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Associations of sleep duration and social jetlag with cardiometabolic risk factors in the Study of Latino Youth

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Abstract

Objective: We investigated associations of sleep duration and social jetlag with cardiometabolic outcomes.

Participants: Boys and girls aged 8 to 16 years from the Hispanic Community Health Study/ Study of Latino (HCHS/SOL) Youth.

Measurements: Participants (n=1,208) completed a clinical examination where anthropometric characteristics, health behaviors and health history were measured. Sleep duration was calculated as the weighted average of self-reported weekday and weekend bedtimes and wake times and categorized into age-specific cutoffs for short vs. normal sleep. “Social jetlag” was defined as the absolute difference in the midpoint of the sleep period between weekdays and weekends, measured continuously and dichotomized (≥ 2 hours), with higher values indicating more displacement of sleep timing across the week. Regression models tested the associations between sleep measures (separately) and cardiometabolic outcomes [e.g. healthy eating index (0–100), physical activity-minutes per week, obesity, diabetes, hypertension] after adjustment for covariates.

Results: The average sleep duration was 9.5 hours (95% confidence interval: 9.3, 9.6) and the mean social jetlag was 2.5 (2.4, 2.7) hours. Participants with social jetlag reported more physical activity [$\beta=34.8$ (13.14), $P<0.01$], had a higher healthy eating index [$\beta=1.77$ (0.87), $P<0.05$] and

lower odds of being overweight [OR=0.66, (95% CI 0.44, 0.99)]. Short sleep duration was associated with less physical activity but did not relate to other cardiometabolic outcomes.

Conclusions: Social jetlag was associated with healthier behaviors and a lower odds of being overweight. Given these mixed findings, future research should further evaluate how to best characterize sleep timing differences in youth to identify health consequences.

Keywords

sleep; youth; Hispanic/Latino; cardiometabolic risk factors; minority health; social jetlag

Introduction

Inadequate sleep (e.g. short sleep duration, poor sleep quality) and sleep disturbances are highly prevalent among adolescents. Results from the National Survey of Children's Health demonstrated that 39.3% of adolescents (12–17 years) reported inadequate sleep at least 1 night of the preceding week.¹ Only 15% of adolescents report sleeping the recommended 8.5 or more hours per night, and 26% report sleeping 6.5 hours or less on school nights.² Short sleep duration and other sleep problems among adolescents are associated with daytime sleepiness that contributes to poor academic performance, mood problems, and negative health outcomes.^{1, 3–5} In particular, children and adolescents may be at risk for social jetlag (difference in sleep timing between weekdays and weekends) because of early school start times and lack of consistent sleep schedules. The variability in sleep duration between school days and free days or weekends can cause circadian misalignment and negatively impact cardiometabolic systems.⁶

Growing research demonstrates that inadequate sleep is associated with increased risk for adverse cardiometabolic conditions such as adiposity, decreased insulin sensitivity, and elevated blood pressure among children and adolescents.^{7–10} However, these associations are understudied among racial/ethnic minority youth. A few studies of adolescents have shown an association of sleep duration and social jetlag (studied to a lesser extent) with obesity and elevated blood pressure.^{3, 11–17} Research addressing social jetlag in children and adolescents, particularly in racial/ethnic minorities may be particularly important given their high exposure to poorer sleep.¹⁸ In particular, there is little research on sleep among Hispanic/Latino youth. Evidence from the few available studies supports that Hispanic/Latino adults and children experience poorer sleep including shorter sleep duration, more daytime sleepiness, and a higher prevalence of sleep disorders in comparison to non-Hispanic white populations.^{19–25} Social jetlag in particular may be prevalent in this group due to the frequency of exposures to factors that may delay bedtimes (e.g., lack of bedtime routines)²⁶ and require early wake times (school start times and transportation times needed to get to school).²⁷ Additionally, Hispanics/Latinos disproportionately reside in disadvantaged neighborhoods²⁸ that are prone to more crime, violence, noise and inopportune light which are known to disrupt sleep.²⁹ Exploring sleep patterns may be important for identifying strategies to reduce the burden of obesity and diabetes, which are prevalent among Hispanics/Latinos.³⁰

Given the rising prevalence of overweight/obesity in Hispanic/Latino youth, it is important to understand the influence of potentially modifiable risk factors such as sleep duration and social jetlag on obesity as well as other cardiovascular health-relevant behaviors of physical activity and diet as well as clinical measures of adiposity, insulin sensitivity and blood pressure. Using data from the Youth of the Hispanic Community Health Study/Study of Latinos (SOL Youth), we investigated the associations of both sleep duration and social jetlag with various health behaviors (e.g., physical activity and diet) and cardiometabolic risk factors (e.g., measures of adiposity including body mass index [BMI], waist circumference and body fat percentage as well as blood pressure and glucose/insulin resistance). We hypothesized that short sleep duration and social jetlag will be associated with adverse cardiometabolic risk factors.

Methods

SOL Youth is an ancillary to the NIH/NHLBI-funded Hispanic Community Health Study/Study of Latino Youth (HCHS/SOL) cohort study. HCHS/SOL is a population-based cohort study of 16,415 Latino adults (ages 18–74 years) designed to identify prevalence, incidence and risk factors of cardiovascular disease and other chronic conditions. HCHS/SOL participants were selected using probability sampling from Chicago, IL, Miami, FL, Bronx, NY, San Diego, CA between 2008 and 2011. Further details regarding the methodology of HCHS/SOL were previously published.³¹ Between 2012 and 2014 1,466 children were recruited to participate in SOL Youth. Children and adolescents between the ages of 8 and 16 years that lived in the homes of HCHS/SOL participants who were the youth's parents or legal guardians were eligible to participate. Youth who were currently pregnant or had significant physical or cognitive comorbidities were ineligible. SOL Youth participants (n=1,208) with complete data for sleep and cardiometabolic measures were included in the current analysis. The Institutional Review Boards at all participating institutions approved the study protocol, and all participants (youth and caregivers) signed an assent or consent (caregivers & youth > 12 years) form. Additional details regarding the methodology for SOL Youth were previously published.³²

Measurements

In this cross-sectional study, participants were invited to attend a single clinical examination between the hours of 8am and 12pm following an overnight (>12 hour) fast. Questionnaires were administered in Spanish or English, in accordance with the language preference of the participant. All measures were collected in a standardized manner across the four field centers.

Sleep Measures

The exposure variables of interest were sleep duration and social jetlag.³³ Participants self-reported sleep duration in response to the following questions: 1) "What time do you usually go to bed? a. On weekdays? b. On weekends?"; and, 2) "What time do you usually wake up? a. On weekdays? b. On weekends?". Sleep duration was then calculated as the weighted average of weekday (5 days) and weekend (2 days) bedtimes and wake times and averaged to represent sleep duration continuously, in hours. We further categorized sleep duration into

age-specific cutoffs defined according to the National Sleep Foundation for short sleep (<9 hours for those <13 years of age and <8 hours for those >13 years of age) vs. normal (9 hours or 8 hours).

Social jetlag is a marker of circadian misalignment.³⁴ Greater social jetlag can represent an irregular sleep schedule illustrated by the difference in sleep timing on school days and non-school days as a marker of misalignment. For example, social jetlag can result from sleeping more and at a later time on weekends than weekdays due to social demands (e.g. school) as opposed to internally regulated sleep-wake times. It is hypothesized that the effects of social jetlag are similar to those experienced when flying across time zones. Also, evidence suggests that social jetlag disrupts physiological processes (e.g. blood pressure).³⁵ We defined social jetlag as the absolute difference in hours in the midpoint of sleep duration, between weekdays and weekends,³⁶ and further dichotomized as 2 hours based on the literature concerning associations of social jetlag with poor health outcomes.^{6, 35, 37} For example, if a participant reported a sleep onset of 8:00pm and wake time of 6:00am on weekdays (midpoint: 1:00am) and a 10:00pm sleep onset and 10:00am wake time on weekends (midpoint: 4:00am), their social jetlag was 3 hours.

Health Behaviors

Participants wore accelerometers for 7-days (ActiCal, MiniMitter Respironics) and also completed a physical activity questionnaire.^{38–40} In brief, during the clinic visit, participants were fitted with a belt, and were instructed to wear it above the iliac crest on the right side.⁴⁰ Participants were asked to wear the accelerometer for all activities except swimming, showering, and sleeping. Adherence to the accelerometers was defined as a wear time 8 hours/day for 3 days. The maximum wear time was 19 hours; accelerometer data from midnight to 5am were excluded. Activity thresholds were as follows: light (18–440 counts/15-second), moderate (441–872 counts/15-second, and vigorous (>873 counts/15-second).⁴¹ Minutes/day of moderate to vigorous physical activity (MVPA) were summed and averaged across adherent days, and multiplied by the number of days to obtain a measure of minutes per week. MVPA was further defined as >420 minutes/week which is at least 60 minutes daily. The Healthy Eating Index 2010 was determined based on two 24-hour diet recalls administered to the youth participants and aided by the parents (for the younger children). This index is a validated diet quality index that reflects the 2010 Dietary Guidelines and includes 12 components. The components include an adequate amount of total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids as well as a moderate amount of refined grains, sodium and empty calories.⁴² Scores for the healthy eating index range between 0 to 100 with higher scores indicating a healthier diet.

Cardiometabolic Risk Factors

The clinical examination included phlebotomy, anthropometry (Tanita Body Composition Analyzer TBF-300A, wall-mounted stadiometer, Gulick anthropometric tape), seated blood pressure (OMRON HEM-907XL), and study questionnaires. The following outcome variables were ascertained from the clinical examination: adiposity (BMI, waist circumference, body fat percentage from the Tanita scale), glucose/insulin resistance (fasting

glucose, hemoglobin A1c [HbA1c], homeostatic model assessment-insulin resistance [HOMA-IR]) and blood pressure. Details of the measurements were previously published.⁴³ In brief, BMI was assessed according to measured height (cm) with a wall stadiometer and weight (kg) using a digital scale (Tanita Body Composition Analyzer, TBF, 300, Japan). The Centers for Disease Control and Prevention standard guidelines were used to classify adiposity as underweight/normal weight (BMI <85th percentile), overweight (BMI 85th to <95th percentile), or obese (BMI ≥95th percentile). The digital scale used to measure weight also assessed % body fat. Fasting plasma glucose was measured using a hexokinase enzymatic method. HbA1c was measured from whole blood using a Tosoh G7 Automated HPLC Analyzer. Elevated fasting glucose was defined as fasting glucose ≥100 mg/dL or HbA1c ≥5.7% and pre-diabetes as 100 mg/dL to <126 mg/dL or HbA1c 5.7 to 6.4%. We calculated HOMA-IR as [fasting glucose (in mg/dl * insulin (in pmol/L)/6/405] with a HOMA-IR ≥2.5 as insulin resistance.⁴⁴ details of this model were previously published.⁴⁵ For blood pressure, participants were seated at rest for 5 minutes, three blood pressure measures were collected consecutively, and the last two measures averaged. Systolic and diastolic blood pressure (SBP and DBP, respectively) percentiles were based on standard age, height, and sex adjusted equations. Hypertension was categorized as high blood pressure (≥95th age, sex and height standardized percentile)⁴⁶, borderline high blood pressure (90th to <95th percentile or 120/80), or normal. Cardiometabolic risk factors were also analyzed continuously.

Covariates

Participants self-reported age, sex, and ethnicity. Caregivers reported youth Hispanic/Latino heritage and their own level of education. Caregiver education was categorized as less than high school, high school diploma, or greater than high school education. Sleep can vary across seasons, particularly for students with summer vacation, therefore a variable was included to adjust for season. Field center was also included as a covariate.

Statistical Analysis

We used a sequential modeling approach to fit a series of multivariable linear regression models (for continuous outcomes) and logistic regression models (for dichotomous outcomes), as well as multinomial logistic regression models (for categorical outcomes) to estimate the associations of sleep duration or social jetlag simultaneously and independently with health behaviors and cardiometabolic risk factors. Because the distribution of HOMA-IR was skewed, it was natural log-transformed in the linear regression models. There was no evidence of a non-linear association between sleep duration and the outcomes, therefore sleep duration was modeled as a categorical [short sleep duration vs. normal] as well as continuous variable. First, the associations between sleep measures and health behaviors were assessed, then we explored the association between sleep measures and cardiometabolic outcomes. Models were adjusted for demographics, sleep duration (social jetlag models), field center, Hispanic/Latino heritage, caregiver education, physical activity, diet, and season (summer vs. school year). All analyses were conducted using survey weighting to account for the sampling design and clustering within families.

Results

The study sample ($n=1,208$) had a mean age of 12.3 (95% confidence interval (CI): 12.1, 12.5) years, the predominant background group was Mexican (48.9%) and 49.1% were female. The average sleep duration was 9.5 (95% CI: 9.3, 9.6) hours and the mean social jetlag (i.e., difference in sleep midpoint between weekdays and weekends) was 2.5 (95% CI: 2.4, 2.7) hours. There were few differences between youth with low vs. high social jetlag (Table 1). Compared with those with low social jetlag, those with high social jetlag (≥ 2 hours) were older and were more likely to reside in the Bronx, $P<0.01$. Sleep duration was longer, and the sleep midpoint was later on weekends among those with high social jetlag compared to those with low social jetlag (Table 1). Sleep duration was weakly correlated ($r=0.25$) with social jetlag.

Health Behaviors

Short (< 9 hours for those aged 6–13 years or < 8 hours for those aged 14–16 years) compared to normal (≥ 9 hours or ≥ 8 hours) sleep duration was associated with less MVPA before and after adjustment for potential confounders (Table 2). A unit increase in sleep duration was associated with more MVPA in unadjusted models, but the association did not persist after adjustment for potential confounders. In adjusted models only, youth with high social jetlag (≥ 2 hours) reported more MVPA, $\beta=33.8$ [standard error (SE): 13.0, $P<0.01$] and had a higher healthy eating index, $\beta=1.7$ (SE: 0.87, $P<0.05$) relative to those with a lower social jetlag. There was no association between sleep duration and healthy eating.

Cardiometabolic Risk Factors

Short compared to normal sleep duration was related to a higher waist circumference $\beta=2.23$ [SE: 1.19, $P<0.10$] and higher body fat percentage $\beta = 1.72$ [SE: 0.89, $P<0.10$], although the associations were not statistically significant (Table 3).

Table 4 shows the associations between sleep duration and social jetlag with cardiometabolic risk factors expressed as odds ratios. In fully adjusted analyses, youth with social jetlag (≥ 2 hours) had lower odds of being overweight, OR=0.66, (95% CI: 0.44, 0.99). There was no association between sleep duration and odds of elevated cardiometabolic risk factors.

Discussion

Among a sample of Hispanic/Latino youth, we investigated the associations of sleep duration and social jetlag with a variety of cardiometabolic risk factors. In general, self-reported measures of short sleep duration or social jetlag were not consistently associated with adverse cardiometabolic outcomes. Short sleep duration was associated with less physical activity. In adjusted analyses social jetlag was associated with more physical activity, healthier diet and lower odds of being overweight. Social jetlag represents a discrepancy between the biological clock and social schedules which often results in chronic sleep loss.³⁶ The methods and thresholds for characterizing biologically adverse sleep exposures in children and adolescents are not well understood, which may provide rationale for our unexpected findings. In particular, we studied a group across a wide age range, where

sleep needs may change. Also, sleep timing and duration may require more age-specific characterization.

There are racial/ethnic disparities in sleep, particularly among youth.^{47–50} In a study of racially/ethnically diverse young adolescents (mean age 12.3 years), Hispanic/Latino and African American adolescents self-reported a shorter sleep duration than white and Asian adolescents.⁵⁰ In the prior study, the average sleep duration among Hispanic/Latino adolescents was 8.1 hours, which is a shorter sleep duration than reported in the current study (9.5 hours). However, the younger age of our population includes children, who have a longer sleep duration than adolescents. Combs and colleagues reported that the shorter sleep duration found among Hispanic/Latino children compared to non-Hispanic white children can be attributed to a delayed bedtime for Hispanic children, which likely contributes to greater social jetlag if more sleep is occurring on the weekend.²⁷ This difference in bedtimes was independent of socioeconomic class, age and parental education.

Our study found that social jetlag was associated with increased moderate to vigorous physical activity and a higher healthy eating index after adjustment for confounders. Studies among adults have reported that social jetlag was negatively associated with physical activity^{6, 51} and healthy food intake⁵². However, among a sample of high school students (14–17 years of age), social jetlag was not associated with less favorable eating habits or physical activity.³⁷ Other studies among children and adolescents have shown that social jetlag was associated with a higher BMI;^{15, 37} however, while our results showed no association with BMI, we did report an association with a lower odds of being overweight. Although our findings were contrary to prior studies, there are a few plausible explanations. School related activities or work and household (e.g. chores) demands may be confounding factors. For example, youth that participate in school sports likely practice during weekdays, therefore they are more physically active and may also have a shorter sleep duration due to the demands of practice and homework; however, data were not available to test these hypotheses. The students are likely compensating for the sleep loss on the weekend, thus contributing to greater social jetlag. Also, our finding may be due to how social jetlag was computed. High social jetlag was defined as the difference in the sleep midpoint on weekends and weekdays of 2 or more hours, which includes both early chronotypes and later chronotypes in this group. Most of the high social jetlag youth may be morning chronotypes, which in general have better cardiovascular health than evening chronotypes.⁵³ Future studies should further examine the role of social jetlag using objective sleep data and health behaviors and weight.

We unexpectedly found inconsistent associations between short sleep duration and cardiometabolic risk factors. Short sleep duration was associated with less physical activity, but not with other cardiometabolic risk factors such as adiposity, glucose or blood pressure. In prior studies, short sleep duration in adolescents and children were associated with obesity and CVD risk factors.⁸ Other studies among youth have reported that short sleep duration was associated with a higher BMI, body fat, waist and hip circumference, and fat mass index,¹³ as well as a higher odds of prehypertension,¹⁴ and obesity^{11, 54–58}. In fact, a study of 829 adolescents found that longer sleep duration and higher sleep efficiency were associated with a more favorable cardiometabolic health profile.¹⁷ The prior study assessed

sleep objectively, whereas self-reported sleep was collected in the current study. The different results may be due to measurement error associated with self-reported sleep duration and our age range. Additionally, there could be other factors (e.g. cultural) that may mitigate the effects of insufficient sleep on cardiometabolic risk in this population. For example, researchers have demonstrated that sleep is viewed as positive and necessary in the Hispanic culture.⁵⁹ Other cultural factors such as a greater emphasis on religion/church attendance may shape sleep timing, particularly wake times on weekends. Future studies should explore the role of cultural factors in relation to the sleep of Hispanic/Latino Youth.

To our knowledge, this is the first study to investigate associations between sleep and cardiometabolic risk factors among a large sample of Hispanic/Latino youth. We examined a variety of cardiometabolic risk factors and expanded the literature to examine social jetlag, which is particularly relevant to youth. Investigating the sleep of youth is important, given that short sleep duration and high social jetlag can affect school performance and may cause adverse health effects later on in life, particularly among Hispanic/Latino youth. Our study has several limitations. Although we measured two sleep outcomes, sleep duration and social jetlag, these were self-reported sleep measures that are prone to measurement errors. In particular, self-reported sleep duration is often overestimated.⁶⁰ There is also the possibility of bias in our measurement of social jetlag, which may be due to different biases influencing reporting of weekday and weekend sleep. Additionally, the cross-sectional design does not allow inference of directionality. Although we assessed the sleep of an understudied population of Hispanic/Latino youth, we cannot generalize to other Hispanic/Latino groups that were not included in the sample such as those who reside in rural locations. Also, we did not collect information regarding participation in school sports which may be a potential confounder.

In conclusion, our study provides new insight into the relation of sleep and cardiometabolic risk factors among Hispanic/Latino youth, a population at increased risk of cardiovascular outcomes.⁶¹ Social jetlag was associated with more physical activity, a healthy diet and a lower odds of being overweight among youth. These findings suggest that those with higher social jetlag may engage in behaviors that are protective for health, however, more research is needed to understand the protective factors. Also, further research on the best methods for defining sleep and circadian related risks across childhood are needed; improving sleep habits in youth may provide novel strategies to improve health disparities.

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Table 1.

Distribution of Demographic and Cardiometabolic Risk Factors by Social Jetlag, HCHS/SOL 2012–2014

Characteristics*	Total Sample (N=1208)	Low social jetlag (<2 hours) (N=576)	High social jetlag (2 hours) (N=632)	P-value**
	Mean or % (95% CI)	Mean or % (95% CI)	Mean or % (95% CI)	
Age, year	12.3 (12.1, 12.5)	11.7 (11.4, 11.9)	12.8 (12.6, 13.0)	<0.001
Caregiver's education level, %				0.41
Less than High School	38.3 (33.9,42.7)	37.1 (31.5,42.8)	39.3 (33.6, 45.0)	
High School/Equiv.	29.2 (24.9, 33.5)	27.7 (22.5, 32.9)	30.4 (24.5, 36.2)	
More than High School	32.5 (28.3, 36.8)	35.2 (29.1,41.3)	30.3 (25.3, 35.4)	
Sex (Girl), %	49.1 (45.5, 52.8)	47.9 (42.5, 53.3)	50.1 (45.3,55.0)	0.54
Field Center (%)				<0.001
Bronx	36.6 (32.1,41.2)	28.4 (22.9,33.9)	43.3 (37.2,49.4)	
Chicago	14.0 (11.5, 16.4)	15.1 (11.4, 18.7)	13.1 (10.2, 15.9)	
Miami	13.7 (10.7, 16.6)	13.8 (10.1, 17.6)	13.5 (9.9,17.1)	
San Diego	35.8 (30.5,41.0)	42.7 (36.4, 49.0)	30.1 (23.5,36.8)	
Hispanic/Latino (%)				<0.001
Dominican	13.5 (10.4 16.6)	9.4 (6.0, 12.8)	16.8 (12.3,21.3)	
Puerto Rican	10.1 (7.4, 12.8)	7.4 (4.7, 10.1)	12.3 (8.5, 16.1)	
Cuban	5.6 (3.9,7.3)	5.5 (3.4, 7.7)	5.6 (3.3,7.9)	
Central/South American	10.5 (8.0, 12.9)	9.3 (6.4, 12.2)	11.4 (8.3,14.6)	
Mexican	48.9 (43.9,53.9)	57.2 (51.5,62.9)	42.2 (35.7, 48.6)	
Other	11.5 (8.9,14.0)	11.2 (8.1, 14.2)	11.7 (8.2,15.2)	
Spanish Preference, %	20.5 (16.4, 24.6)	20.9 (16.5,25.3)	20.2 (14.4, 26.0)	0.830
Health Eating Index, score	53.6 (52.5, 54.7)	53.6 (52.1,55.0)	53.6 (52.1, 55.1)	0.96
Moderate to vigorous physical activity, minutes/month	243.6 (231.3,256.0)	232.9 (214.9, 250.8)	252.4 (235.1,269.8)	0.13
Sleep duration (hours)	9.5 (9.3, 9.6)	9.4 (9.2, 9.6)	9.5 (9.3, 9.8)	0.48
Sleep duration-weekday (hrs)	9.2 (9.0, 9.3)	9.3 (9.1,9.5)	9.0 (8.7, 9.3)	0.08
Sleep duration-weekend (hrs)	10.2 (10.0, 10.5)	9.6 (9.4, 9.8)	10.7 (10.3,11.1)	<.001
Sleep midpoint-weekday [^]	2:43am	2:27am	2:56am	<.001
Sleep midpoint-weekend [^]	4:35am	3:26am	5:36am	<.001
Short sleep, %	29.3 (25.3, 33.3)	28.9 (23.2, 34.6)	29.6 (24.3, 34.8)	0.86
Social jetlag	2.5 (2.4, 2.7)	1.1 (1.1, 1.2)	3.7 (3.5, 3.9)	N/A
BMI, kg/m ²	22.4 (22.0, 22.8)	22.0 (21.3, 22.7)	22.7 (22.1, 23.3)	0.11
Waist Circumference, cm	77.5 (76.4, 78.5)	76.7(75.1, 78.4)	78.1 (76.6, 79.5)	0.23
Body Fat Percent	26.2 (25.3, 27.0)	26.1 (24.9, 27.2)	26.2 (25.0, 27.4)	0.89
Systolic Blood Pressure Percentile	44.4 (42.5, 46.4)	45.7 (42.9, 48.4)	43.4 (40.9, 46.0)	0.22
Diastolic Blood Pressure Percentile	42.6 (40.7, 44.5)	42.1 (39.6, 44.7)	43.0 (40.6, 45.3)	0.60
Pre/Hypertension, %	5.5 (3.6, 7.4)	4.9(2.6, 7.1)	6.0 (3.2, 8.7)	0.53
Fasting glucose, mg/dL	91.7(91.2, 92.3)	91.8(90.9, 92.6)	91.7(91.1, 92.4)	0.92
Hemoglobin Ale,	5.2(5.2, 5.3)	5.3(5.2, 5.3)	5.2 (5.2, 5.3)	0.66

Characteristics [*]	Total Sample (N=1208)	Low social jetlag (<2 hours) (N=576)	High social jetlag (2 hours) (N=632)	P-value ^{**}
Prediabetes/diabetes, %	16.2(13.4, 19.0)	16.0(12.5, 19.5)	16.4(12.1, 20.7)	0.91
HOMA-IR	3.4(3.2, 3.6)	3.4(3.1, 3.6)	3.4(3.2, 3.7)	0.73
HOMA-IR 2.5 %	56.2 (52.5, 60.0)	59.5(54.1, 64.9)	53.6 (48.4, 58.8)	0.13

^{*} Data were weighted except the number of participants.

^{**} P-value for differences between social jetlag groups.

[^] Presented in clock time.

N/A, Not Applicable;

BMI, body mass index;

HOMA_IR, homeostatic model assessment insulin resistance.

Table 2.

Associations between sleep duration and social jetlag with healthy behaviors, HCHS/SOL 2012–2014

	Moderate to vigorous physical activity				Healthy Eating Index 2010			
	Model 1 Beta (SE)	Adjusted R-squared	Model 2 Beta (SE)	Adjusted R-squared	Model 1 Beta (SE)	Adjusted R-squared	Model 2 Beta (SE)	Adjusted R-squared
Short sleep [†] vs. normal (referent) sleep	−28.02 (11.61) **	0.005	−23.13 (11.49) **	0.086	−1.96 (1.23)	0.004	−1.17 (1.07)	0.110
Sleep duration	8.91 (3.70) **	0.012	4.43 (3.10)	0.084	0.35 (0.26)	0.002	0.14 (0.24)	0.108
High social jetlag [‡] vs. low (referent)	19.56 (12.85)	0.003	33.77 (12.97) ***	0.093	0.049 (1.01)	−0.0007	1.71 (0.87) **	0.111
Social jetlag, hours	7.61 (3.90) *	0.007	8.24 (4.22) *	0.092	−0.39 (0.24)	0.003	−0.18 (0.23)	0.108

Model 1: Unadjusted;

Model 2: Model 1 + age, sex, field center, sleep duration (social jetlag model), Hispanic/Latino heritage, season and adult's education;

P<0.01,**
P<0.05,*
P<0.10.[†]: <9 hours for those aged 6–13 years old or <8 hours for those aged 14–16 years old;[‡]: >2 hours

Table 3.

Adjusted associations between sleep duration or social jetlag and cardiometabolic risk factors, HCHS/SOL 2012–2014

	BMI		Waist Circumference		Fasting glucose		HbA1c		LnHOMA-IR		SBP percentile		DBP percentile		Body fat %	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2-i	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)	Beta (SE)
Short sleep [†] vs. normal sleep (referent)	0.50 (0.47)	0.58 (0.48)	1.94 (1.18) [*]	2.23 (1.19)	0.22 (0.54)	0.30 (0.54)	0.06 (0.02)	0.06 (0.02) ^{**}	0.08 (0.06)	0.08 (0.06)	−0.30 (2.39)	−0.25 (2.39)	0.60 (2.05)	1.15 (2.02)	1.64 (0.87) [*]	1.72 (0.89) [*]
Sleep duration (bra)	−0.14 (0.11)	−0.15 (0.12)	−0.27 (0.30)	−0.32 (0.31)	−0.003 (0.10)	−0.02 (0.10)	0.0005 (0.005)	−0.0009 (0.005)	−0.01 (0.01)	−0.01 (0.01)	−0.52 (0.49)	−0.53 (0.50)	−0.52 (0.54)	−0.63 (0.55)	−0.42 (0.25) [*]	−0.43 (0.25) [*]
High social jetlag [‡] vs. low (referent)	−0.23 (0.46)	−0.22 (0.45)	−1.07 (1.10)	−0.99 (1.07)	0.50 (0.47)	0.37 (0.50)	0.004 (0.02)	0.0004 (0.02)	0.002 (0.05)	0.002 (0.05)	0.38 (1.81)	0.50 (1.89)	1.83 (1.58)	1.65 (1.54)	−0.42 (0.81)	−0.23 (0.78)
Social jetlag (bra)	0.10 (0.13)	0.16 (0.13)	0.19 (0.36)	0.33 (0.36)	0.14 (0.10)	0.12 (0.12)	0.005 (0.005)	0.005 (0.005)	0.01 (0.01)	0.01 (0.01)	−0.29 (0.49)	−0.17 (0.56)	0.41 (0.42)	0.48 (0.44)	0.23 (0.26)	0.40 (0.26)

Model 1: Adjusted for age, sex, field center, Hispanic/Latino heritage;

Model 2: Model 1 + sleep duration (social jetlag models), adult's education, season, diet, and physical activity

P<0.01,

**
P<0.05,

*
P<0.10;

[†]: <9 hours for those aged 6–13 years old or <8 hours for those aged 14–16 years old;

[‡]: >2 hours; BMI, body mass index;

HOMA-IR, homeostatic model assessment insulin resistance;

SBP, systolic blood pressure; DBP diastolic blood pressure

Table 4.

Adjusted associations between sleep duration or social jetlag with odds (95% confidence interval) of cardiometabolic risk factors, HCHS/SOL 2012–2014

	BMI Status *				Pre/diabetes vs. normal glycemic status		Hypertension / Elevated Blood Pressure vs. normal		High HOMA-IR vs. Low	
	Model 1		Model 2		Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	Overweight vs. normal	Obese vs. normal								
Short sleep [†] vs. normal (referent) sleep	1.19 (0.78, 1.83)	1.31 (0.86, 2.01)	1.20 (0.77, 1.85)	1.36 (0.88, 2.08)	1.21 (0.76, 1.93)	1.21 (0.75, 1.96)	0.94 (0.37, 1.88)	0.83 (0.37, 1.84)	1.26 (0.87, 1.82)	1.29 (0.89, 1.87)
Sleep duration	0.96 (0.89, 1.03)	0.96 (0.86, 1.07)	0.96 (0.89, 1.03)	0.96 (0.86, 1.07)	0.97 (0.89, 1.06)	0.97 (0.89, 1.06)	0.98 (0.83, 1.15)	1.00 (0.83, 1.19)	0.98 (0.90, 1.08)	0.98 (0.89, 1.07)
Social jetlag										
High [‡] vs. Low (referent)	0.70* (0.47, 1.03)	0.88 (0.59, 1.29)	0.66** (0.44, 0.99)	0.88 (0.60, 1.28)	1.14 (0.74, 1.75)	1.12 (0.72, 1.73)	1.52 (0.80, 2.91)	1.46 (0.76, 2.81)	0.77 (0.56, 1.06)	0.78 (0.56, 1.08)
Social jetlag (hrs)	0.93 (0.84, 1.02)	1.03 (0.94, 1.12)	0.92 (0.83, 1.03)	1.04 (0.95, 1.15)	1.01 (0.92, 1.11)	1.02 (0.91, 1.13)	0.99 (0.86, 1.15)	0.98 (0.83, 1.17)	0.97 (0.89, 1.05)	0.97 (0.89, 1.06)

Model 1: Adjusted for age, sex, field center, Hispanic/Latino heritage;

Model 2: Model 1 + sleep duration (social jetlag models), adult's education, season, diet, and physical activity

P<0.01,

**
P<0.05,

*
P<0.10

OR: Odds Ratio, CI: Confidence Interval

*
Multinomial models

[†]: <9 hours for those aged 6–13 years old or <8 hours for those aged 14–16 years old;

High HOMA-IR, homeostatic model assessment insulin resistance 2.5