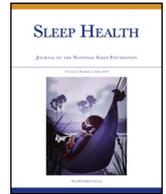




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A composite measure of sleep health predicts concurrent mental and physical health outcomes in adolescents prone to eveningness[☆]

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ABSTRACT

Background: Sleep health can be characterized using multiple dimensions, including regularity, satisfaction, alertness, timing, efficiency, and duration. This study provides a preliminary derivation of a Sleep Health Composite score in adolescents with eveningness chronotype and examined its associations with mental and physical health outcomes.

Methods: Participants were 176 adolescents (mean age 14.77 years, 58% female) who participated in a randomized controlled trial examining the Transdiagnostic Sleep and Circadian intervention. At study entry, the sample was characterized by evening circadian preference, later bedtime, and increased risk in 1 of 5 health domains (emotional, cognitive, behavioral, social, and physical). The Sleep Health Composite was derived using 7-day sleep diary and self-report rating scales. Each dimension was categorized as “good” or “poor” using cut-offs informed by prior studies and expert consensus. Mental and physical health outcomes were assessed using self-report rating scales, semistructured clinical interviews, parent report, or biometric measurement.

Results: Sleep duration and satisfaction dimensions were most commonly rated as poor. Greater sleep health, as indexed by greater Sleep Health Composite score, was concurrently associated with lower risk in emotional, cognitive, and social domains, as well as fewer physical symptoms and reduced odds for obesity and current mood or anxiety disorders.

Conclusions: Sleep health is an important correlate of mental and physical health outcomes in adolescents. The Sleep Health Composite has potential application as an outcome measure in treatment studies of sleep and circadian problems.

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Sleep and circadian disturbances are prominent across a wide range of mental and medical disorders. These disturbances may include insomnia, hypersomnia, reduced sleep need, and delayed and advanced sleep phase, each of which may co-occur with the others, and be present at syndromal or subsyndromal levels.^{1–3} Our goal was to provide a “proof-of-concept” example of a composite measurement that includes multiple sleep dimensions. In so doing, we build on prior work designed to unify methodological practices for single disorders, such as the standard research assessment for insomnia.⁴

The sleep health framework is the theoretical basis for this study.⁵ *Sleep health* is defined as “a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promotes physical and mental well-being.” This definition emphasizes that sleep health is a broader construct than specific sleep disorders and that it plays a positive role in the overall health and functioning of an individual or population.⁵ This approach encourages us to view sleep health as a multidimensional construct comprising 6 dimensions of sleep and circadian functioning: satisfaction, alertness, timing, efficiency, duration, and regularity. These 6 dimensions were proposed based on theoretical plausibility and empirical evidence linking each dimension with physical and mental health outcomes.⁵ A recent investigation found that an aggregate measure based on 5 of the dimensions proposed in the sleep health framework was associated with prevalent and incident depression symptoms.⁶ Another recent study found that multidimensional sleep variables were associated with mortality in older men.⁷

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The present study sought to extend this approach by testing the utility of a Sleep Health Composite score derived from self-reported sleep measure.

Composite measures of sleep health can also inform treatment. The Transdiagnostic Sleep and Circadian (TranS-C) intervention is under empirical examination in youth and adult populations.⁸ TranS-C is designed to address a variety of sleep problems across psychiatric disorders, including insomnia, delayed and advanced sleep phase, difficulty waking up or getting out of bed in the morning, too much time in bed, daytime sleepiness, inadequate opportunity to sleep, irregular sleep-wake schedules, and worry/rumination. During the development and testing of TranS-C, it became apparent that the use of single disorder-focused measures for a transdiagnostic treatment is problematic. For example, *decreased* time in bed is often indicated in the treatment of insomnia, but *increased* time in bed is indicated in the case of insufficient sleep. Also, an *earlier* bedtime indicates a positive change in the case of delayed sleep phase, but a *later* bedtime is a positive change in the case of advanced sleep phase. Therefore, simple computations of time in bed and sleep timing cannot be used as outcome measures for TranS-C. The Sleep Health Composite is intended to capture the variety and complexity of the sleep problems experienced by people with a wide range of mental and medical disorders and accommodates differences in treatment goals that may vary depending on the presenting sleep-circadian problem.

The current study provides a proof-of-concept example of the utility of measuring multidimensional sleep health in adolescents. This is a particularly important and interesting group developmentally, as it poses challenges to several of the proposed sleep health dimensions, especially timing, duration, and regularity. Social changes (eg, less parental control), increased academic demands (eg, early wake-up times for school), and a biological shift toward a delayed phase sleep triggered by puberty onset often interact to result in short duration, late timing, and reduced regularity of sleep. The current study used baseline data from a randomized controlled trial (RCT) testing TranS-C in adolescents who exhibited these sleep problems. The current study had 3 specific aims: (1) to describe the preliminary development of a Sleep Health Composite derived from self-reported sleep measures and report its descriptive statistics; (2) to investigate whether the Sleep Health Composite was concurrently associated with the primary outcomes related to the 5 health domains of the TranS-C RCT at pretreatment; (3) to investigate whether the Sleep Health Composite was concurrently associated with additional psychiatric and physical conditions, as well as past-year medical history, at pretreatment. We examined outcomes such as obesity⁹ and major depressive disorders⁶ that have been associated with sleep disturbances, and/or evening circadian chronotype in the extant literature.

Methods

Participants and procedures

Participants were 176 adolescents recruited through clinician referrals and advertisements from January 2013 to February 2016. Table 1 shows the demographic information for the participants. A detailed description of the study procedure can be found elsewhere.¹⁰ Briefly, participants and parents/guardians were first screened for eligibility via a telephone interview, and potentially eligible individuals participated in an in-person assessment session to determine eligibility. Eligible participants were randomized to receive either TranS-C or psychoeducation for 6 weekly sessions. All participants' parents or guardians provided informed consent, and participants provided informed assent. The current study used only pretreatment data for the whole sample.

Table 1
Demographic characteristics of the sample (N = 176)

Characteristic	n (%) or M (SD)
Female	102 (58)
Hispanic/Latino	27(15)
Race	
White	114 (65)
African American/black	12 (7)
American Indian or Alaska Native	0 (0)
Asian	18 (10)
Native Hawaiian/other Pacific Islander	2 (1)
Mixed race	30 (17)
Family annual income	
≤20,000	6 (3)
20,001-50,000	21 (12)
50,001-100,000	42 (24)
100,000+	102 (58)
Refused to answer/missing	5 (3)
Current grade	9.39
Any current K-SADS Dx (teen report)	63/171 (37)
Any past K-SADS Dx (teen report)	77/171 (45)
Any current K-SADS Dx (parent report)	49/168 (29)
Any past K-SADS Dx (parent report)	55/168 (33)
Age	14.77 (1.84)

M = Mean; SD = Standard Deviation.

Inclusion criteria were as follows: (1) 10 to 18 years old, living with a parent or guardian, and attending a class/job by 9:00 AM at least 3 days per week; (2) fluent in English; (3) able and willing to give informed assent; (4) self-reported eveningness as demonstrated by scoring within the lowest quartile of the Children's Morningness-Eveningness Preferences Scale (CMEP; 27 or lower¹¹) and sleep onset time of 10:40 PM or later for 10- to 13-year-olds, 11:00 PM or later for 14- to 16-year-olds, and 11:20 PM or later for 17- to 18-year-olds at least 3 nights per week for the last 3 months with a 7-day sleep diary^{12,13}; and (5) scoring "at risk" on at least 1 of the 5 health domains (for specific criteria, see Appendix A).

Exclusion criteria included an active, progressive physical illness or neurological degenerative disease directly related to the sleep disturbance, evidence of obstructive sleep apnea, restless legs syndrome, or periodic limb movement disorder (per self-report or Duke structured interview for sleep disorders), pervasive developmental disorder, bipolar, schizophrenia, taking medications that directly affect sleep (eg, hypnotics) within 4 weeks of the assessment (2 weeks for melatonin), substance dependence in the past 6 months, and current suicide risk sufficient to preclude treatment on an outpatient basis.

Measures

Sleep diary

Sleep diary¹⁴ was collected by trained research assistants via phone calls in the morning to adolescent participants during a 1-week (7-day) period at pretreatment. Sleep duration (total sleep time [TST]), timing (midpoint sleep), regularity (SD of midpoint sleep), and sleep efficiency (TST/total time in bed) dimensions of the Sleep Health Composite were derived using sleep diary indices. TST was calculated as follows: TST = time in bed – sleep onset latency – wake after sleep onset – terminal wakefulness. Descriptive statistics of all sleep diary indices are reported in Supplemental Table S1.

Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index¹⁵ (PSQI) was administered at pretreatment assessment. The satisfaction dimension of the Sleep Health Composite was derived using question 6 from the PSQI: "During the past month, how would you rate your sleep quality overall?"

Participants were asked to rate on a 4-point scale (0 = very good, 1 = fairly good, 2 = fairly bad, and 3 = very bad).

Sleepiness Scale

The 10-item Sleepiness Scale¹⁶ was administered at pretreatment assessment. Each item was rated on a 4-point scale (0 = no, 1 = struggled to stay awake, 2 = fallen asleep, 3 = both struggled to stay awake and fall asleep). The alertness dimension of the Sleep Health Composite was derived using the Sleepiness Scale (reverse coded).

Children's Morningness-Eveningness Preferences Scale

CMEP¹⁷ was used to assess the adolescents' chronotype. Scores range from 10 (extreme evening preference) to 43 (extreme morning preference).

Functioning in 5 health domains

Five youth self-report composite risk scores, each composed of measures in emotional, cognitive, behavioral, social, or physical health, were used to indicate functioning in 5 health domains. Specific measures for each domain are detailed in the supplement. The composite scores were calculated for each of the 5 health domains by taking the mean of standardized summary scores for specific measures within that domain. Composite scores were created because individual measures within each domain used different scales. Because of the large number of measures in this study, creating a composite score was also a method to control for the multiplicity problem and increase statistical power.¹⁸ As shown in Table 3, composite scores have means close to 0 and standard deviations slightly less than 1. The interpretation of the composite scores is similar to standardized scores: a positive/larger composite score indicates greater risk in that domain, whereas a negative/smaller composite score indicates lower risk. Summary scores for specific measures were reverse coded when necessary so that all scores of specific measures within a domain would have the same direction.

Kiddie Schedule for Affective Disorders and Schizophrenia-Present and Lifetime Version

The Kiddie Schedule for Affective Disorders and Schizophrenia—Present and Lifetime Version (K-SADS-PL)¹⁹ was administered to adolescent and 1 parent to determine current and lifetime *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV), Axis I disorder at the pretreatment assessment by trained graduate-level clinicians and trained project coordinators under the supervision of licensed clinical psychologists. We focused on current DSM-IV Axis I disorders in the current study. The interrater reliability in the current study for the K-SADS diagnosis was $\kappa = 0.78$.

To simplify K-SADS variables for the current analysis, we categorized DSM-IV diagnoses into 3 main classes following Merikangas et al²⁰: (1) any current mood disorder, including major depressive disorder, dysthymia, bipolar I, bipolar II, and bipolar not otherwise specified; (2) any current anxiety disorder, including agoraphobia, generalized anxiety disorder, social phobia, specific phobia, panic disorder, posttraumatic stress disorder, and acute stress disorder; and (3) any current behavioral disorder, including attention-deficit/hyperactivity disorder (ADHD), oppositional defiant disorder, conduct disorder, and substance use disorders (alcohol abuse/dependence and drug abuse dependence). Note that substance use disorders were grouped into the behavioral disorder class because of very low occurrence (2 cases based on adolescent interview and 1 based on parent interview). There was no case for eating disorder in this sample.

Medical history

At pretreatment assessment, parents provided a past-year medical history of the adolescents via questionnaire. For the purpose of this study, to construct the past-year medical problem variable, we selected 5 medical conditions (diabetes, infections, hypertension, high cholesterol, and injury/accidents) most relevant to sleep health based on evidence reviewed by Buysse (2014).⁵

Body mass index

Adolescents' weight and height were measured twice at preassessment, and the average of the 2 measurements was used to derive the age- and sex-adjusted body mass index (BMI) using the BMI calculator for teens made available by the Centers for Disease Control and Prevention.²¹

Derivation of the Sleep Health Composite

Derivation of the Sleep Health Composite (see Table 2 for summary) was based on several considerations. First, we made an a priori decision to dichotomize each dimension as “good” or “poor” because this approach is deemed more feasible and deployable in clinical practice as opposed to keeping each individual dimension as a continuous scale. For each dimension, “good” is coded as 1 and “poor” is coded as 0. The Sleep Health Composite was constructed such that higher score indicates better sleep health. The reverse of the Sleep Health Composite represents the number of “poor” or risk dimensions a participant met, similar to a cumulative risk score (eg, Evans et al²²). Second, to choose the most appropriate cut-off point for each dimension, we combined 3 approaches: (1) wherever available, the cut-off point was primarily guided by recommendations from the extant literature; (2) when recommendations were not available, the cut-off point was informed by data from previously published studies in normative samples (ie, healthy, community adolescents); (3) if none of the aforementioned were available, in addition to item 2, we also considered the observed distribution in the current sample, keeping in mind that it is a unique, nonrepresentative sample of community adolescents with eveningness chronotype and who exhibit increased risk in 1 of the health domains.

Regularity

Regularity is operationalized as midpoint sleep fluctuation (ie, SD for midpoint across 7-day sleep diary) ≤ 1 hour. Midpoint sleep is preferred over bedtime or risetime because it incorporates both bedtime and risetime. To the best of our knowledge, no prior literature offers an exact recommendation or cut-off point for what constitutes good regularity. The 1-hour cut-off was selected based on both prior literature and the sample distribution in the current study as follows. First, a main source of the intraindividual variability for adolescents comes from the weekday-weekend discrepancy in sleep patterns. Sleep midpoint values reported in Crowley et al²³ were 2:00 AM for weekdays and 4:00 AM for weekends in middle schoolers and 3:00 AM for weekdays and 5:00 AM for weekends in high schoolers. Therefore,

Table 2

Operational definition of 6 sleep health dimensions and tabulation of each dimension in the current sample

Dimension	Definition
Regularity	Midpoint sleep fluctuation across a 7-d sleep diary ≤ 1 h
Satisfaction	Question 6 of the PSQI rated “very good” or “fairly good”
Alertness	Sleepiness Scale score ≤ 7.5
Timing	Average midpoint sleep across 7-d sleep diary between 2:00 and 4:00 AM
Efficiency	Average sleep efficiency of the 7-d sleep diary $\geq 85\%$
Duration	TST average across 7-d sleep diary between 9 and 11 h for 10-13 y and between 8 and 10 h for 14-18 y

roughly 1-hour weekday-weekend discrepancy on midpoint was observed for both younger and older adolescents in normative samples.

Table 3
Descriptive statistics of the Sleep Health Composite and other study variables

Variables	M (SD) or n (%)
Sleep Health Composite	
Total score (continuous)	3.66 (1.36)
Total count	175 ^b (100.00)
0	3 (1.71)
1	10 (5.71)
2	19 (10.86)
3	42 (24.00)
4	49 (28.00)
5	41 (23.43)
6	11 (6.29)
Dimensions (% poor)	
Regularity	52 (31.52)
Satisfaction	78 (46.71)
Alertness	63 (36.63)
Timing	30 (18.07)
Efficiency	25 (15.06)
Duration	113 (68.07)
Sleep and circadian outcomes	
TST weeknights	456.48 min (63.18 min)
Bedtime weeknights	22 h, 56 min (1 h, 04 min)
CMEP	21.35 (3.81)
Youth self-report composite risk score	
Emotional domain ^a	0.02 (0.86)
Children's Depression Rating Scale	33.52 (9.55)
Multidimensional Anxiety Scale for Children	46.07 (16.82)
Cognitive domain ^a	0.004 (0.80)
Attention Control Scale	50.94 (7.73)
Youth Social Adjustment Scale: school/cognitive	11.78 (2.89)
Behavioral domain ^a	−0.003 (0.83)
Sensation Seeking Scale	26.86 (6.07)
Alcohol and substance use	5.73 (7.42)
Social domain ^a	−0.005 (0.66)
Youth Social Adjustment Scale: friends	18.66 (4.79)
Youth Social Adjustment Scale: family	12.14 (3.57)
Youth Social Adjustment Scale: romantic	7.45 (1.86)
Physical domain ^a	0.01 (0.71)
Modifiable Activity Questionnaire	3.10 (4.85)
Physical Health Questionnaire	8.92 (4.89)
BMI	
BMI (continuous)	22.28 (4.68)
Obese (BMI ≥30)	9 (5.20)
Overweight & obese (BMI ≥25)	32 (25.00)
Underweight (BMI <18.5)	36 (27.27)
Normal weight (BMI 18.5–24.99)	96 (55.49)
Medical problem (past year)	31 (17.03)
K-SADS diagnostic classes	
Any current mood disorder (T)	16 (9.09)
Any current mood disorder (P)	15 (8.57)
Any current anxiety disorder (T)	49 (27.84)
Any current anxiety disorder (P)	29 (16.57)
Any current behavior disorder (T)	23 (13.37)
Any current behavior disorder (P)	20 (11.43)

All models controlled for age and sex. Higher Sleep Health Composite indicates better sleep health. For variables under “Youth Self-Report Composite Risk Score,” all variables, except for Attention Control Scale and Modifiable Activity Questionnaire, were coded such that higher score indicates greater risk/worse outcome. Medical problem (past year) includes diabetes, infections, hypertension, high cholesterol, and injury/accidents. Any current mood disorder includes major depressive disorder, dysthymia, bipolar I, bipolar II, and bipolar not otherwise specified. Any current anxiety disorder includes agoraphobia, generalized anxiety disorder, social phobia, specific phobia, panic disorder, posttraumatic stress disorder, and acute stress disorder. Any current behavior disorder includes ADHD, oppositional defiant disorder, conduct disorder, and substance use disorders (alcohol abuse/dependence and drug abuse dependence. T, teenager interview; P, parent interview.

^a Composite scores derived by obtaining the mean of the standardized scores of all measures within each domain. Higher composite risk scores indicate greater risk in that health domain.

^b One participant had an incomplete sleep diary at pretreatment and thus had a missing value on the Sleep Health Composite.

Second, in a sample of community-dwelling adolescents with naturalistically unconstrained sleep, *low intraindividual variability* (defined as the lower 20% of the sample) was about 0.8 hour for bedtime, about 0.9 hour for rise time, and about 1 hour for time in bed.²⁴ Third, in the current sample, the mean SD for midpoint sleep is 0.9 hour, and the majority (75%) of the sample had ≤1 hour of sleep fluctuation over a week.

Satisfaction

Satisfaction is operationalized as the rating for question 6 on the PSQI. This question asks, “how would you rate your sleep quality?” For the Sleep Health Composite, responses of “very good and fairly good” were combined to create the category of good satisfaction and “fairly bad and very bad” were combined to create the category of poor satisfaction.

Alertness

Alertness is operationalized as the total score on the 10-item Sleepiness Scale ≤7.5. This cut-off was selected because 7.5 equals the mean plus 1 SD reported in healthy adolescents with adequate sleep.¹⁶

Timing

Good sleep timing is operationalized as having an average midpoint sleep across the 7-day sleep diary between 2:00 and 4:00 AM. The cut-off range was selected because 2:00–4:00 AM was derived from normative samples as follows. First, midpoint was 2:42 AM for weekdays and 3:47 AM for weekends in adolescents from the National Sleep Foundation 2011 Poll.²⁵ Second, midpoint values calculated using average bedtime and rise time reported in the Crowley et al²³ review were 2:00 AM for weekdays and 4:00 AM for weekends in middle schoolers and 3:00 AM for weekdays and 5:00 AM for weekends in high schoolers. Third, the observed midpoint averaged across 7-day sleep diary (mean ± 1 SD) in our sample of adolescents with evening circadian preference at pretreatment is between 2:16 AM and 4:36 AM.

Efficiency

Good sleep efficiency, derived from recommendations in the adolescent sleep literature (eg, Hysing et al²⁶ and Lovato et al²⁷), is operationalized as ≥85% average sleep efficiency in the 7-day sleep diary.

Duration

Good sleep duration is operationalized as TST, averaged across the 7-day sleep diary, of 9–11 hours for 10- to 13-year-olds and 8–10 hours for 14- to 18-year-olds. These cut-offs are derived from recommendations in the literature^{28,29} and values used in prior research.¹³

Data analysis

All analyses were completed in Stata 15. The Sleep Health Composite score was modeled as a continuous variable. Multiple regression analysis was used for aims 2 and 3 for continuous outcomes (eg, composite risk scores), logistic regression was used for binary outcomes

Table 4
Most common poor sleep health profiles for 1, 2, and 3 “poor” sleep dimensions

Most common poor sleep health profiles	n	%
One “poor” sleep dimension		
Duration	27	15.40
Satisfaction	10	5.70
Two “poor” sleep dimensions		
Alertness + duration	8	4.60
Satisfaction + duration	7	4.00
Three “poor” sleep dimensions		
Satisfaction + alertness + duration	13	7.40
Regularity + satisfaction + duration	4	4.49

Table 5
Association between Sleep Health Composite and primary outcomes of the RCT measured at pretreatment baseline

Sleep Health Composite (predictor)	b	SE	p	95% CI
Youth self-report composite risk score (outcome)				
Emotional domain ^a				
Children's Depression Rating Scale	-1.44	0.55	.01	-2.52, -0.36
Multidimensional Anxiety Scale for Children	-3.04	0.99	.003	-5.01, -1.08
Cognitive domain ^a				
Attention Control Scale	0.39	0.45	.39	-0.50, 1.29
YSAS: school/cognitive	-0.49	0.16	.003	-0.81, -0.16
Behavioral domain ^a				
Sensation Seeking Scale	-0.43	0.35	.22	-1.12, 0.26
Alcohol and substance use	-0.12	0.07	.08	-0.25, 0.17
Social domain ^a				
YSAS: friends	-0.62	0.27	.02	-1.17, -0.08
YSAS: family	-0.67	0.20	.001	-1.07, -0.27
YSAS: romantic	0.22	0.10	.04	0.01, 0.43
Physical domain ^a				
Modifiable Activity Questionnaire	-0.04	0.09	.63	-0.21, 0.13
Physical Health Questionnaire	-0.76	0.29	.01	-1.34, -0.19

All models controlled for age and sex. All variables, except for Attention Control Scale and Modifiable Activity Questionnaire, were coded such that higher score indicates greater risk/worse outcome. A value of 0 in the risk composite score indicates the average level of "risk" in that health domain in this sample. YSAS, Youth Social Adjustment Scale.

^a Composite scores derived by obtaining the mean of the standardized scores of all measures within each domain. Higher composite risk scores indicate greater risk in that health domain.

(eg, K-SADS variables, BMI categories), and negative binomial regression was used for count data (alcohol and substance use, modifiable activity questionnaire). Because of the significant developmental changes as well as documented sex differences during adolescents in terms of sleep, chronotype, and health, we adjusted for sex and age in all models. A significance level of .05 was used throughout.

Results

Aim 1

Table 3 shows the descriptive statistics of the Sleep Health Composite in the current sample; higher scores indicate better sleep health. The average Sleep Health Composite was 3.66 at

pretreatment, suggesting that adolescents had good sleep health in fewer than 4 of the 6 dimensions. Duration and satisfaction were the dimensions most commonly rated as poor in this sample. Table 4 shows the most common poor sleep profiles in the current sample. Poor duration (while being good on other sleep health dimensions) was the most common poor sleep profile (15.4%).

Aim 2

Better sleep health, as indexed by a higher Sleep Health Composite, was associated with reduced risk in the emotional ($b = -0.19, p < .001$), cognitive ($b = -0.13, p = .01$), and social domains ($b = -0.09, p = .04$) (Table 5). The regression coefficients for behavioral ($b = -0.07, p = .20$) and physical domains ($b = -0.08, p = .11$) were in the expected direction, though not statistically significant. For specific measures under the 5 health domains, better sleep health was associated with lower depressive ($b = -1.44, p = .01$) and anxiety ($b = -3.04, p = .003$) symptoms, lower cognitive problems ($b = -0.49, p = .003$), fewer social problems related to friends ($b = -0.62, p = .02$) and family ($b = -0.67, p = .001$), and fewer physical symptoms ($b = -0.76, p = .01$). Better sleep health was associated with more social problems related to romantic relationship ($b = 0.22, p = .04$). Regression coefficients for the covariates (age and sex) in these models are reported in Supplemental Table S2.

Figure 1 presents the means of the 5 health composite risk scores in relation to Sleep Health Composite scores; participants with higher Sleep Health Composite score had lower health composite risk scores. Figure 2 illustrates the associations between sleep health and risk in the 5 health domains.

Aim 3

Table 3 presents the descriptive statistics for BMI, past-year medical problems, and K-SADS psychiatric disorder diagnostic categories (mood, anxiety, and behavior disorders). As presented in Table 6, better sleep health, as indexed by a higher Sleep Health Composite score, was significantly associated with decreased odds for obesity (odds ratio [OR] = 0.60, $p = .03$) but was not associated with overweight, underweight, normal weight, or continuous BMI. Sleep health was not associated with any past-year medical problem (diabetes, infections, hypertension, high cholesterol, and injury/accidents) per parent report.

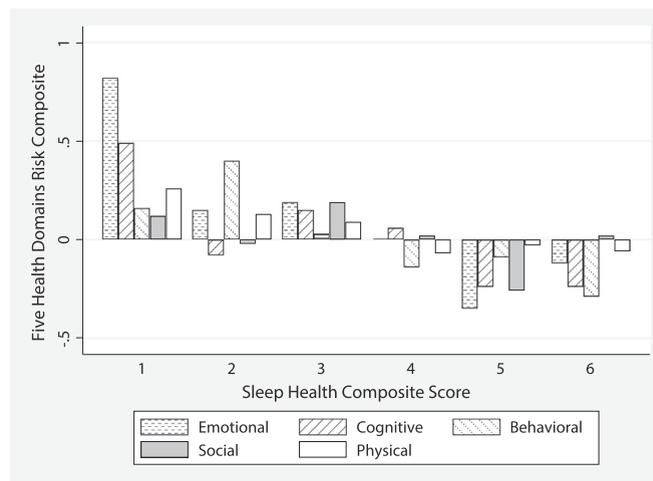


Fig. 1. Means of the five health risk domains over the Sleep Health Composite Score. Positive and larger values for the 5 health risk domains composite scores indicate greater risk; negative and smaller values indicate lower risk. Sleep Health Composite Score = 0 was not plotted because there were only 3 observations.

Better sleep health was significantly associated with reduced odds of having any current mood disorder ($OR = 0.65, p = .04$) and any current anxiety disorders ($OR = 0.63, p = .002$) per teenager interview. Better sleep health was not associated with any current behavior disorder per teenager interview or any K-SADS diagnostic classes per parent interview. Regression coefficients for the covariates (age and sex) in these models are reported in Supplemental Table S2.

Additional analyses

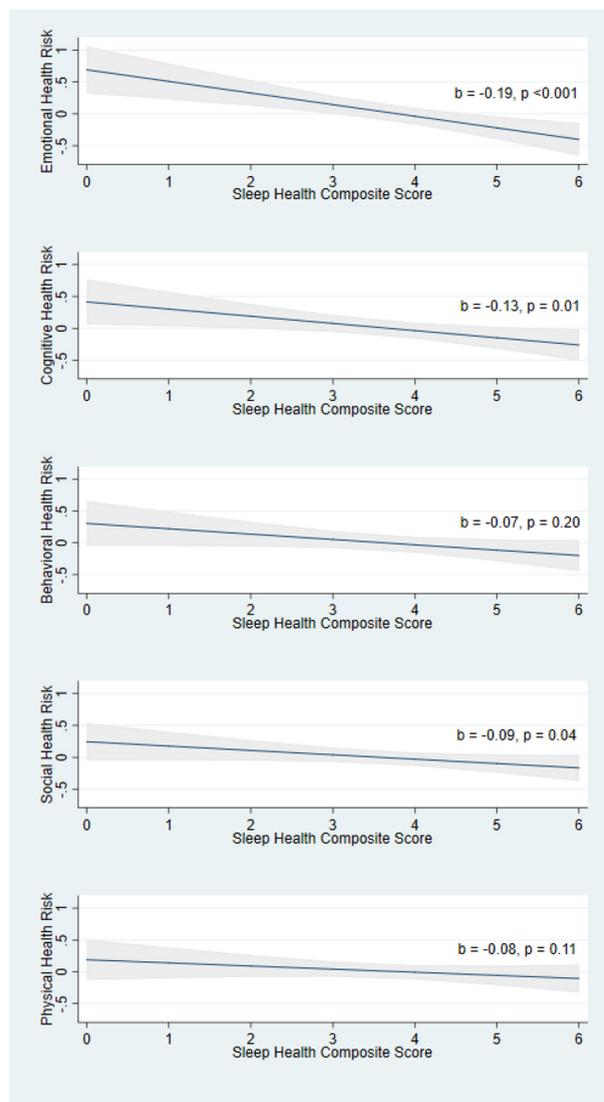
We conducted sensitivity analyses to examine whether applying different cut-offs for the Sleep Health Composite would change the results. Supplemental Tables S3 and S4 present these cut-offs and the distributions of resulting Sleep Health Composite scores. We repeated the analyses conducted for aims 2 and 3 using the alternative Sleep Health Composite and found similar results (Supplemental

Table S5), supporting the conclusion that the Sleep Health Composite is associated with mental and physical outcomes.

We also conducted additional analyses examining the associations between single dimensions of sleep health and mental/physical outcomes. Because of the relatively large number of sleep health dimensions and outcomes, we examined only composite risk scores in the 5 health domains that were significantly related to the Sleep Health Composite (ie, K-SADS diagnostic categories and obesity). Supplemental Table S6 suggests that the Sleep Health Composite was more consistently associated with outcomes of interest than single dimensions.

Discussion

The current study presents the preliminary derivation of a Sleep Health Composite based on the sleep health framework⁵ and examined whether the Sleep Health Composite was concurrently



Note. Graphs showing fitted regression lines with 95% CIs. Higher Sleep Health Composite Score indicates better sleep health. Positive and larger health risk composite score indicates greater risk in that domain; negative and smaller health risk composite score indicates lower risk in that domain.

Fig. 2. Negative associations between Sleep Health Composite and 5 health risk domains. Graphs show fitted regression lines with 95% confidence intervals. Higher Sleep Health Composite Score indicates better sleep health. Positive and larger health risk composite score indicates greater risk in that domain; negative and smaller health risk composite score indicates lower risk in that domain.

Table 6
Association between Sleep Health Composite and psychiatric and medical conditions

Sleep Health Composite	<i>b</i>	<i>SE</i>	<i>p</i>	95% CI
BMI (continuous)	−0.51	0.26	.05	−1.03, 0.01
	<i>OR</i>	<i>SE</i>	<i>p</i>	95% CI
Obese (BMI ≥30)	0.60	0.14	.03	0.37, 0.96
Overweight (BMI ≥25)	0.97	0.15	.87	0.72, 1.32
Underweight (BMI < 18.5)	1.15	0.18	.37	0.85, 1.55
Normal weight (BMI 18.5–24.99)	1.02	0.12	.89	0.81, 1.27
Medical problem (past year)	1.15	0.16	.33	0.87, 1.51
K-SADS diagnostic classes				
Any current mood disorder (T)	0.65	0.14	.04	0.43, 0.98
Any current mood disorder (P)	0.93	0.19	.71	0.62, 1.38
Any current anxiety disorder (T)	0.63	0.09	.002	0.47, 0.84
Any current anxiety disorder (P)	0.98	0.17	.89	0.69, 1.38
Any current behavior disorder (T)	0.76	0.14	.14	0.61, 1.30
Any current behavior disorder (P)	1.07	0.22	.74	0.65, 1.47

All models controlled for sex and age. BMI was adjusted for age and sex. Medical problem = presence of any following medical conditions in the past year per parent report: diabetes, infections, hypertension, high cholesterol, and injury/accidents. Current episode includes those that were probable, in partial remission, and definite. Any current mood disorder includes major depressive disorder, dysthymia, bipolar I, bipolar II, and bipolar not otherwise specified. Any current anxiety disorder includes agoraphobia, generalized anxiety disorder, social phobia, specific phobia, panic disorder, posttraumatic stress disorder, and acute stress disorder. Any current behavior disorder includes ADHD, oppositional defiant disorder, conduct disorder, and substance use disorders (alcohol abuse/dependence and drug abuse dependence).

associated with functioning in sleep, circadian, and physical and mental health domains in a sample of adolescents who exhibited late bedtime and evening circadian chronotype and were at risk in at least 1 of 5 health domains. This Sleep Health Composite was associated with elevated risk in multiple health domains in adolescents with eveningness chronotype.

Most participants scored “good” on only 3 or 4 sleep health dimensions. Sleep duration and sleep satisfaction were most frequently rated as “poor,” but no single problem, or combination of problems, accounted for large percentages of the poor sleep health profiles. This heterogeneity suggests a strength of the multidimensional Sleep Health Composite approach. We found a paucity of literature on what constitutes “good” sleep health for adolescents, particularly for the regularity and timing dimensions. We consulted the distributions of these dimensions in normative adolescent samples, but such samples are unlikely to constitute an ideal index of optimal adolescent health. Given the prevalence of eveningness in adolescents, future research should examine specific parameters that define good sleep health in this population.

As predicted, better Sleep Health Composite scores were associated with less risk in the emotional, cognitive, and social health domains. Similar but statistically nonsignificant trends were observed in behavioral and physical health domains. Additionally, better sleep health was associated with reduced odds of obesity and having any current mood or anxiety disorder per clinical interview with the adolescent. These results are consistent with prior research suggesting associations between individual sleep health dimensions and health domains, including physical health such as obesity⁹ and general health,^{30,31} as well as mental health such as depression and anxiety.^{32,33} Two other recent studies have examined the association between multivariate measures of sleep based on the sleep health framework in the context of depression⁶ and mortality⁷ among large, older adult populations. Together, these results provide additional evidence for the sleep health framework.

Some of the observed relationships have uncertain significance. For instance, better sleep health was associated with more problems in romantic relationships. In addition, although we found that higher

Sleep Health Composite was associated with fewer self-reported physical symptoms, we did not find a relationship between the Sleep Health Composite and relevant past-year medical problems. This lack of association could be attributed to measurement problems such as low base rates of these disorders or to the use of retrospective parent reports.

The current analyses have several limitations. First, the sample was not a representative sample of community-dwelling, healthy adolescents. As such, results cannot be generalized to healthy adolescents, to other age groups (eg, adults), or to clinical populations such as those with other sleep disorders (eg, obstructive sleep apnea). However, the unique features of the current sample may serve as a first step to gauge the potential utility of the Sleep Health Composite. A more thorough psychometric study should evaluate the reliability and validity indices of the Sleep Health Composite score using large representative samples of healthy adolescents as well as other clinical and nonclinical samples. Second, the sleep health framework was not proposed specifically for adolescents. It is possible that the dimensions most important for sleep health in adolescents may be different from adults. A related limitation is that, in the current study, each dimension was given equal weight in the construction of the Sleep Health Composite score. Different dimensions may warrant different weights in adolescent or adult samples, or other specific populations. Third, the construction of the 6 sleep health dimensions relied on sleep diary and self-report rating scales. Future studies should use objective measures of sleep such as actigraphy, as was done in Wallace et al (2017). Nevertheless, sleep diary is considered the gold standard for measuring subjective sleep and is widely used in clinical practice,^{4,14} presumably making the derivation of Sleep Health Composite more deployable in clinical settings.

The current study only provides a proof-of-concept example of the utility of a Sleep Health Composite using the baseline data of an intervention study. Future research may consider using a similar approach as offered here to derive a Sleep Health Composite in other populations and contexts. Additional methods include using the simple self-report scale “RU SATED,” which is designed to assess the construct of sleep health.⁵ The current study focused on the linear relationship between the Sleep Health Composite score and health outcomes. Future research should examine the contribution of each sleep health dimension on health outcomes and test for both linear and nonlinear effects between specific dimensions of sleep health and health outcomes. Future research should also examine potential age effects on the multidimensional construct of sleep health both within adolescence and across even broader age ranges. Finally, we tested cut-off values for each sleep health dimension that were based on values and recommendations from previously published literature. However, other strategies, such as receiver operating characteristic analyses, could be used to empirically define these cut points in subsequent, larger studies.

To summarize, the current study documents a process for constructing a Sleep Health Composite in a sample of community-residing adolescents with evening circadian chronotype and at risk in 1 of the 5 health domains. The derivation of a multidimensional Sleep Health Composite has potential research and clinical application as an outcome measure in treatment studies of sleep and circadian problems. Finally, these results support sleep health as an important correlate of physical and mental health in adolescents.

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Appendix A. Inclusion criteria operationalizing “at risk” for the 5 health domains (from Harvey et al¹⁰)

Risk domain	Criteria for Inclusion
Emotional	≥ 4 on any of the following items on the CDRS: difficulty having fun, social withdrawal, irritability, depressed feelings, excessive weeping, or a T-score of 61 or above on the MASC-10, based on age group (10–11 y, 12–15 y, 16–19 y) using the MASC-10 Profile
Behavioral	An SSS score greater than 3.93 for males aged 10–13, greater than 3.19 for females aged 10–13, greater than 4.07 for males aged 14–18, or greater than 3.19 for females aged 14–18 or taking ADHD medication or the K-SADS indicating a diagnosis of ADHD or current alcohol or substance abuse assessed with the K-SADS
Social	A parent rating their child as “worse” than others the participants age on 1 or more of the social behavior items (Section VI) from the CBCL
Cognitive	A parent rating their child as “failing” in 1 or more academic class from CBCL Section VII
Physical	A score of 4 or above on the PHQ-15, 6 or more days of school absences, or a BMI above the 85th percentile for the participant’s sex and age

CDRS, Child Depression Rating Scale³⁴ (the cut-off is commensurate with “clinical symptoms”); MASC-10, Multidimensional Anxiety Scale for Children (the cut-off T-score was selected to capture the “slightly elevated” through to the “very elevated” range)³⁵; SSS, Sensation Seeking Scale³⁶ (the cut-off corresponds to at or above 1 SD over the normative average)³⁷; CBCL, Child Behavior Checklist³⁸ (which asks the parent if their child does “worse,” “average,” or “better” than other teens their age or if the teen is “failing,” “below average,” “average,” or “above average”); PHQ-15, Physical Health Questionnaire-15 (the cut-off corresponds to “minimal somatic symptom severity” through to the “high somatic symptom severity” range).³⁹ The cut-off for BMI corresponds to 1 SD above the mean.

Appendix B. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.sleh.2018.11.009>.

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