have free night actigraphy data which precluded the calculation of midpoint of sleep and social jet lag. This reduced the sample to 68 for analyses involving free night sleep duration, midpoint of sleep, and social jet lag. Briefly, participants were mostly female (74%), post-pubertal (75%), racially/ethnically diverse (36% Hispanic, 38% White, 22% Black, 4% Asian), free/reduced lunch participants (64%) with a mean age of 15.5 (SD, 0.7). Forty one percent of the participants were overweight or obese (BMI ≥ 85th percentile); 54% were abdominally obese (waist to height ratio ≥ 0.5).

Most participants (76%) had later midpoints of sleep on free days than school days. Most participants took daytime naps before 6pm on school or free days (N=36). Six participants took naps after 6pm only on school or free days. Table 1 lists the sleep characteristics for the total sample and separately for males and females. The univariate associations of each participant characteristic with midpoint of sleep (corrected) and social jetlag are listed in Table 2. Later midpoints of sleep (corrected) were associated with less sports team participation (b = −0.23, 95% CI = −0.46, 0.00, $p = 0.05$), more screen time (b = 0.11, 95% CI = 0.00, 0.22, $p = 0.05$) and higher waist to height ratios (b = 5.33, 95% CI = 0.93, 9.73, $p = 0.02$). Greater social jetlag was associated with females (b = −0.58, 95% CI = −1.07, −0.10, $p = 0.02$), post pubertal participants (b = −1.00, 95% CI = −1.69, −0.31, $p = 0.01$), higher BMI z scores (b = 0.26, 95% CI = 0.01, 0.50, $p = 0.04$), and higher waist to height ratios (b= 5.04, 95% CI = 1.71, 8.37, $p < 0.01$).

Sleep Duration, Midpoint of Sleep (corrected), Social jetlag, Morningness/eveningness and Anthropometric Characteristics

Table 3 reports the associations between sleep duration, midpoint of sleep (corrected), social jetlag, and morningness/eveningness with BMI z scores. Characteristics, significant at alpha level of 0.2, identified from the univariate analyses (model 1), were used to build the multivariable model (model 2). Social jetlag was positively associated with BMI z scores ($p = 0.01$) after adjusting for variables that were influential in the univariate analysis: sex, fruit/vegetable intake, screen time, school night sleep duration, daytime naps (school days and free days). School night sleep duration was no longer associated with BMI z scores after adjusting for sex, fruit/vegetable intake, screen time, daytime naps (school days and free days), and social jetlag. Males had higher BMI z scores than females ($p = 0.04$). Morningness/eveningness did not moderate the association between sleep duration and BMI z scores (data not shown).

Table 4 reports the associations between sleep duration, midpoint of sleep (corrected), social jetlag, and morningness/eveningness on waist to height ratios using the same model building strategies. Variables, significant at alpha level of 0.2, identified from the univariate analyses (model 1), were used to build the multivariable models (model 2: midpoint of sleep, model 3: social jetlag). Midpoint of sleep (corrected) and social jetlag remained positively associated with waist to height ratios after adjusting for variables that were influential in the univariate analysis ($p = 0.01$). Due to multicollinearity between midpoint of sleep (corrected) and social jet lag, separate general linear models were generated (see Table 4 model 2 (midpoint of sleep (corrected)) and Table 4 model 3 (social jetlag)). Greater fruit/vegetable intake was also associated with higher waist to height ratios (model 2: $p = 0.01$; model 3: $p = 0.01$).

Discussion

The aims of this study were to determine whether sleep duration, midpoint of sleep, social jet lag and/or morningness/eveningness associated with BMI z scores and waist to height ratios in 9th and 10th grade students. Our main finding was that greater social jetlag was associated with higher BMI z scores and higher waist to height ratios. This finding is consistent with one earlier report of a positive association between social jetlag and BMI in adults (Wong, Hasler, Kamarck, Muldoon, & Manuck, 2015) and extends the findings of a positive association reported by others that relied on self-reported sleep and self- reported anthropometric measures (Randler, Haun, & Schaal, 2013; Roenneberg et al., 2012).

Our finding is similar to reports of a positive association between irregular sleep-wake times (differences in bedtimes and wake times on school days and free days) and BMI in adolescent females (Lytle et al., 2011). Additionally, children with irregular sleep-wake times (greater than 45 minute delays in bedtimes on weekends) and long sleep durations had larger increases in BMI over time than children with regular sleep-wake times and long sleep durations (Miller et al., 2014). These findings suggest that regular sleep-wake patterns are important for maintaining a healthy BMI during growth and development. To date, only one study has reported that "sleeping in" on weekends was a beneficial compensatory mechanism for insufficient nocturnal sleep in Hong Kong children (Wing, Li, Li, Zhang, &

Kong, 2009). This latter study relied on parental reports of bedtimes and wake times as well as parental reports of height and weight to estimate BMI z scores. Parental estimates of anthropometric measurements are often inaccurate (Harris, Kuramoto, Schulzer, & Retallack, 2009). These differences may explain the disparate findings from this study.

These findings are important because social jetlag is prevalent in adolescents. Eighty eight percent of adolescents report going to bed later on free nights than school nights and 44% of high school students report a two or more hour difference in bedtimes on free night and school nights (National Sleep Foundation, 2006). Our mean social jetlag of 1.3 hours (SD, 0.9 hours) was smaller than might be expected given this two hour difference in free night and school night bedtimes. This may stem from differences in self-reported sleep times and actigraphy monitored sleep times. Additionally, as midpoints of sleep become progressively later through 20 years of age, social jetlag increases (Roenneberg et al., 2007; Roenneberg et al., 2004). Thus, it may be expected that the social jetlag in our sample of 14–17 year olds will increase over time. This is concerning because obesity risk for shift workers increases based on years of exposure (Parkes, 2002). Our finding that social jetlag is associated with higher BMI z scores and waist to height ratios in youth during their first and second years of high school bodes poorly for reducing obesity rates in adolescents.

Our finding that later midpoints of sleep were associated with higher waist to height ratios raises further concerns for cardio-metabolic health. Youth with higher waist to height ratios (≥ 0.5) have adverse levels of low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglycerides, and insulin, even in the presence of a healthy BMI ($< 85^{th}$ percentile) (Mokha et al., 2010). Norwegian female adolescents with higher waist measurements are more likely to become overweight over time (Bratberg, Nilsen, Holmen, & Vatten, 2007). Although the underlying mechanisms for the association between later midpoints of sleep and higher waist to height ratios are uncertain, later midpoints of sleep have been associated with fewer days of physical activity per week in adolescents (Malone et al., 2015).

Our hypotheses that later midpoints of sleep and eveningness would be associated with higher BMI z scores were not supported. This is inconsistent with one study of UK adolescents whereby eveningness was associated with a higher BMI (Arora & Taheri, 2015) and with another study of Australian children whereby later bedtimes and later wake times were associated with higher BMIs (Olds, Maher, & Matricciani, 2011). Disparate findings may be attributed to different measurement strategies. Arora and Taheri (2015) assessed morningness/eveningness with one question from the Horne–Ostberg Morningness/ Eveningness Questionnaire (Horne & Ostberg, 1976). Olds, Mayer and Matricciani determined bedtimes and wake times from 2 day recall time survey data (Olds et al., 2011).

Higher BMI z scores in males in our study may reflect the inability of BMI measurements to distinguish fat mass from fat free mass. The higher BMI z scores in males may indicate the rapid gain in fat free mass that is part of normal adolescent male development rather than increased fat mass (Veldhuis et al., 2005). It is also possible that these data reflect the greater prevalence of obesity in adolescent males compared to females that has been reported in the US (Ogden, Carroll, Kit, & Flegal, 2014).

In sum, findings from this study suggest that regular sleep wake patterns may be important for preventing obesity in adolescents. Reaping the cardio-metabolic benefits of longer sleep for adolescents may hinge on establishing regular sleep-wake patterns and earlier sleep-wake times. To that end, delaying school start times 30 to 60 minutes can increase school night sleep duration and may improve the regularity of sleep-wake patterns (Hansen, Janssen, Schiff, Zee, & Dubocovich, 2005; Warner, Murray, & Meyer, 2008). However, the benefits of these delays for sleep duration vary by sex and urbanicity. Adolescent males from metropolitan areas have been reported to benefit most in terms of longer sleep duration from school start time delays (Paksarian, Rudolph, He, & Merikangas, 2015).

As a cross-sectional study, these findings represent associations and the direction of these relationships cannot be determined. Several factors limit the generalizability of these findings. Our sample consisted of more females and free/reduced lunch participants than state (New Jersey) and nationally representative samples of high school students (Davis & Bauman, September 2013; U.S. Department of Education, Institute of Education Sciences, & National Center for Education Statistics). This may limit the generalizability of these findings to male adolescents and more affluent socio-economic groups. However, greater racial/ethnic diversity in our sample than state and nationally representative samples of high school students is an important strength (Davis & Bauman, September 2013). Additionally, parent/guardian consent was required for participation, potentially limiting participation from some students (Tigges, 2003). Another limitation of this study was that neither self-reported school attendance nor official school attendance records were obtained to verify that students attended school. Hence, it is possible that a student's absence my not reflect a school night for that particular individual. Future studies should consider reframing definitions of school nights and free nights to reflect these potential individual variations. Although estimating sleep parameters using actigraphy was a strength of our study, our sample size was small. It will be important to replicate these findings in larger samples using actigraphy-estimated, as well as, self-reported sleep parameters.

The associations identified in this study between social jetlag and BMI raise interesting questions about what aspects of sleep are most relevant to obesity risk and present novel opportunities for interventions if replicated in future studies. Interventions should target aligning the timing of specific behaviors (e.g. sleep-wake, activity-rest) with individual circadian rhythms to mitigate social jetlag. This approach resonates with growing interest in personalized preventative care. Furthermore, interventions aimed at reducing social jetlag and promoting earlier midpoints of sleep may have a broad sweeping impact on obesity and cardio-metabolic health at the population level because two thirds of the population report social jetlag and average midpoints of sleep have become progressively later over the past decade (Roenneberg et al., 2012).

Acknowledgments

We would like to thank Kathleen Celli, Mary Whalen, and the Long Branch High School administration, faculty, parents/guardians, and students for their help with recruitment and data collection. We would also like to acknowledge Dr. Philip Gehrman for providing additional feedback on analyzing actigraphy data and Drs. David Dinges and Namni Goel for their input on this manuscript.

References

Acebo C, Sadeh A, Seifer R, Tzischinsky O, Wolfson AR, Hafer A, Carskadon MA. 1999; Estimating sleep patterns with activity monitoring in children and adolescents: how many nights are necessary for reliable measures? Sleep. 22(1):95–103. [PubMed: 9989370]

Al-Disi D, Al-Daghri N, Khanam L, Al-Othman A, Al-Saif M, Sabico S, Chrousos G. 2010; Subjective sleep duration and quality influence diet composition and circulating adipocytokines and ghrelin levels in teen-age girls. Endocr J. 57(10):915–923. [PubMed: 20733266]

Arora T, Taheri S. 2015; Associations among late chronotype, body mass index and dietary behaviors in young adolescents. Int J Obes (Lond). 39(1):39–44. DOI: 10.1038/ijo.2014.157 [PubMed: 25135376]

Biggs SN, Dollman J. 2007; Association between sleep, BMI and waist girth in children and adolescents: a retrospective analysis. Acta Paediatrica (Oslo, Norway : 1992). 96(12):1839–1840. DOI: 10.1111/j.1651-2227.2007.00518.x

Bratberg GH, Nilsen TI, Holmen TL, Vatten LJ. 2007; Early sexual maturation, central adiposity and subsequent overweight in late adolescence. a four-year follow-up of 1605 adolescent Norwegian boys and girls: the Young HUNT study. BMC public health. 7:54.doi: 10.1186/1471-2458-7-54 [PubMed: 17430580]

Brooks-Gunn J, Warren MP, Rosso J, Gargiulo J. 1987; Validity of self-report measures of girls' pubertal status. Child Dev. 58(3):829–841. [PubMed: 3608653]

Calamaro CJ, Park S, Mason TB, Marcus CL, Weaver TE, Pack A, Ratcliffe SJ. 2010; Shortened sleep duration does not predict obesity in adolescents. J Sleep Res. 19(4):559–566. DOI: 10.1111/j.1365-2869.2010.00840.x [PubMed: 20545836]

Carskadon MA, Acebo C. 1993; A self-administered rating scale for pubertal development. J Adolesc Health. 14(3):190–195. [PubMed: 8323929]

Carskadon MA, Acebo C, Jenni OG. 2004; Regulation of adolescent sleep: implications for behavior. Ann N Y Acad Sci. 1021:276–291. DOI: 10.1196/annals.1308.032 [PubMed: 15251897]

Carskadon MA, Vieira C, Acebo C. 1993; Association between puberty and delayed phase preference. Sleep. 16(3):258–262. [PubMed: 8506460]

Chaput JP, Sjodin AM, Astrup A, Despres JP, Bouchard C, Tremblay A. 2010; Risk factors for adult overweight and obesity: the importance of looking beyond the 'big two'. Obes Facts. 3(5):320–327. DOI: 10.1159/000321398 [PubMed: 20975298]

Control, C. f. D., & Prevention. Web Page. 2009. CDC Growth Chart Training Modules: Other Growth Chart Resources.

Crowley SJ, Acebo C, Fallone G, Carskadon MA. 2006; Estimating dim light melatonin onset (DLMO) phase in adolescents using summer or school-year sleep/wake schedules. Sleep. 29(12): 1632–1641. [PubMed: 17252895]

Davis, J, Bauman, K. School Enrollment in the United States 2011: Population Characteristics. Sep, 2013

Freedman DS. 2011; Obesity - United States, 1988–2008. MMWR Surveill Summ. 60(Suppl):73–77.

Gates M, Hanning RM, Martin ID, Gates A, Tsuji LJS. 2013; Body mass index of First Nations youth in Ontario, Canada: influence of sleep and screen time. Rural Remote Health. 13:2498. [PubMed: 24033103]

Giannotti F, Cortesi F, Sebastiani T, Ottaviano S. 2002; Circadian preference, sleep and daytime behaviour in adolescence. J Sleep Res. 11(3):191–199. [PubMed: 12220314]

Gordon-Larsen P, The NS, Adair LS. 2010; Longitudinal trends in obesity in the United States from adolescence to the third decade of life. Obesity (Silver Spring). 18(9):1801–1804. DOI: 10.1038/oby.2009.451 [PubMed: 20035278]

Gordon, C, Chumlea, W, Roche, A. Stature, Recumbent Length, and Weight. In: Lohman, T, Roche, A, Martorell, R, editors. Anthropometric Standarization Reference Manual. Champaign, Illinois: Human Kinetics Books; 1988. 1–8.

Guidolin M, Gradisar M. 2012; Is shortened sleep duration a risk factor for overweight and obesity during adolescence? A review of the empirical literature. Sleep Med. 13(7):779–786. DOI: 10.1016/j.sleep.2012.03.016 [PubMed: 22633283]

Gupta NK, Mueller WH, Chan W, Meininger JC. 2002; Is obesity associated with poor sleep quality in adolescents? Am J Hum Biol. 14(6):762–768. DOI: 10.1002/ajhb.10093 [PubMed: 12400037]

Hansen M, Janssen I, Schiff A, Zee PC, Dubocovich ML. 2005; The impact of school daily schedule on adolescent sleep. Pediatrics. 115(6):1555–1561. DOI: 10.1542/peds.2004-1649 [PubMed: 15930216]

Harris KC, Kuramoto LK, Schulzer M, Retallack JE. 2009; Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne. 180(7):719–726. DOI: 10.1503/cmaj.080966

Himes JH, Bouchard C. 1989; Validity of anthropometry in classifying youths as obese. Int J Obes. 13(2):183–193.

Horne JA, Ostberg O. 1976; A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. Int J Chronobiol. 4(2):97–110. [PubMed: 1027738]

Johnson NL, Kirchner HL, Rosen CL, Storfer-Isser A, Cartar LN, Ancoli-Israel S, … Redline S. 2007; Sleep estimation using wrist actigraphy in adolescents with and without sleep disordered breathing: a comparison of three data modes. Sleep. 30(7):899–905. [PubMed: 17682661]

Kong AS, Sussman AL, Yahne C, Skipper BJ, Burge MR, Davis SM. 2013; School-based health center intervention improves body mass index in overweight and obese adolescents. J Obes. 2013:575016.doi: 10.1155/2013/575016 [PubMed: 23589771]

Li C, Ford ES, Mokdad AH, Cook S. 2006; Recent trends in waist circumference and waist-height ratio among US children and adolescents. Pediatrics. 118(5):e1390–1398. DOI: 10.1542/peds.2006-1062 [PubMed: 17079540]

Lipman TH, Hench K, Logan JD, DiFazio DA, Hale PM, Singer-Granick C. 2000; Assessment of growth by primary health care providers. Journal of pediatric health care : official publication of National Association of Pediatric Nurse Associates & Practitioners. 14(4):166–171. DOI: 10.1067/mph.2000.104538

Lipman TH, Hench KD, Benyi T, Delaune J, Gilluly KA, Johnson L, … Weber C. 2004; A multicentre randomised controlled trial of an intervention to improve the accuracy of linear growth measurement. Arch Dis Child. 89(4):342–346. [PubMed: 15033843]

Lowry R, Eaton DK, Foti K, McKnight-Eily L, Perry G, Galuska DA. 2012; Association of Sleep Duration with Obesity among US High School Students. Journal of obesity. 2012:476914.doi: 10.1155/2012/476914 [PubMed: 22530111]

Lytle LA, Pasch KE, Farbakhsh K. 2011; The relationship between sleep and weight in a sample of adolescents. Obesity (Silver Spring, Md). 19(2):324–331. DOI: 10.1038/oby.2010.242

Malone SK, Zemel B, Compher C, Souders M, Chittams J, Thompson AL, Lipman TH. 2015; Characteristics Associated With Sleep Duration, Chronotype, and Social Jet Lag in Adolescents. J Sch Nurs. doi: 10.1177/1059840515603454

McCarthy HD, Jarrett KV, Emmett PM, Rogers I. 2005; Trends in waist circumferences in young British children: a comparative study. Int J Obes (Lond). 29(2):157–162. DOI: 10.1038/sj.ijo.0802849 [PubMed: 15570313]

Miller AL, Kaciroti N, Lebourgeois MK, Chen YP, Sturza J, Lumeng JC. 2014; Sleep timing moderates the concurrent sleep duration-body mass index association in low-income preschool-age children. Acad Pediatr. 14(2):207–213. DOI: 10.1016/j.acap.2013.12.003 [PubMed: 24602585]

Mokha JS, Srinivasan SR, Dasmahapatra P, Fernandez C, Chen W, Xu J, Berenson GS. 2010; Utility of waist-to-height ratio in assessing the status of central obesity and related cardiometabolic risk profile among normal weight and overweight/obese children: the Bogalusa Heart Study. BMC Pediatr. 10:73.doi: 10.1186/1471-2431-10-73 [PubMed: 20937123]

Moore M, Kirchner HL, Drotar D, Johnson N, Rosen C, Redline S. 2011; Correlates of adolescent sleep time and variability in sleep time: the role of individual and health related characteristics. Sleep Med. 12(3):239–245. DOI: 10.1016/j.sleep.2010.07.020 [PubMed: 21316300]

Nambiar S, Truby H, Abbott RA, Davies PS. 2009; Validating the waist-height ratio and developing centiles for use amongst children and adolescents. Acta Paediatr. 98(1):148–152. DOI: 10.1111/j.1651-2227.2008.01050.x [PubMed: 18976352]

National Sleep Foundation. Summary of Findings. 2006. Retrieved February 1, 2015, from http://sleepfoundation.org/sites/default/files/2006_summary_of_findings.pdf

Nedeltcheva AV, Kilkus JM, Imperial J, Kasza K, Schoeller DA, Penev PD. 2009; Sleep curtailment is accompanied by increased intake of calories from snacks. Am J Clin Nutr. 89(1):126–133. DOI: 10.3945/ajcn.2008.26574 [PubMed: 19056602]

Ogden CL, Carroll MD, Kit BK, Flegal KM. 2014; Prevalence of childhood and adult obesity in the United States, 2011–2012. JAMA. 311(8):806–814. DOI: 10.1001/jama.2014.732 [PubMed: 24570244]

Olds TS, Maher CA, Matricciani L. 2011; Sleep duration or bedtime? Exploring the relationship between sleep habits and weight status and activity patterns. Sleep. 34(10):1299–1307. DOI: 10.5665/sleep.1266 [PubMed: 21966061]

Olinsky A, Chen S, Harlow L. 2003; The comparative efficacy of imputation methods for missing data in structural equation modeling. European Journal of Operational Research. 151(1):53–79. DOI: 10.1016/s0377-2217(02)00578-7

Paksarian D, Rudolph KE, He JP, Merikangas KR. 2015; School Start Time and Adolescent Sleep Patterns: Results From the US National Comorbidity Survey-Adolescent Supplement. Am J Public Health. 105(7):1351–1357. DOI: 10.2105/AJPH.2015.302619 [PubMed: 25973803]

Parkes K. 2002; Shift work and age as interactive predictors of body mass index among offshore workers. Scandinavian journal of work, environment & health. 28(1):64–71.

Petersen A, LC, MR, AB. 1988; A self-report measure of pubertal status: Reliability, validity, and initial norms. Journal Youth Adolescence. 17(2):117–133.

Randler C, Haun J, Schaal S. 2013; Assessing the influence of sleep-wake variables on body mass index (BMI) in adolescents. Europe's Journal of Psychology. 9(2)doi: 10.5964/ejop.v9i2.558

Roenneberg T, Allebrandt KV, Merrow M, Vetter C. 2012; Social jetlag and obesity. Curr Biol. 22(10): 939–943. DOI: 10.1016/j.cub.2012.03.038 [PubMed: 22578422]

Roenneberg T, Kuehnle T, Juda M, Kantermann T, Allebrandt K, Gordijn M, Merrow M. 2007; Epidemiology of the human circadian clock. Sleep Med Rev. 11(6):429–438. DOI: 10.1016/j.smrv.2007.07.005 [PubMed: 17936039]

Roenneberg T, Kuehnle T, Pramstaller PP, Ricken J, Havel M, Guth A, Merrow M. 2004; A marker for the end of adolescence. Curr Biol. 14(24):R1038–1039. DOI: 10.1016/j.cub.2004.11.039 [PubMed: 15620633]

Sadeh A, Sharkey KM, Carskadon MA. 1994; Activity-based sleep-wake identification: an empirical test of methodological issues. Sleep. 17(3):201–207. [PubMed: 7939118]

Schwimmer JB, Burwinkle TM, Varni JW. 2003; Health-related quality of life of severely obese children and adolescents. JAMA. 289(14):1813–1819. DOI: 10.1001/jama.289.14.1813 [PubMed: 12684360]

Skinner AC, Perrin EM, Moss LA, Skelton JA. 2015; Cardiometabolic Risks and Severity of Obesity in Children and Young Adults. N Engl J Med. 373(14):1307–1317. DOI: 10.1056/NEJMoa1502821 [PubMed: 26422721]

Spiegel K, Tasali E, Penev P, Van Cauter E. 2004; Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. Annals of Internal Medicine. 141(11):846–850. [PubMed: 15583226]

Streiner D. 2003; Starting at the beginning: an introduction to coefficient alpha and internal consistency. Journal of Personality Assessment. 80(1):99–103. [PubMed: 12584072]

Sun Y, Sekine M, Kagamimori S. 2009; Lifestyle and overweight among Japanese adolescents: the Toyama Birth Cohort Study. J Epidemiol. 19(6):303–310. [PubMed: 19776497]

Suwazono Y, Dochi M, Sakata K, Okubo Y, Oishi M, Tanaka K, … Nogawa K. 2008; A longitudinal study on the effect of shift work on weight gain in male Japanese workers. Obesity (Silver Spring). 16(8):1887–1893. DOI: 10.1038/oby.2008.298 [PubMed: 18535539]

Taras H, Potts-Datema W. 2005; Obesity and student performance at school. J Sch Health. 75(8):291–295. DOI: 10.1111/j.1746-1561.2005.00040.x [PubMed: 16179079]

Tigges BB. 2003; Parental consent and adolescent risk behavior research. J Nurs Scholarsh. 35(3):283–289. [PubMed: 14562498]

U.S. Department of Education, Institute of Education Sciences, & National Center for Education Statistics. Digest for Education Statistics. Retrieved June 3, 2014, from http://nces.ed.gov/programs/digest/d10/tables/dt10_044.asp

US Department of Agriculture Food and Nutrition Services. National School Lunch Program Fact Sheet. 2012. Aug, Retrieved March 3, 2013, from http://www.fns.usda.gov/cnd/Lunch/AboutLunch/NSLPFactSheet.pdf

Veldhuis JD, Roemmich JN, Richmond EJ, Rogol AD, Lovejoy JC, Sheffield-Moore M, … Bowers CY. 2005; Endocrine control of body composition in infancy, childhood, and puberty. Endocr Rev. 26(1):114–146. DOI: 10.1210/er.2003-0038 [PubMed: 15689575]

Warner S, Murray G, Meyer D. 2008; Holiday and school-term sleep patterns of Australian adolescents. Journal of adolescence. 31(5):595–608. DOI: 10.1016/j.adolescence.2007.10.005 [PubMed: 18076979]

Wing YK, Li SX, Li AM, Zhang J, Kong AP. 2009; The effect of weekend and holiday sleep compensation on childhood overweight and obesity. Pediatrics. 124(5):e994–e1000. DOI: 10.1542/peds.2008-3602 [PubMed: 19858153]

Wittmann M, Dinich J, Merrow M, Roenneberg T. 2006; Social jetlag: misalignment of biological and social time. Chronobiol Int. 23(1–2):497–509. DOI: 10.1080/07420520500545979 [PubMed: 16687322]

Wong PM, Hasler BP, Kamarck TW, Muldoon MF, Manuck SB. 2015; Social Jetlag, Chronotype, and Cardiometabolic Risk. J Clin Endocrinol Metab. 100(12):4612–4620. DOI: 10.1210/jc.2015-2923 [PubMed: 26580236]

Author Manuscript
Author Manuscript
Author Manuscript

Table 1

Sleep Characteristics of Sample

	Total Sample (N = 69)	Females (N = 51)	Males (N = 18)
	N (%) or M (SD)	N (%) or M (SD)	N (%) or M (SD)
Total night sleep (hours)[^]	7.28 (0.76)	7.31 (0.77)	7.19 (0.74)
School night (hours)[^]	7.07 (0.79)	7.08 (0.79)	7.07 (0.82)
≤ 6	9 (13)	6 (12)	3 (17)
> 6 to ≤ 7	22 (32)	18 (35)	4 (22)
> 7 to ≤ 8	28 (41)	19 (37)	9 (50)
> 8 to ≤ 9	10 (15)	8 (16)	2 (11)
> 9	0	0	0
School day naps			
yes	28 (41)	21 (41)	7 (39)
no	41 (59)	30 (59)	11 (61)
Free night (hours) [^] [a]	8.11 (1.53)	8.27 (1.55)	7.68 (1.44)
≤ 6	5 (7)	4 (8)	1 (6)
> 6 to ≤ 7	9 (13)	4 (8)	5 (28)
> 7 to ≤ 8	19 (28)	12 (24)	7 (39)
> 8 to ≤ 9	19 (28)	17 (33)	2 (11)
> 9	16 (23)	13 (26)	3 (17)
Free day naps [a]			
yes	8 (12)	7 (14)	1 (6)
no	61 (88)	44 (86)	17 (94)
Sleep onset (hours:minutes)			
School nights	23:17 (1:01)	23:15 (1:04)	23:49 (0:53)
Free nights [a]	23:55 (1:15)	23:57 (1:21)	23:48 (0:57)
Sleep offset (hours:minutes)			
School days (Monday–Friday)	6:28 (00:42)	6:26 (0:43)	6:35 (0:40)
Free days (Saturday–Sunday) [a]	8:20 (1:43)	8:35 (1:42)	7:38 (1:34)
Alarm used for waking (yes)			
School days (Monday – Friday)[b]	58 (84)	45 (88)	13 (72)
Free days (Saturday – Sunday)[c]	7 (10)	4 (8)	3 (17)
Morningness/eveningness[^]	26.88 (4)	26.57 (4.51)	27.78 (3.34)
Midpoint of Sleep – corrected (hour:minutes)[a]	3:29 (1:10)	3:34 (1:14)	3:15 (1:00)
Social jetlag (hours) [a]	1.3 (0.9)	1.47 (0.91)	0.88 (0.80)

Notes. M = mean, SD = standard deviation

[^]M (SD)

[a]N = 68

[b]N = 63

[c]N = 62

Author Manuscript

Author Manuscript

Author Manuscript

Table 2

Participant characteristics and their association with midpoint of sleep and social jetlag

	N (%) or M (SD)	Midpoint of Sleep[a] b (95% CI)	Social Jetlag[a] b (95% CI)
Socio-demographic Variables			
Age	15.50 (0.65)^	−0.01 (−0.05, 0.03)	−0.01(−0.04, 0.02)
Sex			
male	18 (26)	−0.32 (−0.97, 0.33)	−0.58 (−1.07, −0.10)**
female	51 (74)	reference	reference
Race/ethnicity			
Hispanic	25 (36)	reference	reference
White	26 (38)	0.42 (−0.25, 1.30)	−0.06 (−0.58, 0.46)
Black	15 (22)	0.31 (−0.47, 1.08)	−0.30 (−0.90, 0.30)
Asian	3 (4)	−0.15 (−1.59, 1.30)	0.19 (−0.94, 1.32)
Free/reduced lunch participation			
yes	44 (64)	reference	reference
no	25 (36)	−0.10 (−0.70, 0.50)	−0.05 (−0.52, 0.41)
Physical Characteristics			
BMI z score	0.66 (0.93)^	0.18 (−0.12, 0.49)	0.26 (0.01, 0.50)*
BMI percentile			
< 85th (non-obese)	41 (59)	reference	reference
≥85th (obese)	28 (41)	0.34 (−0.24, 0.92)	0.14 (−0.32, 0.59)
Waist to height ratio	0.50 (0.06)^	5.33 (0.93, 9.73)*	5.04 (1.71, 8.37)**
< 0.5	32 (46)	−0.73 (−1.28, −0.19)**	−0.76 (−1.16, −0.35)***
≥ 0.5	37 (54)	reference	reference
Pubertal Category			
mid	10 (14)	−0.18 (−0.99, 0.62)	−0.48 (−1.08, 0.12)
late	7 (10)	−0.88 (−1.81, 0.06)	−1.00 (−1.69, −0.31)**
post	52 (75)	reference	reference
Health Behavior Variables	Median (IQR)	**Midpoint of Sleep**[a] b (95% CI)	**Social Jetlag**[a] b (95% CI)
Eating habits (servings per day)			
fruit/vegetables	1.86 (1.71)	−0.05 (−0.18, 0.08)	0.01(−0.09, 0.11)
milk	0.29 (0.71)	−0.14 (−0.45, 0.18)	−0.06 (−0.03, 0.15)
soda	0.29 (0.71)	0.13 (−0.13, 0.38)	0.04 (−0.16, 0.24)
juice	0.71 (0.71)	−0.18 (−0.50, 0.13)	−0.19 (−0.43, 0.05)
Ate breakfast (days per week)	4 (5)	−0.04 (−0.15, 0.07)	−0.06 (−0.14, 0.02)
Physically active for 60 minutes (days per week)	3 (4)	−0.10 (−0.23, 0.03)	−0.07 (−0.17, 0.03)
Played on a sports team (number per year)	1 (3)	−0.23 (−0.46, 0.00)*	−0.14 (−0.32, 0.04)

	N (%) or M (SD)	Midpoint of Sleep[a] b (95% CI)	Social Jetlag[a] b (95% CI)
Screen time (hours per day)	5 (3)	0.11 (0.00, 0.22) *	0.06 (−0.03, 0.15)

Notes. M = mean, SD = standard deviation, CI = confidence interval

^M (SD)

[a]N = 68

IQR = Interquartile range,

* $p<0.05$

** $p<0.01$

*** $p < 0.001$

Author Manuscript
Author Manuscript
Author Manuscript

Table 3

Relationship of Social jetlag to BMI z scores

	BMI z score (Model 1)	BMI z score (Model 2)
	b (95% CI)	**b (95% CI)**
Age	−0.01 (−0.04, 0.02)	
Sex (reference: female)	0.36 (−0.14, 0.86)	0.49 (0.01, 0.97) *
Race/ethnicity (reference: Hispanic)		
White	−0.04 (−0.59, 0.48)	
Black	−0.21 (−0.83, 0.40)	
Asian	−0.53 (−1.68, 0.61)	
Free/reduced lunch (reference: yes)	−0.13 (−0.60, 0.33)	
Pubertal category (reference: post)		
mid	0.29 (−0.36, 0.93)	
late	0.13 (−0.62, 0.88)	
Eating Habits (servings per day)		
juice	0.001 (−0.24, 0.24)	
fruit/vegetables	0.09 (−0.02, 0.19)	0.07 (−0.02, 0.17)
soda	−0.08 (−0.28, 0.12)	
milk	0.06 (−0.19, 0.31)	
Breakfast (days per week)	0.05 (−0.04, 0.13)	
Physical Activity		
screen time (hours per day)	−0.07 (−0.16, 0.02)	−0.05 (−0.13, 0.04)
days active (days per week)	0.06 (−0.04, 0.16)	
sports (number per year)	0.00 (−0.19, 0.19)	
Sleep duration (hours)		
school nights	0.23 (−0.05, 0.51)	0.092 (−0.17, 0.36)
free nights [a]	0.05 (−0.10, 0.20)	
School day naps (reference: yes)	0.50 (0.05, 0.94)	0.28 (−0.17, 0.73)
Free day naps (reference: yes)	0.95 (0.28, 1.61)	0.49 (−0.22, 1.19)
Morningness/eveningness	0.03 (−0.02, 0.08)	
Midpoint of sleep – corrected (hours) [a]	0.11 (−0.08, 0.31)	
Social jetlag (hours) [a]	0.26 (0.01, 0.50)	0.33 (0.09, 0.57) **

Notes. CI = confidence interval

[a] N = 68

Model 1: unadjusted general linear model. Model 2: general linear model adjusted for covariates with alpha levels < 0.20 in the unadjusted general linear model (Model 1)

* $p < 0.05$

** $p < 0.01$.

Table 4

Relationship of Midpoint of Sleep (corrected) and Social jetlag to Waist to Height Ratios

	Waist to height ratios (Model 1)	Waist to height ratios (Model 2: midpoint of sleep (corrected))	Waist to height ratios (Model 3: social jetlag)
	b (95% CI)	**b (95% CI)**	**b (95% CI)**
Age	0 (−0.002, 0.002)		
Sex (reference: female)	−0.018 (−0.053, 0.016)		
Race/ethnicity (reference: Hispanic)			
White	−0.01 (−0.04, 0.03)		
Black	−0.03 (−0.07, 0.02)		
Asian	−0.06 (−0.13, 0.02)		
Free/reduced lunch (reference: yes)	−0.02 (−0.05, 0.01)		
Pubertal category (reference: post)			
mid	−0.01 (−0.06, 0.03)		
late	−0.04 (−0.09, 0.01)		
Eating Habits (servings per day)			
juice	0.003 (−0.01, 0.02)		
fruit/vegetables	0.01 (0.00, 0.01)	0.009 (0.003, 0.016) **	0.008 (0.002, 0.015) *
soda	−0.01 (−0.02, 0.01)		
milk	0.001 (−0.02, 0.02)		
Breakfast (days per week)	0.002 (−0.004, 0.007)		
Physical Activity			
screen time (hours per day)	−0.001 (−0.01, 0.01)		
days active (days per week)	−0.001 (−0.007, 0.006)		
sports (number per year)	−0.010 (−0.023, 0.002)	−0.01 (−0.022, 0.002)	−0.011 (−0.023, 0.001)
Sleep duration (hours)			
school nights	0 (−0.02, 0.02)		
free nights	0.002 (−0.008, 0.012)		
Naps: school days (reference: yes)	0.02 (−0.02, 0.05)		
Naps: free days (reference: yes)	0.03 (−0.01, 0.08)	0.04 (−0.01, 0.08)	0.03 (−0.02, 0.07)
Morningness/eveningness	0.001 (−0.002, 0.005)		
Midpoint of sleep- corrected (hours)[a]	0.015 (0.003, 0.028)	0.015 (0.003, 0.028) *	
Social jetlag (hours)[a]	0.02 (0.01, 0.04)		0.02 (0.01, 0.04) *

Notes. CI = confidence interval

[a]N = 68

Model 1: unadjusted general linear model. Model 2 and Model 3: general linear model adjusted for covariates with alpha levels < 0.20 in the unadjusted general linear model (Model 1)

* $p < 0.05$

** $p < 0.01$.