



Interactions between sleep duration and quality as predictors of adolescents' adjustment



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ABSTRACT

Objectives: We examined interactions between adolescents' sleep duration and quality as predictors of their internalizing symptoms and externalizing behaviors. As a secondary aim, we assessed adolescent sex, race/ethnicity, and socioeconomic status (SES) as additional moderators of risk (ie, 3-way interactions among sleep duration; quality; and sex, race, or SES).

Design: The study used a cross-sectional design.

Setting: Participants were from small towns and semirural communities in Alabama.

Participants: The sample consisted of 235 adolescents ($M_{\text{age}} = 15.78$ years, $SD = 9.60$ months) and was diverse with respect to sex (54% female), race/ethnicity (32% Black/African American, 67% White), and SES. **Measurements:** Sleep duration (actual sleep minutes) was examined with actigraphs for 1 week. Adolescents reported on their subjective sleep quality, internalizing symptoms, and externalizing behavior with psychometrically sound measures.

Results: Findings revealed interactions between sleep duration and sleep quality as predictors of adolescents' adjustment. Adolescents with both short sleep duration in conjunction with poor sleep quality had the highest levels of internalizing symptoms and aggressive and rule-breaking behavior. SES interacted with sleep duration and sleep quality to predict rule-breaking behavior, and the highest level of problems was observed for adolescents from lower-SES homes who had short sleep duration accompanied by poor sleep quality.

Conclusions: Findings identify the conjoint role of sleep duration and quality as predictors of adolescents' socioemotional adjustment and emphasize the importance of examining multiple sleep parameters simultaneously toward a better understanding of adaptation in adolescence.

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Insufficient and poor-quality sleep is highly prevalent in adolescents.¹ A rapidly expanding body of work has documented relations between short sleep duration and internalizing and externalizing problems in youth.^{2–4} Likewise, an increasing number of studies and literature reviews have reported that poor subjective sleep quality is associated with emotional and behavioral problems including aggression and rule-breaking behavior.^{5–7} Investigations of the shared influence of sleep duration and sleep quality as predictors of adaptation and maladaptation in adolescence are scarce,^{8,9} and their consideration may bolster understanding in this flourishing area of inquiry. In particular, investigations of interactions between the 2 sleep parameters may help pinpoint the conditions under

which sleep problems may be especially detrimental. In this study, we assessed such a moderation model and aimed to identify whether the association between sleep duration and adolescents' adjustment is dependent on a second sleep parameter, namely, quality.

In the sleep literature at large, there are a number of studies that have assessed the combined influence of sleep duration and sleep quality. However, the vast majority of these investigations have examined physical health (eg, hypertension, blood glucose) in adults.^{10,11} Very few studies have examined interactions between sleep duration and quality as predictors of any adjustment domain in adolescence, yet such assessments are critical given that sleep problems are especially pronounced during this life stage.¹ Indicative of the potential significance of such assessments, there is some evidence of moderation effects showing that sleep quality problems influence the extent to which short sleep duration confers risk for adjustment problems in youth. For example, the highest level of

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aggression in a sample of Dutch youth was found for those with short self-reported time in bed accompanied by poor subjective sleep quality; sex-related comparisons revealed that the effects were somewhat more pronounced for boys.⁸ Furthermore, in a study of Australian adolescents and adults, poor subjective sleep quality was a robust predictor of emotional and social functioning problems for individuals with both short and long self-reported sleep duration.⁹ These initial findings buttress the proposition that different sleep parameters may interact to influence developmental outcomes.

We examined self-reported sleep quality as a moderator of relations between sleep duration and both internalizing symptoms (eg, depression, anxiety) and externalizing problems (aggression, rule-breaking). Sleep duration (minutes) was derived with actigraphy, which estimates actual time spent asleep across multiple consecutive nights.¹² Sleep quality was examined with a well-established instrument (School Sleep Habits Survey¹³) that assesses broad aspects of sleep/wake behavior in adolescence including erratic sleep, staying up very late, problems with going to sleep, staying asleep, and waking up in the morning, as well as satisfaction with one's sleep. Children's and adolescents' reports on this scale have been associated with emotional problems, aggression, risk-taking behavior, and substance use.^{4,6,14} Our reference to sleep problems in this article reflects either short sleep duration and/or poor sleep quality examined along a continuum and not categorization into groups. "Short" sleep and "poor-quality" sleep are used relative to the sample. The assessment of variables along a continuum allows for capitalizing on the full variability in the measures that may otherwise be lost by categorizing scores.¹⁵

Consistent with dual- and cumulative-risk propositions,^{16,17} we expected that adolescents with short sleep duration along with poor sleep quality would be most at risk for internalizing symptoms and externalizing problems. Because sleep duration and quality have been associated with both internalizing symptoms and externalizing behaviors,⁴ we had no differential hypotheses regarding the effects of sleep on these adjustment domains. Although findings are not uniform across all studies, differences in sleep duration and quality have been observed based on youths' sex,^{8,18} race/ethnicity, and socioeconomic status (SES).^{19–22} Thus, toward further elucidation of the role of sleep for adolescents' adjustment, we conducted 3-way interactions and explored whether the moderation effects involving sleep duration and quality were qualified by sex, race/ethnicity (White, Black/African American), and SES. We had no well-founded directional hypotheses regarding the 3-way interaction effects, and thus, these analyses were considered exploratory.

Methods

Participants

Participants were recruited from semirural areas and small towns in Alabama as part of the larger Family Stress Study, which examines children's health and adjustment in the context of family functioning and bioregulation. The current investigation used data collected in 2012–2013 during the fourth wave of the study when participants were in high school, ages 14–18 ($M = 15.78$ years, $SD = 9.60$ months). Actigraphic sleep assessments were not obtained at earlier time points. A total of 251 children from 2-parent families had been recruited at the first wave in 2005 via letters distributed to children and their parents through local elementary schools. To increase sample size, an additional 53 participants were recruited at the fourth wave using the same enrollment strategies as those of the original cohort. At recruitment, inclusion criteria required parents to have been married or cohabitating for at least 2 years. Exclusion criteria comprised a diagnosis of a sleep disorder,

attention deficit/hyperactivity disorder, chronic illness, or an intellectual disability based on mothers' reports.

Of 304 participants, 77% provided sleep assessments and therefore were included in the analytic sample for the present study ($N = 235$ adolescents). These participants were diverse with respect to sex (54% female), race/ethnicity (32% Black/African American; 67% White), and income (44% living at or below the federal poverty line, 22% were middle class, and 34% were upper middle class).

Procedure

Approval was obtained from the university's Institutional Review Board, and all parents and adolescents provided written consent and assent. Adolescents wore actigraphs at home for 1 week during the school year excluding holidays. At an average of 3.53 ($SD = 11.02$) days after the last night of sleep data collection, adolescents visited a laboratory on campus to complete questionnaires and to provide measurements of body mass index (BMI). Participants were given privacy away from parents and other participants while completing questionnaires; research assistants entered the rooms periodically to inquire whether participants had questions.

Measures

Sleep duration and quality

The actigraphs were Octagonal Basic Motionloggers and, following standard protocol, were worn on the nondominant wrist (Ambulatory Monitoring, Ardsley, NY). Sadeh's scoring algorithm²³ was used to estimate *sleep minutes* between sleep onset time and wake time in 1-minute epochs using zero crossing mode. Sleep minutes were averaged across all available nights, excluding nights of medication use, and were stable over the week of assessment ($\alpha = .75$). Sleep data were treated as missing for 18% of participants ($n = 42$) who had fewer than 5 nights of data; these individuals were still retained for all analyses.²⁴ Adolescents had missing data for reasons such as forgetting to wear the actigraph or using medication before bed.

Sleep quality was assessed using adolescents' reports on the sleep/wake problems scale (10 items; $\alpha = .77$) of the School Sleep Habits Survey.¹³ Items measured the frequency of erratic sleep behaviors including staying up very late, difficulty sleeping and waking up in the morning, and falling asleep in class, with item responses varying from 1 ("Never") to 5 ("Everyday"). Summed scores were used in analyses such that the full possible range was 10 (no sleep/wake problems) to 50 (sleep/wake problems on a daily or nightly basis).

Adjustment

Adolescents reported on their adjustment over the previous 6 months using the well-established Youth Self-Report internalizing symptoms ($\alpha = .92$), aggressive behavior ($\alpha = .88$), and rule-breaking behavior ($\alpha = .83$) scales.²⁵ Given the increasing distinction between aggressive and rule-breaking behavior in adolescence, these variables were examined separately. The internalizing score encompasses 31 depressive, anxiety, and related somatic symptoms. The aggressive behavior scale includes 17 items such as excessive arguing, use of threats, and property destruction. The rule-breaking scale comprises 15 items that survey risk-taking behaviors, theft and alcohol, tobacco, and illicit substance use. In parts of this article, aggressive and rule-breaking behaviors are referred to collectively as externalizing problems when no distinction is needed. Per common practice, *T* scores, which are normed for age and sex with a range of 100, were used in the analysis.

Control variables

During the laboratory visit, mothers reported on the adolescents' age, sex, and ethnicity. Adolescents' BMI was calculated from weight

and height recorded on a Tanita digital weight scale (Model BC-418) and wall-mounted stadiometer (Arlington Heights, IL) and computed into a standardized score (zBMI) using a SAS program developed by the Centers for Disease Control and Prevention.²⁶ Mothers also reported annual family income, which was used to calculate the family's income-to-needs ratio as a measure of SES (US Department of Commerce, 2013).²⁷ Representing the ratio between the family's income and the poverty threshold taking into account household size, scores <2 indicate that participants are living at or below the federal poverty line, scores between 2 and 3 signify middle class, and scores >3 denote upper middle class.

Plan of analysis

To reduce outlier effects, values that exceeded 4 SDs were recoded to the highest or lowest values within 4 SDs.²⁸ None of the primary study variables were skewed. A series of path models was fit in AMOS 23,²⁹ and full-information maximum likelihood was used to handle missing data; this approach uses all available data to produce the least biased estimates and fewest type I errors.³⁰ Rates of missing data among primary study variables were relatively low (sleep minutes [18%], sleep/wake problems [4%], and adjustment variables [8%]). The amount of missingness is within the acceptable range for full-information maximum likelihood.³⁰

Internalizing symptoms, aggressive behavior, and rule-breaking behaviors were examined in separate models. For conservative analyses, covariates (age, sex, race/ethnicity, SES, zBMI) were included in the models along with the sleep minutes and sleep quality variables to examine their associations with adolescents' adjustment. Two-way interactions (sleep duration × quality) and 3-way interactions (involving sex, race/ethnicity, and SES) were added to the models. Exogenous variables that were significantly related were allowed to covary. In addition, $\Delta\chi^2$ tests were used to determine whether removing the interaction effect significantly weakened model fit; this approach provides additional support for the inclusion of an interaction term in the model. Significant interactions were plotted at high (+1 SD) and low (−1 SD) levels of sleep minutes and sleep quality using the interaction utility of Preacher et al (2006).³¹ Models were considered a good fit to the data if they had a nonsignificant χ^2 , root mean square error of approximation <.08, and comparative fit index >.90.³² In this article, we use *predict* in the statistical and not causal sense. In initial analyses, we examined actigraphy-based sleep efficiency (% of the night scored asleep) and long wake episodes (frequency of wake episodes >5 minutes each)

as other markers of sleep quality. However, sleep minutes did not interact with either sleep parameter in the prediction of internalizing symptoms or externalizing problems (see Supplementary Tables 1 and 2). To streamline the article, these sleep variables were not considered further. In addition, the large majority of studies conducted in the field use self-reported sleep duration. Thus, although not a focus on our study, we conducted analyses with this variable and report a summary of findings in Supplementary Table 3 and Fig. 1.

Results

Preliminary analysis

Table 1 includes descriptive statistics and correlations among study variables. Independent-samples *t* tests indicated sex and race differences for sleep minutes. Specifically, girls (*M* = 418.8 minutes, *SD* = 53.4) slept longer than boys (*M* = 391.9 minutes, *SD* = 53.2), and White adolescents (*M* = 413.5 minutes, *SD* = 50.2) slept longer than their African American counterparts (*M* = 387.9 minutes, *SD* = 61.9). A small percentage of participants endorsed internalizing (20%), aggressive (11%), and rule-breaking (7%) symptoms and behavior at clinical or borderline-clinical levels (*T* score ≥ 60 for internalizing and ≥ 65 for aggressive and rule-breaking behavior). Bivariate correlations revealed that sleep quality problems were associated with internalizing symptoms and aggressive and rule-breaking behavior. Results of *t* tests indicated that the analytic sample was demographically representative of the full recruitment sample (ie, there were no significant differences) and that the individuals whose sleep data were excluded did not differ on demographic or main study variables from the full analytic sample.

Path models

Internalizing symptoms

The path model that examined interactions between sleep minutes and sleep quality was a good fit to the data ($\chi^2 [22] = 18.43$, *P* = .68, root mean square error of approximation [RMSEA] = .00, 95% confidence interval [CI] 0-.04, comparative fit index [CFI] = 1.00) and accounted for 12% of the variance in internalizing symptoms. After accounting for covariates, short sleep duration and poor sleep quality were significantly associated with higher levels of internalizing symptoms (Table 2).

Supportive of moderation effects, there was a significant interaction between sleep minutes and sleep quality in the prediction of

Table 1
Descriptive statistics and correlations among study variables

	1	2	3	4	5	6	7	8	9	10
1. Age	–									
2. Sex	.22***	–								
3. Race/ethnicity	–.08	–.05	–							
4. Income-to-needs	–.03	–.01	–.26***	–						
5. zBMI	–.01	–.02	.14*	–.09	–					
6. Sleep minutes	–.09	–.25***	–.21**	.16*	–.03	–				
7. Sleep quality problems	.01	–.04	.10	–.11	.03	–.09	–			
8. Internalizing symptoms	.02	–.04	.04	–.10	–.10	–.13	.23***	–		
9. Aggressive behavior	.08	–.06	.00	–.09	–.07	.00	.30***	.57***	–	
10. Rule-breaking behavior	.16*	.06	–.05	–.06	–.08	–.14	.28***	.44***	.73***	–
Mean	15.78	–	–	2.39	.87	406.37	19.78	50.39	54.80	54.22
(SD)	(0.80)	–	–	(1.31)	(0.99)	(54.84)	(6.56)	(11.34)	(7.32)	(5.92)
Range	14.2–18.4			.14–6.7	–2.3 – 2.8	239.4–543.1	10.0–46.0	27–99	50–86.2	50–81.4

Age reported in years but was coded in months for analyses; sex (0 = girl; 1 = boy); race (0 = White; 1 = Black); zBMI = standardized body mass index score; internalizing, aggressive, and rule-breaking behaviors are represented in *T* scores; 406.37 minutes = 6.77 hours.

* *P* < .05.
 ** *P* < .01.
 *** *P* < .001.

Table 2

Unstandardized and standardized coefficients of associations linking sleep quantity, sleep quality, and adjustment in adolescents

Predictor	Internalizing symptoms			Aggressive behavior			Rule-breaking behavior		
	B	SE	β	B	SE	β	B	SE	β
Age	0.01	0.08	.01	0.06	0.05	.08	0.07~	0.04	.12
Sex	-1.56	1.55	-.07	-1.51	0.97	-.10	0.03	0.78	.003
Race/ethnicity	-0.43	1.66	-.02	-0.41	1.04	-.03	-0.90	0.85	-.07
Income-to-needs	-0.59	0.59	-.07	-0.43	0.36	-.08	-0.13	0.30	-.03
zBMI	-1.27~	0.75	-.11	-0.56	0.46	-.08	-0.41	0.37	-.07
Sleep minutes	-0.03*	0.02	-.16	-0.02~	0.01	-.16	-0.02~	0.01	-.14
Sleep quality problems	0.35**	0.11	.20	0.27**	0.09	.24	0.21***	0.06	.24
Minutes \times quality	-0.01**	0.002	-.19	-0.01***	0.002	-.32	-0.003*	0.001	-.16

Path models controlled for age, sex, race/ethnicity, income-to-needs, and zBMI. Path coefficients reported are from the final model. Sex (0 = girl; 1 = boy); race (0 = White; 1 = Black).

~ $P < .10$.

* $P < .05$.

** $P < .01$.

*** $P < .001$.

internalizing symptoms (Table 2), which accounted for 4% of unique variance. $\Delta\chi^2$ tests indicated that the inclusion of the moderation effect significantly increased model fit, providing further support for its importance ($\Delta\chi^2 [1] = 5.86$).

The moderation pattern illustrates a negative association between sleep minutes and internalizing symptoms for adolescents with poor sleep quality (Fig. 1). Furthermore, adolescents with poor sleep quality had greater internalizing symptoms when they also had short ($M = 57.8$) in comparison to longer ($M = 49.0$) sleep, a difference of .77 SD (Fig. 1). In essence, youth with poor sleep quality in conjunction with short sleep duration appeared to be at greatest risk for internalizing symptoms. Furthermore, as indicated by a nonsignificant slope, adolescents with better sleep quality had lower predicted means for internalizing symptoms regardless of their sleep minutes. Calculation of the “regions of significance” indicated that relations between shorter sleep duration and greater internalizing symptoms were significant for those with a sleep quality score >15.69 ($n = 154$). No significant 3-way interactions with demographic characteristics in relation to internalizing symptoms emerged.

Aggressive behavior

The path model fit the data well ($\chi^2 [22] = 18.71, P = .66, RMSEA = .00, 95\% CI 0-.04, CFI = 1.00$) and accounted for 15% of the variance in aggressive behavior. After accounting for covariates, poor sleep quality was positively associated with aggressive behavior (Table 2); a similar association with sleep minutes approached

conventional levels of statistical significance. Furthermore, supportive of moderation, the 2 sleep variables interacted to predict aggressive behavior and accounted for 4% of unique variance. $\Delta\chi^2$ tests indicated that the addition of the moderation effect significantly increased model fit ($\Delta\chi^2 [1] = 7.58$).

Simple slopes analysis revealed a negative association between sleep minutes and aggressive behavior for adolescents with poor sleep quality (Fig. 2). For these adolescents, predicted means for aggressive behavior were 59.4 for those with short sleep and 55.5 for their counterparts with longer sleep, a difference of .53 SD. For youth with better sleep quality, a positive association between sleep minutes and aggressive behavior emerged. For these adolescents, predicted means for aggressive behavior were 51.8 for those with short sleep and 55.0 for those with long sleep duration, a difference of .43 SD. Thus, youth at most risk for aggressive behaviors were those with both short and poor-quality sleep. Testing of the “regions of significance” showed that the association between short sleep duration and more aggressive behavior was observed for those with a sleep quality score >19.71 ($n = 97$). No significant 3-way interaction involving the 3 demographic variables was found.

Rule-breaking behavior

The path model was a good fit to the data and accounted for 19% of the variance in rule-breaking behavior ($\chi^2 [43] = 38.71, P = .63, RMSEA = .00, 95\% CI 0-.02, CFI = 1.00$). After accounting for covariates, sleep quality problems were positively associated with rule-breaking behavior (Table 2); a similar association at the statistical trend level was observed for sleep minutes. In addition, a significant moderation effect between sleep minutes and sleep quality problems was observed but was qualified by a 3-way interaction with SES (Table 2), and thus, the former was not interpreted. The 3-way interaction accounted for 3% of the unique variance in rule-breaking behavior. $\Delta\chi^2$ tests indicated that the estimation of each of these interaction paths resulted in significant change in model fit ($\Delta\chi^2 [1] = 3.88$).

Graphing the 3-way interaction showed that, for low-SES adolescents with poor sleep quality, a pronounced negative association was observed between sleep minutes and rule-breaking behavior ($B = .003, SE = .001, P < .05$). At short sleep duration, adolescents with poor sleep quality had higher levels of rule-breaking behaviors ($M = 60.0$) than their counterparts with better sleep quality ($M = 50.9$), a difference of 1.53 SD (Fig. 3). For lower-SES adolescents with longer sleep duration, predicted means for rule-breaking behavior were similar at higher ($M = 53.8$) and lower ($M = 52.9$) levels of sleep quality (Fig. 3). Furthermore, for lower-SES adolescents with better sleep quality, a positive slope was found, indicating that those with short yet better quality sleep had the lowest levels of

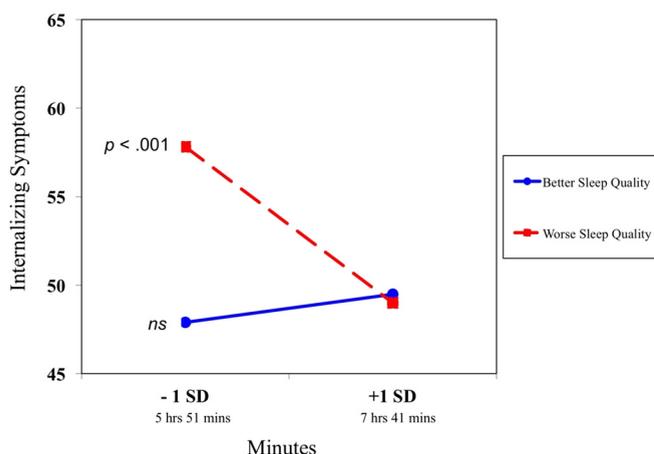


Fig. 1. Associations between sleep minutes and internalizing symptoms at higher and lower levels of sleep quality. Internalizing symptoms are represented in T scores.

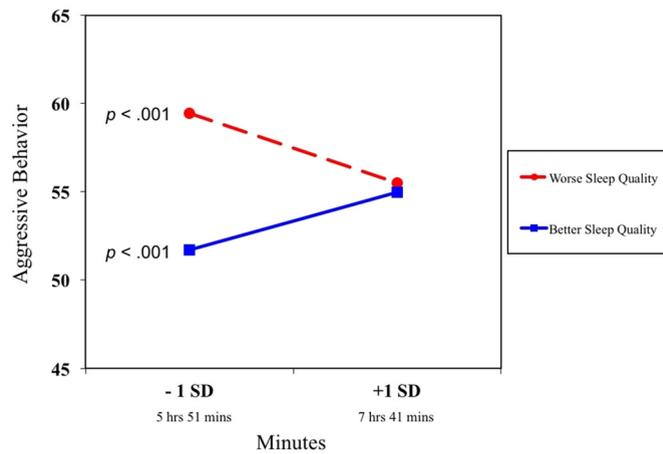


Fig. 2. Associations between sleep minutes and aggressive behavior at higher and lower levels of sleep quality. Aggressive behavior is represented in T scores.

rule-breaking behavior in the sample ($M = 50.74$). In addition, for higher-SES adolescents, slopes were not significantly different from zero, and they appear to have moderate levels of rule-breaking behavior regardless of their sleep duration or quality. Overall, all adolescents had similar levels of rule-breaking behavior when they had longer sleep independent of their SES or sleep quality. Furthermore, the negative effect of poor sleep quality on adolescents' rule-breaking behavior was especially evident for those with short sleep in conjunction with lower SES. Testing of the "regions of significance" indicated that the association between short sleep duration and more rule-breaking behavior was significant for lower-SES youth with a sleep quality score >16.63 ($n = 22$). No significant 3-way interaction involving rule-breaking behavior was found for sex or race.

Discussion

Building on the expanding literature that is highlighting the importance of sleep duration and sleep quality for adolescents' adjustment, we examined interactions between the 2 sleep parameters as predictors of internalizing symptoms and externalizing problems. This moderation model addresses the question of whether the effects of one sleep variable on adolescents' adjustment are contingent upon

another sleep parameter. Novel moderation findings show that not all youth are at equal risk for adjustment problems when their sleep is either of short duration or of poor quality. Rather, effects associated with sleep duration are dependent on sleep quality and vice versa.

Consistent with expectations, sleep duration and self-reported sleep quality interacted, and adolescents with both short sleep accompanied by poor quality sleep were particularly at risk for internalizing symptoms and aggressive behavior. This pattern of effects is supportive of dual-risk propositions in which the presence of 2 risk factors may have more detrimental effects than either factor alone.¹⁷ Findings also illustrated that greater sleep quality protected against internalizing symptoms otherwise associated with short sleep. Similarly, adolescents with longer sleep were observed to have lower levels of internalizing symptoms independent of their sleep quality, indicating that longer sleep duration may help protect against the negative consequences of poor sleep quality. These results highlight the importance of contemporaneous assessments of multiple sleep parameters when examining their associations with adolescent's adjustment.

Findings are somewhat similar to those reported by Meijer and colleagues (2010) in that the highest level of aggression in their study was predicted for boys with short time in bed accompanied by poor sleep quality.⁸ Although our results and those reported by Lallukka and colleagues (2018) illustrate the joint contribution of sleep duration and quality for adjustment, their findings indicate that sleep quality has a more significant influence than sleep duration on participants' emotional functioning.⁹ There are many differences among the few existing studies (eg, sample characteristics, methodologies, constructs) that have investigated this moderation question, and until the number of such studies increase, it may not be prudent to attempt literature integration.

Our assessment of sleep quality also included actigraphy-derived sleep efficiency and long wake episodes, although neither served as a moderator of effects. Reasons for why subjective but not objective sleep quality interacted with sleep duration to predict adolescents' adjustment are not clear. Individuals likely differ in what constitutes "good" sleep, and such individual differences may underlie the differential effects observed for objective and subjective sleep quality. In other words, not all adolescents experiencing the same level of objective sleep quality (eg, efficiency) will perceive and report that their sleep is similarly restful or poor. In addition, the self-reported items measured multiple aspects of sleep quality including difficulty sleeping and waking up and satisfaction with one's sleep. Thus, reports on this scale may reflect a broader construct of sleep quality than the one indexed by actigraphy.

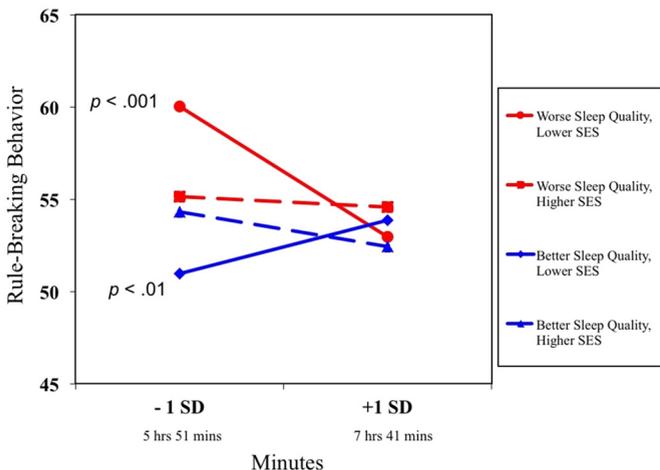


Fig. 3. Associations between SES, sleep minutes, and rule-breaking behavior at higher and lower levels of sleep quality. Rule-breaking behavior is represented in T scores.

For a more thorough assessment of research questions, 3-way interactions were examined to assess whether adolescent sex, race, and SES interacted with sleep duration and quality to predict adolescents' adjustment. Most of the tested 3-way interactions (8 out of 9) were null, and only 1 interaction involving SES emerged in relation to rule-breaking behavior. Thus, this interaction needs to be interpreted cautiously in its accurate context. Whereas higher-SES children tended to have moderate levels of rule-breaking behavior regardless of either their sleep duration or quality, lower-SES children were affected by both. The most pronounced finding was that for lower-SES children who had short sleep, their rule-breaking behavior was much higher when they had worse quality sleep. Poverty is a risk-laden environment that can exacerbate the effects of biological dysregulation including sleep problems on adolescents' adjustment. There are a growing number of studies documenting relations between SES and sleep in youth,²⁰ and a small number supporting SES as a moderator of risk that strengthens relations between sleep problems and multiple developmental difficulties.^{33,34} The present investigation adds to this literature by demonstrating that the conjoint influence of short and poor-quality sleep on adjustment problems is worsened for adolescents exposed to economic adversity.

Participants slept an average of 6.77 hours (actual sleep duration). Short sleep and long sleep (as indicated by a 1-SD difference from the mean) correspond to 5.86 and 7.69 hours. This sleep duration is far below the National Sleep Foundation's³⁵ recent recommendation of 8 to 10 hours of sleep per night for this age group. Note, however, that these recommendations are based on "time in bed" and not actual sleep duration as assessed in the current study. For sleep quality problems, the average score was 19.78, and ± 1 SD corresponds to scores of 26.34 and 13.22. Given that the possible range is 10–50 for the sleep quality measure, there was noticeable variability in sleep quality problems in the sample. As colleagues tackle this research question, it is vital to observe whether similar moderation effects exist in other samples with varying amounts of sleep duration (subjectively and objectively derived) and quality.

The findings carry important implications. Average sleep duration was far below national recommendations, and continued work to improve children's sleep is of critical importance. The interaction effects illustrate that efforts made to improve youths' development through sleep may have greater success by targeting both sleep duration and quality. Moreover, clinical efforts focused on reducing socioeconomic-related disparities in adolescents' development would likely benefit from focusing on the improvement of sleep health.

Confidence in the findings is strengthened by covarying potential confounds and thus conducting conservative analyses. Examining sleep duration using actigraphy is another positive feature of this study, which complements other methodologies particularly self-reported sleep in the majority of the relevant literature. The diverse sample in relation to adolescents' sex, race (White, Black/African American) and SES, with a high percentage of children living in poverty, is considered an asset in the context of the broader literature that relies heavily on middle-income, White youth. Nevertheless, features of this community sample dictate caution in generalizations to populations with varying characteristics. Furthermore, caution needs to be exercised when generalizing findings to other developmental stages. In addition, there was an unexpected positive slope between sleep duration and aggressive behavior for adolescents with better sleep quality, and we are not sure what to make of this finding. Furthermore, we examined one facet of family SES, namely, income-to-needs ratio. Although this provides a robust index of family resources, other SES indices, including those at the community level (eg, neighborhood disadvantage), would augment the assessment of this construct. There are many key sleep parameters that

we did not examine including night-to-night variability³⁶ and chronobiology.³⁷ As the literature on interactions between various sleep parameters expands, assessment of various sleep/wake domains is warranted.

Conflict of interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.sleh.2018.11.004>.

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