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Sleep Duration and Social Jetlag are Independently Associated with Anxious Symptoms in Adolescents

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Abstract

Although short total sleep time (TST) is associated with increased anxious symptoms in adolescents, it is unknown whether social jetlag, a misalignment between sleep timing on the weekend and school week, is independently associated with anxious symptoms. In the current study, sleep timing, anxious symptoms and demographic information were assessed from 3,097 adolescents (48% female, mean ± SD age 15.59 ± .77 years) from the age 15 wave of the Fragile Families and Child Wellbeing Study (FFCWS). Social jetlag was calculated as the absolute value of the midpoint of sleep on the weekend minus the midpoint of sleep during the school week. Anxious symptoms were measured through the 6-item anxiety subscale of the Brief Symptom Inventory 18. We assessed associations between sleep variables and anxious symptoms using multiple linear regression. Adjusted analyses controlled for sex, race/ethnicity, age in years, body mass index percentile, number of other children below the age of 18 in the household, and primary caregiver (PCG) married/cohabiting with youth's biological parent, PCG employment status, PCG household income, and PCG education level. In fully adjusted models (R^2 = .034), school night TST (b = −.04, ΔR^2 = .005, p < .001) was negatively associated with anxiety symptoms, while social jetlag (b = .04, ΔR^2 = .009, p < .001) was positively and independently associated with anxiety symptoms. Findings indicate small associations of school night TST and social jetlag with anxious symptoms. Thus, maintenance of optimal emotional health in adolescents may require both sufficient sleep duration and regularity of sleep timing across the week.

Keywords

social jetlag; sleep duration; total sleep time; anxious symptoms; chronobiology; emotional health; adolescence

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DECLARATION OF INTEREST STATEMENT

The authors have indicated no financial conflicts of interest relevant to the current study.

INTRODUCTION

For optimal health and wellbeing, the American Academy of Sleep Medicine recommends that adolescents 13–18 years of age obtain 8 to 10 hours of sleep nightly (1). However, more than 70% of adolescents in the United States report sleeping fewer than 8 hours each night (2). The prevalence of insufficient sleep in adolescents is particularly concerning given that short total sleep time (TST) is associated with a host of health-related problems such as emotional dysregulation (3), risk-taking behavior (4), and mental health issues (5), including anxious symptoms (6,7). Anxiety disorders are the most common type of mental disorder in the United States (8). Among adults with a diagnosed anxiety disorder, 38% were initially diagnosed by 15 years of age (9), indicating that anxious symptoms may emerge well before adulthood. Indeed, by the age of 16, 32% of American adolescents have manifested clinical anxiety at some point in their lifetime, with 8% of these adolescents reporting severe impairment (10). Thus, identifying risk factors for anxious symptoms before adulthood may be crucial for early detection and treatment.

Adolescence is a critical developmental time with regard to changes in sleep timing. Adolescents experience a shift toward later chronotype, or later preferred timing of daily activities (e.g., sleep), compared to children and adults (11–14). Relative to TST on the weekend, individuals with later chronotype tend to have shorter TST during the school week resulting from later bedtimes but relatively fixed wake times due to school and other obligations (15–17). As a result, later chronotypes tend to accumulate sleep debt during the school week and must compensate with longer TST on weekends when they are “free” to wake up later (15–17). Later chronotypes thus tend to have a sleep interval with a later midpoint on the weekend relative to the school week (18). This misalignment in sleep-wake timing between the school week and the weekend is referred to as “social jetlag” (18).

Adolescents experience more social jetlag compared to adults (18,19) due to the shift toward later chronotype during adolescence (11–14) and early school start times (20,21). Social jetlag is associated with negative mood states such as depressive symptoms (22,23) and lower psychological wellbeing (18) among adults, but the association between social jetlag and anxious symptoms has not been investigated in adults or in adolescents. While controlling for TST, social jetlag is associated with less resilience (24) and more self-reported verbal aggression (25) in young adults. However, it is unknown whether social jetlag, while controlling for short TST, is associated with anxiety in adolescents.

Short TST is associated with more social jetlag (18) and greater anxious symptoms in adolescents (6,7), but whether social jetlag is associated with anxious symptoms independently of TST is unknown. Therefore, the current study investigated whether school night TST and social jetlag are independently associated with anxious symptoms among adolescents. We hypothesized that more social jetlag would be associated with greater anxious symptoms, independently of school night TST.

MATERIALS AND METHODS

Participants and Design

Data for the current analyses come from the Fragile Families and Child Wellbeing Study (FFCWS; www.fragilefamilies.princeton.edu). The original birth cohort consists of 4,898 children born 1998–2000 in 20 U.S. cities, obtained through stratified random sampling. Non-marital births were over-sampled to obtain a sample of low socio-economic status (SES) (26). To date, data have been collected in six waves: at birth and at ages 1, 3, 5, 9, and 15. The current study examines cross-sectional survey responses of 3,444 youth at age 15 and their primary caregivers (PCGs), defined as the person with whom the youth lives for "half the time" or more. Youth missing demographic, sleep, or anxiety information were excluded from the current study, yielding a final analytical sample of 3,097 youth (89.9% of total). Families were compensated $100 for completion of the PCG questionnaire and $50 for completion of the youth questionnaire. Researchers in the FFCWS are located at multiple institutions, and approval has been obtained from each site's Institutional Review Board (IRB).

Materials and Measures

Youth Age 15 Questionnaire

This questionnaire was administered to youth at age 15. Teens were asked to report sleep variables including bedtime/wake time on school and weekends, anxious symptoms, and demographic information including race/ethnicity, height, and weight (used to calculate body mass index, BMI).

Sleep Measures

Bedtime on school nights and *bedtime on weekend nights* were assessed through the questions, "What time do you usually go to bed on school nights? By school night we mean Sunday night through Thursday night," and "What time do you usually go to bed on weekend nights? By weekend night we mean Friday and Saturday night," respectively. Youth were prompted to report hour, minutes, and AM/PM for bedtimes.

Wake time on school mornings and *wake time on weekend mornings* were assessed through the questions, "What time do you usually wake up on school day mornings?" and "What time do you usually wake up on weekend mornings?" respectively. Youth were prompted to report hour, minutes, and AM/PM for wake times.

The following variables were calculated using bedtime and wake time measures collected from the Youth Age 15 Questionnaire. *Total sleep time (TST) on school nights* (TST School) was calculated as the interval between reported bedtime and wake time on school nights (Sunday through Thursday) in hours. *TST on weekend nights* (TST Weekend) was calculated as the interval between reported bedtime and wake time on weekend nights (Friday and Saturday) in hours. *Weekly average TST* was calculated through the following formula: ((TST School*5) + (TST Weekend*2)) / 7. *Midpoint of sleep on school nights* (mid-sleep work, MSW) was calculated through the following formula: Bedtime School +

(TST School*.5) (15). *Midpoint of sleep on weekend nights* (mid-sleep free, MSF) was calculated through the following formula: Bedtime Weekend + (TST Weekend*.5) (15).

In primary regression models, *social jetlag* in hours was calculated through the following formula: | MSF – MSW | (18). In subsequent regression models, we calculated social jetlag according to alternate definitions described in the literature (22,27). In one regression model, we included a measure of social jetlag corrected for sleep debt accumulated across the school week which was proposed by Jankowski et al. (27): | Bedtime Weekend – Bedtime School |. We furthermore conducted a separate regression analysis using social jetlag categorized as low (≤ 2 hours), moderate (> 2 hours and ≤ 4 hours), and high (> 4 hours), as defined by Levandovski et al., 2011 (28), to test the possibility of a non-linear relationship between social jetlag and anxious symptoms.

Anxious Symptoms Measure

Anxious symptoms were assessed with a modified version of the 6-item anxiety subscale from the Brief Symptom Inventory 18 (BSI 18) (29). The anxiety subscale has previously shown good reliability and validity for detecting psychological distress in at-risk youth (30). Youth selected level of agreement with six statements expressing anxious symptoms from 1 = strongly agree, 2 = somewhat agree, 3 = somewhat disagree, and 4 = strongly disagree. The statements are as follows: “I have spells of terror or panic,” “I feel tense or keyed up,” “I get suddenly scared for no reason,” “I feel nervous or shaky inside,” “I feel fearful,” and “I feel so restless I can’t sit still.” An anxious symptoms score was calculated through the average of item scores and reverse-scored, with greater composite score indicating greater anxious symptomology (i.e., 0 = strongly disagree, 3 = strongly agree). Youth with two or more missing anxious symptoms items were not included in the analytical sample ($n = 1$). The coefficient alpha for the items on the scale was .76, indicating acceptable reliability.

Covariate Measures from Youth Questionnaire

Race and ethnicity consisted of four exclusive categories: “White/Caucasian” (reference); “Black/African American,” “Hispanic and/or Latino,” or a “mixed, other, or none” category.

Body mass index (BMI) percentile at age 15 was assessed using self-reported height and weight. BMI was calculated through the following formula: [weight in pounds / (height in inches^2) x 703] (31) and a percentile was calculated based on 2000 CDC growth charts (32). The 50th percentile indicates the median BMI for the adolescent’s age and sex, and a percentile greater than 68% indicates the adolescent is overweight based on the World Health Organization growth reference study (33).

Covariate Measures from Primary Caregiver Questionnaire

PCGs reported information at the age 15 wave including their employment status, annual household income level, highest level of education completed, number of children in household other than the youth, and whether the PCG (if a biological parent) was married or cohabiting with the youth’s other biological parent (but not if married to someone else).

Statistical Analyses

Analyses were conducted in SPSS 23 (IBM Corporation, Armonk, NY). The relationships between social jetlag and TST (school and weekend) were assessed through bivariate Pearson's correlation analyses. We conducted complete case analysis, and cases were excluded from all analyses if missing any of the following: bedtime or wake time on either school or weekend nights ($n = 63$), more than two items from the BSI 18 anxiety subscale ($n = 1$), and/or covariate questions ($n = 283$).

We conducted ordinary least squares (OLS) linear regression analyses to test the associations of TST School and social jetlag (as defined by Wittmann et al.) (18) with the anxious symptoms score. Model 1 tested the association between school night TST and anxious symptoms, without social jetlag in the model. Model 2 tested the association between social jetlag and anxious symptoms, without school night TST in the model. Model 3 tested the associations of school night TST, social jetlag, and their interaction with anxious symptoms.

We furthermore characterized social jetlag according to the sleep-corrected definition (27) or three social jetlag categories (low, moderate, or high social jetlag) in Model 4 and Model 5, respectively. Model 4 tested the associations of school night TST, sleep-corrected social jetlag, and their interaction with anxious symptoms. Model 5 tested the associations of school night TST, social jetlag categories, and their interaction with anxious symptoms.

Covariates were selected *a priori* based on previous literature and were significantly correlated with BSI 18 anxious symptoms score: sex, reported race/ethnicity, age in years, BMI percentile, number of other children below the age of 18 in the household, annual household income, and PCG married/cohabiting with youth's biological parent, PCG employment status, and PCG education level. Categorical covariates were dummy-coded and entered into regression models. The variance inflation factor (VIF) did not exceed 2.5 for any predictor in the regression model, indicating no multicollinearity (i.e., no predictor was strongly correlated with another predictor) (34).

RESULTS

The final analytical sample consisted of 3,097 youths (89.9% of age 15 wave) with a mean anxious symptoms (6-item BSI 18 anxiety subscale) score of .80 (standard deviation, $SD = .65$). Greater social jetlag was correlated with shorter TST on school nights ($r = -.05$, $p = .003$) but was not correlated with TST on weekend nights ($p > .10$). Demographic information for the sample is listed in Table 1; descriptive statistics for sleep timing and sleep duration variables are in Table 2.

Associations of TST School and Social Jetlag with Anxious Symptoms Score

Table 3 shows the coefficients and 95% confidence intervals for the unstandardized beta of each predictor in Models 1, 2, and 3 (Models 4 and 5 not shown). The interaction between TST School and social jetlag on anxious symptoms was not significant in any model ($p > .10$); therefore, the interaction term was dropped from all models. In Model 1, shorter school night TST was associated with greater anxious symptoms score (6-item BSI 18 anxiety subscale) in regression analysis ($b = -.04$, $\Delta R^2 = .005$, $p < .001$). In Model 2, social jetlag

was positively associated with anxious symptoms score ($b = .05$, $\Delta R^2 = .009$, $p < .001$). In Model 3, shorter school night TST ($b = -.04$, $\Delta R^2 = .005$, $p < .001$) and greater social jetlag ($b = .04$, $\Delta R^2 = .009$, $p < .001$) were each independently associated with greater anxious symptoms score. Model 3 explained 3.4% of the variance in anxious symptoms score.

Associations of TST School and Sleep-Corrected Social Jetlag with Anxious Symptoms Score

Model 4 defined social jetlag according to the sleep-corrected definition (27). The results of analyses with sleep-corrected social jetlag in fully adjusted models were similar to Model 3: shorter school night TST ($b = -.05$, $\Delta R^2 = .005$, $p < .001$) and greater social jetlag ($b = .05$, $\Delta R^2 = .012$, $p < .001$) were each independently associated with greater anxious symptoms score. Model 4 explained 3.7% of the variance in anxious symptoms score.

Associations of TST School and Social Jetlag Categories with Anxious Symptoms Score

Model 5 tested the associations of TST School and social jetlag categorized as low, moderate, or high with anxious symptoms. The mean anxious symptoms score for social jetlag categories was as follows: low (≤ 2 hours; $n = 1{,}017$): $M = .74$, $SD = .62$; moderate (> 2 and ≤ 4 hours; $n = 1{,}623$): $M = .79$, $SD = .64$; high (> 4 hours; $n = 457$): $M = .94$, $SD = .68$. Adding social jetlag categories to the regression model explained an additional 0.8% variance in anxious symptoms. Specifically, adolescents with moderate social jetlag reported a trend for greater anxious symptoms than those with low social jetlag ($b = .05$, $p = .077$). Adolescents with high social jetlag reported significantly greater anxious symptoms than those with low ($b = .18$, $p < .001$) and moderate ($b = .14$, $p < .001$) social jetlag. The relationship between social jetlag and anxious symptoms thus appears to follow a positive linear trend. Controlling for social jetlag categories, shorter school night TST was significantly associated with greater anxious symptoms ($b = -.04$, $\Delta R^2 = .005$, $p < .001$). Model 5 explained 3.3% of the variance in anxious symptoms score.

DISCUSSION

We hypothesized that social jetlag would be associated with shorter school night sleep duration and longer weekend night sleep duration. We found that social jetlag was associated with shorter TST on school nights, as expected; however, there was no association between social jetlag and TST on weekend nights. These results corroborate previous findings that a greater sleep deficit during the school week, defined as the difference between school night and weekend sleep duration, correlates with greater social jetlag (18,19). However, youth in the current sample with more social jetlag did not obtain longer weekend TST, despite waking later on weekend mornings; thus, our findings suggest that teens with greater social jetlag were unable to compensate for short TST during the school week with longer sleep on the weekend.

With regard to emotional health, we hypothesized that social jetlag would be associated with anxious symptoms, independent of school night TST. We found significant associations between short school night TST and anxious symptoms in this large adolescent cohort, supporting previous research (6,7). We also found that social jetlag was associated with

greater anxious symptoms in adolescents, independent of school night TST. These results corroborate previous research indicating that jetlag induced by air travel across time zones is associated with depressive symptoms (35,36). The findings from the current study indicate that jetlag, whether induced by misalignment of sleep timing across the week (i.e., social jetlag) or precipitated by air travel, negatively impacts emotional health through a mechanism distinct from short sleep duration.

Our findings indicate that shorter school night TST and greater social jetlag increase the risk for anxious symptoms in adolescents. Youth with later chronotype who must conform to early school schedules are particularly at risk for social jetlag (18,19) and, potentially, decreased emotional health (22,37,38). For example, according to the regression equation in Model 3, a teen with 6 hours of sleep on school nights and 4 hours of social jetlag weekly has a predicted anxious symptoms score of 1.13, nearly 22% greater than a teen with 8 hours of school night TST and 1 hour social jetlag (predicted anxious symptoms score = .93). Thus, targeting either TST or sleep timing alone may be inadequate to maintain optimal emotional health, and future studies should target both to identify and subsequently treat adolescents at risk for anxious symptoms. Reducing the risk of anxious symptoms may be accomplished by lengthening sleep on school nights (e.g., through earlier bedtime or later school start times). In turn, lengthening sleep on school nights may reduce the amount of sleep debt across the week, resulting in lower levels of social jetlag and further reducing the risk of anxious symptoms.

The current study had some limitations. First, the design was cross-sectional and it was not possible to determine temporal order. It is plausible that either short school night TST precedes anxious symptoms or that anxious symptoms precede short school night TST. For example, youth who experience anxious symptoms close to bedtime, such as cognitive arousal (e.g., racing thoughts), obtain fewer hours of sleep than their peers (39,40). Alternatively, short TST may precede anxious symptoms. In one longitudinal study of youth aged 11–17 years, short TST (≤ 6 hours) predicted anxiety disorder at one-year follow-up, adjusting for baseline anxiety disorder. However, adjusting for baseline TST, anxiety disorder did not predict short TST at follow-up (6). These results suggest that short sleep precedes manifestation of clinical anxiety in adolescents. The current study assessed anxious symptoms rather than clinical anxiety; thus, caution is warranted when comparing studies. Alternatively, the relationship between short sleep and anxious symptoms may be reciprocal, with short sleep resulting in anxious mood, and anxious symptoms resulting in shorter sleep. Future intervention studies should investigate whether extending sleep duration and reducing sleep timing misalignment can reduce the risk for development of anxious symptoms.

Previous research indicated statistically significant associations between short sleep and anxious symptoms (6,7) and between short sleep and social jetlag (18,19) in adolescents. To our knowledge, the current study is the first to examine the relationship between social jetlag and anxious symptoms in any population. These findings agree with previous emotional health research, which indicates a positive association between social jetlag and depressive symptoms (22,37). Furthermore, previous studies found that social jetlag and TST are independently associated with less resilience (24) and more self-reported verbal aggression (25) in young adults. Our findings thus corroborate previous research and indicate that

measures of sleep duration and timing constitute distinct dimensions or facets of sleep health.

In the current study, social jetlag was associated with anxious symptoms, independent of TST on school nights. As with TST, the temporal direction of the association between social jetlag and emotional health is unclear. Individuals with later chronotype tend to have greater social jetlag; these individuals may need to awaken and perform at times earlier than dictated by endogenous rhythms (38,41,42), leading to greater social jetlag and more anxious symptoms. For example, research indicates that individuals with high social jetlag perceive themselves less able to handle the demands of the work environment, potentially increasing stress and anxious symptoms (38). Alternatively, it is possible that anxious symptoms precede social jetlag; anxious individuals may delay bedtime on the weekends, resulting in later midpoint of sleep and greater social jetlag (18). To our knowledge, the direction of this association has not yet been investigated, warranting future experimental and longitudinal research.

Another limitation is that the anxiety subscale of the BSI 18 does not have a clinical cutoff for anxiety (29,43). Therefore, while we found independent associations of TST on school nights and social jetlag with anxious symptoms, the level of anxiety experienced in this sample may not reach diagnostic clinical levels and may not translate to decrements in mental well-being and quality of life. Furthermore, though we found significant associations of school night TST and social jetlag with anxious symptoms, the proportion of explained variance (0.5% and 0.9% in adjusted Model 3, respectively) indicated small effect sizes according to Cohen's guidelines (28). These results may indicate that our study was overpowered due to large sample size. Thus, the magnitude of the current findings may not be clinically significant. Moreover, the links between social jetlag and wellbeing may depend on the composition of chronotypes of the sample (44); given that the current study was conducted with adolescents, who have later chronotype (11–14), our results may not generalize to those with morning chronotypes. Additionally, we calculated sleep duration based on the elapsed time between reported bedtime and reported wake time. However, sleep latency may be longer on school days due to adolescents sleeping before their biological night; thus, it is likely that we overestimated sleep duration, particularly on school nights. Finally, we analyzed self-reported sleep data, which may be biased compared with objective measures, particularly in those with emotional problems such as depression or anxiety (45,46). Nevertheless, the findings from the current study guide future research which may employ longitudinal or experimental designs, objective measures of sleep variables (e.g., actigraphy), and measures of clinical anxiety.

Our findings indicate that adolescents with short sleep during the school week experience higher levels of social jetlag. Furthermore, both short TST during the school week and social jetlag are independently associated with greater anxious symptoms in adolescents. Maintenance of optimal emotional health in adolescents may require both sufficient sleep duration and regularity of sleep timing across the week.

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Table 1

—Demographic Information from Analytical Sample (n = 3,097) of Age 15 Wave of the Fragile Families and Child Wellbeing Study (FFCWS)

	n	%
Youth		
Sex[a]		
Female	1494	48.2
Male	1603	51.8
Race/ethnicity		
Black/African American	1438	46.4
Hispanic and/or Latino	741	23.9
White/Caucasian	543	17.5
Other, mixed, or none [b]	375	12.1
	Mean	***SD***
Age (yrs)	15.59	.77
Body mass index (percentile)[c]	68.02	27.96
Household		
Number of other children < 18 years	1.5	1.4
	n	**%**
PCG married or cohabiting with youth biological parent		
Married or cohabiting	839	27.1
Not married or cohabiting	2258	72.9
PCG		
Highest education level completed		
Less than high school	536	17.3
High school or equivalent	604	19.5
Some college or technical school	1354	43.7
College graduate	603	19.5
Employment status		
Unemployed	910	29.4
Employed	2187	70.6
	Mean	***SD***
Annual household income	$62,177	$65,261

[a] Data collected at birth.

[b] Other category includes Asian, Central American/Caribbean, Native American/Alaska Native, and/or Native Hawaiian/Pacific Islander.

[c] Body mass index collected at age 15; percentile calculated based on 2000 CDC growth charts (32).

PCG–Primary caregiver.

Table 2

—Sleep Timing and Duration Descriptive Statistics (n = 3,097)

	Mean	*SD*
Bedtime		
School nights (Sun-Thurs)	22:22	1.13
Weekend nights (Fri-Sat)	00:31	1.91
Wake time		
School days (Mon-Fri)	06:20	.85
Weekend days (Sat-Sun)	09:44	1.84
Sleep duration (hrs)		
School nights	7.98	1.24
Weekend nights	9.22	2.03
Weekly average[a]	8.33	1.17
Social jetlag		
Social jetlag (hrs)[b]	2.81	1.46
Social jetlag, sleep-corrected (hrs)[c]	2.19	1.65

[a]Calculated as [(sleep duration on school nights*5) + (sleep duration on weekend nights*2)] / 7.

[b]Calculated as | midpoint of sleep on weekend nights − midpoint of sleep on school nights | (18).

[c]Calculated as | bedtime on weekend nights − bedtime on school nights | (27)

Table 3

—Regression Model Predicting Anxious Symptoms (BSI 18 Subscale Score[a]) from TST School and Social Jetlag

	UNADJUSTED FOR COVARIATES								
	Model 1a IV: TST School			**Model 2a IV: Social Jetlag[b]**			**Model 3a IVs: TST School &Social Jetlag[b]**		
	b	**95% CI[c]**	**Δ*R*²**	***b***	**95% CI[c]**	**Δ*R*²**	***b***	**95% CI[c]**	**Δ*R*²**
TST School (hrs)	−.03***	−.05, −.02	.004	–––	–––	.011	−.03**	−.05, −.01	.004
Social Jetlag (hrs)	–––	–––	–––	.05***	.03, .06	–––	.04***	.03, .06	.014
	ADJUSTED FOR COVARIATES[d]								
	Model 1b IV: TST School			**Model 2b IV: Social Jetlag[b]**			**Model 3b IVs: TST School &Social Jetlag[b]**		
	b	**95% CI[c]**	**Δ*R*²**	***b***	**95% CI[c]**	**Δ*R*²**	***b***	**95% CI[c]**	**Δ*R*²**
TST School (hrs)	−.04***	−.06, −.02	.005	–––	–––	–––	−.04***	−.05, −.02	.005
Social Jetlag (hrs)	–––	–––	–––	05***	03, .06	.009	.04***	.03, .06	.009

[a] BSI 18 subscale range: 0=low anxious symptoms; 3=high anxious symptoms.

[b] Calculated as | midpoint of sleep on weekend nights − midpoint of sleep on school nights | (18).

[c] 95% confidence interval for unstandardized beta, *b*.

[d] Adjusted for sex, reported race/ethnicity, age in years, body mass index percentile, number of other children below the age of 18 in the household, annual household income, primary caregiver (PCG) married/cohabiting with youth's biological parent, PCG employment status, and PCG education level.

TST—total sleep time

** $p < .01$, two-tailed.

*** $p < .001$, two-tailed