ORIGINAL ARTICLE

Parents still matter: the influence of parental enforcement of bedtime on adolescents' depressive symptoms

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Abstract

Study Objectives: The aim of the current study was to test a multilevel mediation model that examined how adolescent sleep duration might be linked to depressive symptoms via their daytime energy levels. Furthermore, the study examined how parents' enforcement of various types of bedtime rules predicted the duration of adolescent sleep.

Methods: A total of 193 adolescent (ages 14–17; M_{age} = 15.7 years old, SD = .94; 54.4% female; 71% Caucasian) and parent dyads completed baseline, online surveys, and adolescents also completed online 7-day, twice-daily (i.e. morning and evening) reports of their sleep duration (morning diary) and their energy levels and depressive symptoms throughout the day (evening diary). Parents (M_{age} = 47.6 years old, SD = 5.4; 80% female) completed assessments of enforcement of bedtime-related rules (i.e. bedtime, cessation of electronic media usage, prohibiting afternoon/evening caffeine consumption). Multilevel modeling enabled the testing of the mediation model both at the between-person level and within individuals.

Results: Results suggested that adolescents' energy levels mediated the association between adolescents' sleep duration and depressive symptoms. Furthermore, both greater enforcement of bedtimes and later school start times predicted longer sleep durations for adolescents, and were indirectly associated with adolescents' depressive symptoms.

Conclusions: These findings underscore the importance of adolescents obtaining sufficient sleep to support their mental health and suggest a critical point of intervention for preventing or decreasing insufficient sleep. Given the diverse threats to adolescents' sleep as well as adolescents' desire for greater independence, collaborative, autonomy-promoting bedtime limit-setting is recommended to support adolescents' well-being.

Statement of Significance

The majority of adolescents suffer from insufficient sleep, which results in extensive behavioral, psychological, and physical problems. This study builds on research that has examined the influence of parent-set bedtimes and other threats to adolescents' sleep and functioning. Using multilevel modeling to highlight processes through which adolescents' sleep duration might impact their well-being, we found that greater enforcement of parent-set bedtimes and later school start times were associated with longer sleep duration for adolescents. In turn, longer sleep duration predicted lower levels of depressive symptoms, via the mediating influence of adolescents' energy levels during the day. The findings provide an important avenue through which parents can intervene and defend against the myriad impediments to adolescents' sleep and mental health problems.

Adolescents' insufficient sleep remains a critical risk factor for the development of potential mental health problems [1–4]. Extensive research underscores the role that sleep plays in adolescent academic, behavioral, and psychosocial functioning [5–9], including clinical outcomes such as suicidal ideation [10, 11]. This epidemic of insufficient sleep experienced by most adolescents highlights the need for research to identify potential interventions for adolescent sleep problems [3, 6]. According to the National Sleep Foundation's 2014 Sleep in the Modern Family Poll, approximately 25% of parents of 15–17 year olds do not have any formal sleep-related rules [12]. Although parents' enforcement of rules related to bedtime, afternoon/evening caffeine intake, and prebedtime electronic media usage can yield up to approximately an additional hour of sleep per night on school nights, only 35% of parents of 15–17 year olds enforce such rules [12]. Given the functional consequences of adolescents' insufficient sleep [8], the current study sought to examine how day-to-day fluctuations in sleep duration might impact adolescents' mental well-being. Furthermore, given the limited research on parents' enforcement of sleep-related rule enforcement, we further tested how different parent-enforced rules might impact adolescents' sleep duration.

Threats to adolescent sleep

School start times

Considering the ecology of adolescent sleep, the diverse threats to adolescents obtaining sufficient sleep include early school start times, prebedtime media consumption, poor sleep hygiene, and chaotic family environments [7, 13–16]. Specifically, the influence of school start times has emerged over the past decade as a particularly salient feature of adolescents' sleep ecology [13, 14]. Although interventions, such as delaying school start times [17], have demonstrated sustained benefits to adolescents' sleep and their levels of alertness and well-being, only approximately 14% of high schools across America have moved their start times to the American Academy of Pediatricians' recommended start time of 8:30 a.m. or later [6, 18]. Thus, a large majority of adolescents struggle with the negative correlates of early school start times.

Challenging family contexts

Evidence also links chaotic households and parents' dysfunctional sleep-related beliefs as risk factors for the role that the family environment might play in adolescents' sleep and mental health problems [19, 20]. Furthermore, despite the relative effectiveness of sleep hygiene-focused interventions to increase adolescents' sleep duration and physical well-being [21], the use of these interventions remains limited, leaving a majority of adolescents to struggle with sleep problems unaided in any formal way. Taken together, these threats to adolescents' sleep potentially put a greater onus on parents to support their teenagers in getting sufficient sleep. The current study therefore sought to extend previous work by examining the more specific roles that parents can play in this process.

Parent rule-setting

Parent-set bedtimes

In terms of adolescents' psychosocial development, it is expected that parents' influence on their adolescents' behavior will diminish during the high school years, due in part to parents' decreased involvement in their children's sleep routines as they enter adolescence [14, 22]. However, this fact does not preclude the impact that parents and family environments have on adolescents' sleep [23, 24]. Multiple studies have suggested that bedtime-related rules serve to extend adolescents' sleep duration whereas not extending their sleep latency [25, 26]. For instance, Adam and colleagues demonstrated in a nationally representative sample that family rules related to activities (e.g. watching television, homework) were associated with longer sleep durations for older children (ages 12–19) [25]. They did not, however, specifically examine bedtime-related rules or their level of enforcement. Building on this work, in a cross-sectional study with a sample of 5–17 year olds, Pyper and colleagues found that both parents' encouragement as well as enforcement of bedtimes were associated with longer weekday sleep duration [26]. The study, however, was limited by its reliance on parent-reported sleep duration, which has been shown to overestimate children's sleep duration [27].

Extending this work on adolescents' longer sleep duration due to parental rule-setting, multiple studies have examined the consequences of insufficient sleep on both adolescents' mental health and daytime alertness [11, 27, 28]. In one of the first studies to specifically assess parent-set bedtimes on adolescents' sleep duration and symptoms of depression, Gangwisch and colleagues conducted in-home interviews and asked parents to respond to the question, "What times does {name} have to go to bed on weeknights?" [11] Despite demonstrating a significant and cross-sectional indirect association of parent-set bedtimes on adolescents' (ages 11–21) depressive symptoms via sleep duration, the specific question they used potentially introduced two sources of bias, due to parents wanting to provide a socially desirable response and to the implicit assumption that parents set a bedtime for their child [27]. Building on the Gangwisch and colleagues' study [11], Short and colleagues found that adolescents (ages 13–18) who reported a parent-set bedtime also reported longer improved daytime alertness and less daytime fatigue [27]. Despite the use of adolescents' self-reports for sleep duration and fatigue, this study did not assess parents' perspectives on rule enforcement due to concerns about social desirability. Furthermore, in relying upon adolescents' reports of the presence vs. absence of parent-set bedtimes, Short and colleagues were unable to assess the true level and consistency of their enforcement [27]. In addition to including multiple reporters (i.e. parents and adolescents) and by employing a novel sleep diary methodology to capitalize on the temporal aspects of measurement, the current study used a measure of parental bedtime-related rules that attempted to minimize response bias as it provided parents with a continuous scale of parents' levels of enforcement of these rules [29].

Other sleep-related rules

Other areas of potential parental intervention involve the overwhelming presence of electronic media (e.g. smartphones, televisions) in adolescents' bedrooms and adolescents' consumption of caffeinated beverages in the afternoon/evening. Given the negative influence of light emitted from electronic devices on the building of sleep pressure and preparing oneself for sleep [30], numerous studies have found that prebedtime electronic media is associated with later bedtimes [31, 32], shorter sleep duration [33], and increased daytime sleepiness [15].

Although there is some evidence suggesting that the negative influence of screens on sleep is negligible [30, 34], enforcing rules regarding the use of these electronic devices before bedtime can yield longer sleep duration for adolescents, with nightly gains ranging from 12 to 19 min for each school night they were enforced [29]. Research on adolescents' caffeine consumption suggests similar negative outcomes on adolescent sleep duration and functioning [35]. In this light, the current study extended previous work by examining if, as an alternative to enforcing bedtimes, parents could also support their adolescents' sleep and its influence on their mental health by either enforcing screen- or caffeine-related rules.

The costs of adolescents' insufficient sleep on mental health via daytime energy

One clear consequence of adolescents' insufficient sleep is their increased levels of sleepiness or daytime fatigue [4, 36–38]. Excessively sleepy adolescents are at greater risk of depressed mood as self-reported sleepiness has been shown to predict the onset and maintenance of depressive symptomatology [4, 5]. One potential mechanism through which adolescents' sleepiness might lead to depression includes being ill-equipped to handle stressful or frustrating situations [2]. In a study of 385 adolescents (ages 13–18), Short and colleagues demonstrated a significant cross-sectional association between daytime sleepiness and depressed mood; however, adolescents' sleep duration did not significantly predict levels of daytime sleepiness [4]. Short and colleagues suggested that this lack of association might be due to their sample's relatively restricted range of sleep quantity, but it also highlights the complexities of assessing such duration vis-à-vis adolescents' wide-ranging sleep needs [4]. The current study sought to extend this line of research by incorporating daily reports of adolescents' sleep duration, energy levels, and depressive symptoms. By assessing adolescents' sleep duration upon waking and their energy levels and depressive symptoms in the evening, the current study optimized the predictive nature of adolescents' sleep quantity on these critical outcomes.

The current study

Given the important role that parents and the larger family environment play in shaping adolescents' sleep and sleep habits [24, 26, 29, 39], the current study is an investigation of the potential impact of parents' enforcement of sleep-related rules on their adolescent's sleep duration. Furthermore, in order to extend the mediational analyses of Gangwisch and colleagues [11] and Short and colleagues [27], we chose to examine these associations through a short-term, longitudinal mediation model that could simultaneously measure the influence of parental rule enforcement on adolescents' sleep duration and the subsequent process through which sleep duration indirectly influences adolescents' depressive symptoms via their daily energy levels. To this end, we capitalized on a 7-day sleep diary study of 193 adolescents and their parents and incorporated recent methodological advances in the multilevel testing of mediation [40] that allowed us to control for between-person associations when examining the temporal links between our constructs within the diary data. Finally, to create a more ecologically valid

model, the models controlled for proximal factors related to adolescent sleep (i.e. school start times and parent–child bedtime related arguments). This design therefore allowed us to examine the following hypotheses: (1) parents' enforcement of sleep-related rules would predict longer sleep durations for adolescents controlling for school start times and parent–child arguments about bedtime; (2) longer sleep duration would predict higher levels of daytime energy; (3) higher energy levels would predict lower levels of depressive symptoms; and (4) parents' enforcement of sleep-related rules would indirectly predict adolescents' depressive symptoms via the mediating constructs of sleep duration and daily energy levels.

Method

Participants and recruitment

Participants were adolescent–parent dyads (*n* = 193), who were recruited through direct solicitation (e.g. receiving a study brochure following a brief presentation at school), emails to distribution lists (e.g. parenting groups), and through ResearchMatch, a national health volunteer registry that was created by several academic institutions and supported by the U.S. National Institutes of Health as part of the Clinical Translational Science Award program. ResearchMatch has a large population of volunteers who have consented to be contacted by researchers about health studies for which they may be eligible. In order to participate, adolescents had to be in 9–11th grades in either a public or private day school within the United States, between the ages of 14 and 17, living 7 days/week in the participating family's household, and both parent and child had to agree to participate. Families with adolescents with severe cognitive limitations (i.e. developmental disabilities) were excluded from the study.

A total of 193 adolescents (M_{age} = 15.7 years old, *SD* = .94; 54.4% female) completed the baseline and 7-day sleep diary surveys, and their parents (M_{age} = 47.6 years old, *SD* = 5.4; 80% female) provided data from the baseline survey on bedtime-related rule enforcement, frequency of arguments regarding bedtime, and school start times. The adolescents reported being in 9th (37%), 10th (32%), or 11th (31%) grade. The majority of adolescents and parents identified as Caucasian (71% and 79% respectively), with another 14% and 14% (respectively) identifying as African American, 8% and 2% (respectively) identifying as multiracial, 3% and 2% (respectively) identifying as Latino/a, 2% and 2% (respectively) identifying as Asian American, and 2% and 1% (respectively) identifying as "other." Parents had relatively high levels of education, with approximately 42% reporting a graduate degree, 35% with a BA/BS, 19% with some college or an associate degree, and 4% with a high-school diploma or GED or less. Mean income was $81 600 (*SD* = $27 800) with 17.6% of families reporting incomes below the poverty level (i.e. equal to or less than $45 000).

Procedure

The study was approved by the local Institutional Review Board and informed consent from parents and assent from adolescents was obtained prior to participation. The baseline survey took roughly 20–25 min to complete; respondents were compensated $10 each as an incentive. During the baseline survey,

parents and adolescents provided their own email addresses (to obtain a dyadic sample), and parents set a start date for their child to complete the 7-day sleep diary. After completing the baseline survey, adolescents were invited to complete an online 7-day daily sleep diary. In order to optimize the temporal spacing of sleep and daily mood reports, the sleep diary consisted of both a morning and an evening portion. The morning diary survey (e.g. sleep-related measures) was completed within an hour of waking up, and the evening diary survey (e.g. daily functioning and mood-related measures) was completed within an hour of going to sleep. Due to the use of online surveys for the diary, entries were time-stamped to verify that they were completed within the expected timeframe. Adolescent respondents received $15 for completing a minimum of four morning and evening diary entries, an entry to win a lottery prize (an iPad mini) for every diary entry completed, and brief feedback on their sleep (e.g. average bed/wake times based on the diary data they provided) following the conclusion of the data collection.

Attrition

On average, the parents and adolescents completed their baseline surveys 8.4 days (SD = 5.7) before the adolescent began the sleep diary. A total of 178 adolescents (92.2%) completed at least 4 days of the daily diaries, with adolescents completing on average approximately 11.7 diary entries out of a possible 14 (SD = 2.8). ANOVA and χ^2 analyses suggested that the respondents participating in the daily diaries did not differ from participants who only completed the baseline survey across all primary variables and demographic covariates.

Measures

Sleep-related rules (baseline)

To assess the level of rules related to bedtime and other sleep-related behaviors that parents enforced, parents completed a 6-item scale (adapted from Buxton and colleagues [12, 29]) during the baseline assessment. The scale was comprised of three domains of sleep-related rules for bedtime (1 item; "Which comes closest to describing rules your child may have to follow [regarding] the specific time he/she goes to bed?"), usage of electronic media (4 items; "Which comes closest to describing rules your child may have to follow [regarding how late your child can]": watch television, use smart/cellphone, use computer/tablet, play videogames), and consumption of caffeinated beverages in the afternoon/evening (1 item; "Which comes closest to describing rules your child may have to follow [regarding] drinking colas, coffee, or other sources of caffeine in the afternoon or evening?"). These items assessed the presence and level of enforcement of rules in the household and were rated on 4-point scales ("no formal rules" to "have rules, always enforced"). Responses were averaged across the 4 media-related items such that higher scores indicated higher levels of media rule enforcement ($\alpha_{\text{media rules}}$ = .86).

Parent–child bedtime conflict (baseline)

The level of disagreement about bedtime was reported by parents at baseline with a 1-item measure (i.e. "Thinking about the last month, how often have you and your high schooler disagreed about bedtimes?"). The item was rated on a 7-point response scale (0—"not at all in the last month" to 7—"more than once a day"), with higher scores indicating higher levels of disagreements regarding bedtime.

School start times (baseline)

Parents provided the start time for their child's school in the baseline survey.

Sleep duration (daily diary—morning)

Sleep duration was assessed in the morning diaries by calculating the daily differences between the time the child reported going to sleep and waking up the next morning, with both sleep latency (min) and wake-after-sleep-onset durations (min) having been subtracted from each night's time spent in bed.

#### Energy level (daily diary—evening)

Adolescents' self-reported levels of energy were assessed in the evening diaries with a 1-item measure ("indicate the number that best describes how much energy you had today") that was rated on a 5-point response scale (1—"no energy" to 5—"full of energy"). Higher scores indicated higher levels of energy.

Depressive symptoms (daily diary—evening)

To assess adolescents' levels of depressive symptoms, respondents self-reported on adapted versions of the Patient Health Questionnaire-2 in the evening portion of their diary [41]. This measure has demonstrated strong reliability and validity in adolescent samples [42]. Respondents reported how much they had been bothered by the following symptoms since waking up that morning ("little interest or pleasure in doing things," "feeling down, depressed, or hopeless.") The items were rated on 4-point response scales ("not at all" to "nearly all day"), summed so that higher scores indicated higher levels of depressive symptoms (α = .90).

Data analytic strategy

The repeated observations from the daily diaries represented multiple assessments nested within adolescents. To appropriately model the nested nature of the data, a multilevel SEM model (Mplus, Version 8) [43], using a mediational framework [40], was used. As depicted in our conceptual model (Figure 1), repeated assessments within individual adolescents across time (i.e. 7-day daily diary data) were modeled at level 1, and parent-reported data, which served as predictors of adolescent sleep duration, were modeled between families at level 2. Based on the best practices articulated by Preacher and colleagues [40], we employed a 1–1–1 mediational model that simultaneously included the three different domains of parents' sleep-related rule enforcement (bedtime, screentime, caffeine consumption) as predictors of adolescent sleep duration. Because many commonly used multilevel modeling approaches are at high risk of conflating the between- and within-level components of mediational effects, the multilevel SEM approach distinguishes the variation associated both between-person (at level 2, representing between-family trait-like differences on the variables in the model) and within-person (i.e. the repeated assessments at level 1, representing state-like fluctuations of the variables on each day of the diary period) by creating level 2 latent variables based on the level 1 predictors (within-adolescent fluctuations) that thereby represent the stable portion of those constructs across the diary period for each
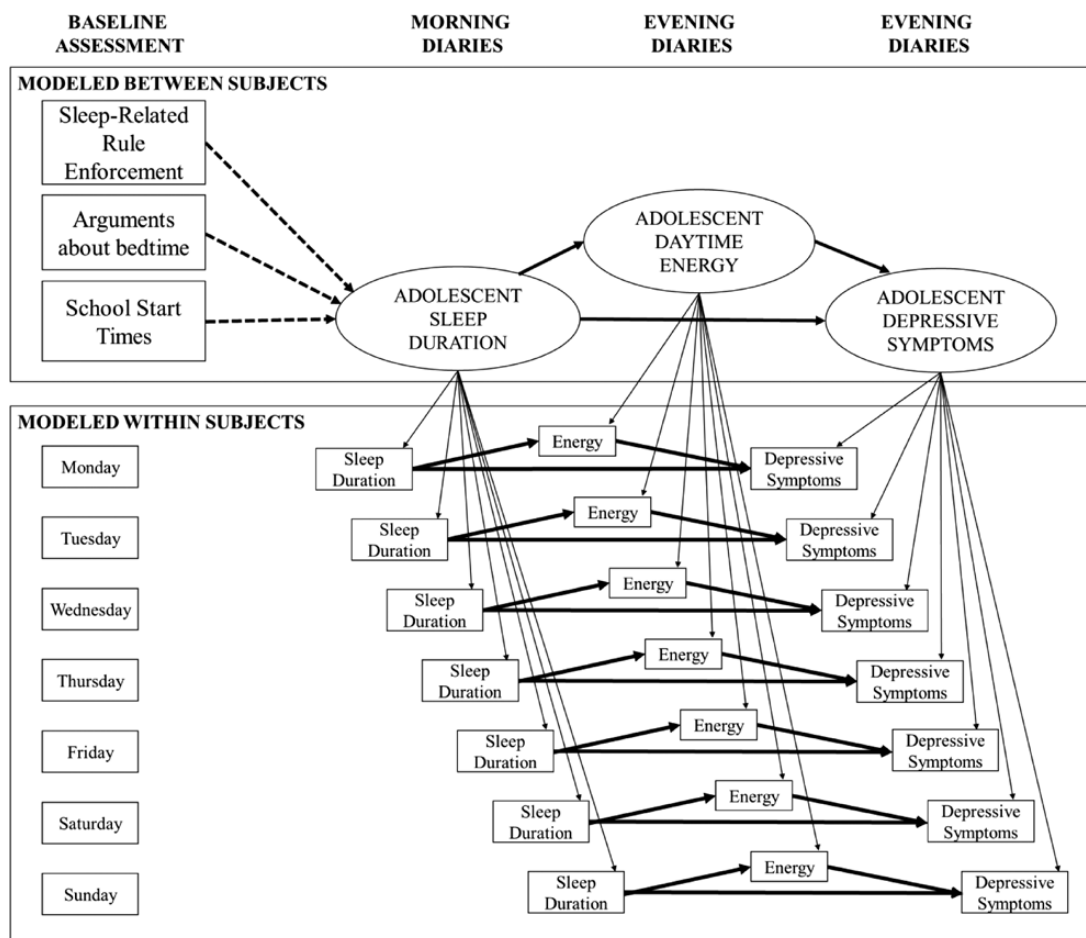
NOTE. In the model tested, Sleep-related Rule Enforcement was comprised of three separate variables (bedtime, cessation of electronic media usage, prohibiting afternoon/evening caffeine consumption) that were modeled simultaneously.

Figure 1. Conceptual model.

adolescent (see Figure 1) [40]. In terms of our process model, this multilevel framework allows for indirect effects to be tested both at the between-family level (i.e. level 2, examining how latent variables representing typical levels of the variables of interest are associated across families) as well as at the within-adolescent level (i.e. level 1, examining how within adolescent fluctuations in the variables covary across the days of the week; see Figure 1). Using current best practices [44], we used asymmetric confidence intervals to test the significance of the level 1 and level 2 mediational paths via RMediation [45].

To control for proximal factors that could also influence adolescent sleep, we also included parent–child arguments about bedtime and school start times as between-family predictors of adolescents' sleep duration. Given that multilevel modeling is tasked with parsing variance between levels (i.e. distinguishing between-person differences from a within-person variation on the variables being examined), all multilevel modeling techniques are unable to provide standardized path coefficients. However, to maximize the generalizability of the current findings, we prepared the data in a way that could provide approximations of standardized path coefficients within this multilevel framework. We did this by standardizing all variables (i.e. converting all predictors, controls, and outcomes to z-scores) before entering them into the analysis (level 1 variables standardized at level 1—across all participants and observations—and level

2 variables standardized at level 2—across all participants). Thus, a level 1 effect of $B = .50$ would suggest that for every one standard deviation higher on the predictor on a specific day of the study, the model would predict outcome scores .50 standard deviations higher. As these are not truly standardized coefficients (as the equations to estimate those do not yet exist for multilevel models), we continue to use "B" rather than "β" to present them. However, their interpretation is close to that of standardized coefficients, providing estimates of standardized effects from the model to place this work in context with the previous literature. Overall model fit was assessed with the comparative fit index (CFI [46]; values above .90 indicating good fit), the root-mean-square error of approximation (RMSEA [47]; values below .08 indicating good fit) and the standardized root-mean-square residual (SRMR [48]; values below .10 indicating good fit). The model fit for the current analysis was very good.

Results

Preliminary analyses

Descriptive statistics for the sample and intercorrelations among the key variables are presented in Table 1. Although a majority of the families reported rules concerning bedtime, prebedtime electronic media usage, and caffeine consumption,

47% of parent respondents reported having no enforced bedtimes, 30% of parents reported no enforced rules regarding prebedtime screen usage, and 48% of parents reported no enforced rules regarding afternoon/evening caffeine consumption. Consistent with this, on 74% of the evening diaries, adolescents and parents agreed that there was no specific suggested or enforced bedtime. In providing data on their average daily sleep duration across the 7 days of the daily diary, adolescents reported an average of 19.4 min (SD = 14.6) of sleep latency and an average of 3.3 (SD = 4.5) min of waking following their episode(s) of wake-after-sleep-onset. Taking into account both sleep latency and post-WASO time awake, adolescents averaged 7.8 h of sleep per night (SD = 1.0), which is consistent with nationally representative datasets of adolescents [29], with an average bedtime of 10:58 p.m. (SD = 1.1) on weekdays and 11:16 p.m. (SD = 1.4) on weekends.

As shown in Table 1, higher levels of enforcement of bedtime-related rules were positively associated with enforcement of screen- and caffeine-related rules, bedtime disagreements, and average daily sleep duration; higher levels of enforcement of screen-related rules were positively associated with enforcement of caffeine-related rules and higher levels of bedtime disagreements. Based on the child-reported daily diary data, later school start times were positively associated with longer average sleep duration; longer average sleep durations were positively associated with higher energy levels; and higher average levels of daytime energy were associated with lower average levels of depressive symptoms across the week. Taken as a set, these correlations support the proposed multilevel SEM path models.

Predicting adolescent sleep duration

Turning to the unique portions of our model, Table 2 presents the between-person path coefficients predicting adolescent sleep duration (the dashed arrows in Figure 1) along with the fit indices for the model. Based on the data from the baseline survey and consistent with our hypothesis, greater bedtime rule enforcement by parents predicted longer adolescent sleep durations (B = .10, SE = .05, p < .05; Table 2; Figure 2). Given the standardized values used in the analyses, this result suggests that for every 1 SD above-average levels of bedtime rule enforcement across families, adolescents are predicted to extend their sleep duration each night by approximately .10 SDs, or about 6.1 min. In addition, later school start times predicted longer

sleep duration (B = .12, SE = .04, p < .01), while higher levels of parent–child disagreement concerning bedtime only marginally predicted shorter adolescent sleep duration (B = −.07, SE = .04, p < .07). These results suggest that for every 1 SD increase in school start times (approximately 29 min), adolescents would be expected to extend their sleep by approximately 7.3 min per night; and for every 1 SD increase in parent–child disagreement about bedtime, adolescents would be expected to decrease their sleep by 4.3 min per night. Contrary to our predictions, neither parents' enforcement of evening screentime usage (B = −.04, SE = .06, ns) nor enforcement of rules concerning afternoon/evening caffeine consumption (B = .02, SE = .06, ns) significantly predicted adolescents' sleep duration during the diary period after controlling for the other effects in the model (Table 2; Figure 2).

Mediation

Hypothesis 1: adolescent sleep duration predicting daytime energy levels

Consistent with our hypothesis, adolescents' sleep duration (assessed each morning of the 7-day diary) significantly predicted their daytime energy levels (assessed each evening of the 7-day diary) such that longer sleep durations were associated with higher daytime energy levels both at the between-adolescent/family level (B = .48, SE = .19, p < .01; Table 2; Figure 2) and at the within-adolescent level (B = .17, SE = .03, p < .001).

Hypothesis 2: daytime energy levels predicting depressive symptoms

Consistent with our hypothesis, adolescents' daytime energy levels significantly predicted their daily reports of depressive symptoms (assessed each evening of the 7-day diary) such that higher daytime energy levels were associated with lower levels of depressive symptoms both at the between-adolescent/family level (B = −.71, SE = .12, p < .001) and at the within-adolescent level (B = −.25, SE = .04, p < .001).

Hypothesis 3: adolescents' daytime energy levels mediate the association of sleep duration on depressive symptoms

Consistent with our hypothesis, the indirect effect of adolescent sleep duration on their depressive symptoms was significant: longer sleep duration predicted higher daytime energy levels, which, in turn, predicted lower levels of adolescents' depressive symptoms (indirect effect = −.34, SE = .16, p < .05; 95% CI: LL = −.65,

Table 1. Psychometrics and bivariate correlations between study variables

Variables	Range	M	SD	Bivariate correlations						
				1	2	3	4	5	6	7
Assessed at baseline (parent-report)										
1. Bedtime-related rules	0–3.0	0.9	1.0	–						
2. Screen-related rules	0–3.0	1.0	1.0	**0.62**	–					
3. Caffeine-related rules	0–3.0	1.2	1.3	**0.34**	**0.58**	–				
4. School start time	6:55–9:30	7:56	29.3	0.03	0.06	−0.13	–			
5. Bedtime disagreement	0–6.0	1.2	1.4	**0.16**	**0.23**	**0.18**	0.12	–		
Assessed during daily diary (child-report)										
6. Avg. daily sleep duration	4.4–11.3	7.8	1	**0.20**	0.07	0.01	**0.18**	−0.06	–	
7. Avg. daily energy level	1.7–5.0	3.8	0.7	0.07	−0.02	−0.04	−0.05	−0.15	**0.20**	–
8. Avg. daily depressive symptoms	0–4.4	0.6	0.9	0.02	0.03	0.06	0.13	0.14	−0.02	**−0.49**

All bolded correlations are significant at the p < .05 level. All diary-reported data have been averaged across all waves of follow-up.

Table 2. Coefficients for multilevel mediation models

	Predicting sleep duration				Model fit				
	B	SE	95% CI		χ2(df)	P	RMSEA	CFI	SRMR
Baseline Predictors of Sleep Duration			LL	UL					
Bedtime rule enforcement	**0.10**	**0.05**	**0.01**	**0.20**	344.1 (31)	<0.001	0.02	0.96	0.07
Screentime rule enforcement	−0.04	0.06	−0.15	0.07					
Caffeine consumption rule enforcement	0.02	0.06	−0.09	0.13					
Arguments about bedtime	−0.07	0.04	−0.15	0.01					
School start time	**0.12**	**0.04**	**0.04**	**0.19**					
	Mediation model (between-adolescents/families)								
	B	SE	95% CI						
			LL	UL					
Sleep duration → energy levels	**0.48**	**0.19**	**0.12**	**0.84**					
Sleep duration → depressive symptoms	0.21	0.22	−0.22	0.64					
Energy levels → depressive symptoms	**−0.71**	**0.12**	**−0.95**	**−0.47**					
Indirect effect	**−0.34**	**0.16**	**−0.65**	**−0.04**					

Note. The predictors and outcome variables were standardized in their final levels of the data prior to running the multilevel models. Thus, the regression coefficients serve as rough approximations of standardized regression coefficients. All bolded results are significant at the $p < .05$ level. RMSEA = root mean square error of approximation. CFI = comparative fit index. SRMR = standardized root mean square residual.
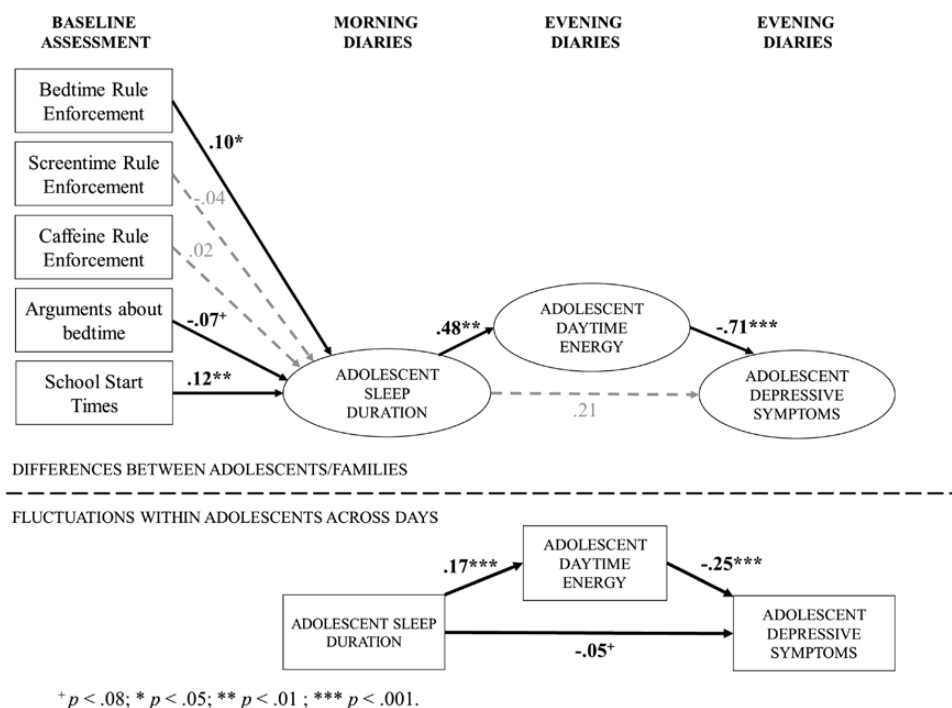

Figure 2. Results of multilevel SEM mediation analyses.

UL = −.04). This result suggests that adolescents with longer sleep durations experienced higher levels of energy during the day and ultimately reported lower levels of depressive symptoms that same day. Thus, although the effect size of this indirect effect is small to moderate in magnitude (.34), the results suggest that it represents one of the mechanisms by which adolescent sleep duration might influence adolescent mental health functioning. After controlling for those indirect paths, the direct effect of adolescent sleep duration on their depressive symptoms was not significant at the between-adolescent/family level (B = .21, SE = .22, *ns*) and only marginally significant at the within-adolescent level (B = −.05, SE = .02, $p < .06$). Taken as a set, the results therefore

suggest that, even after controlling for more stable between-person differences (by creating the latent variables at level 2), daily fluctuations in energy within adolescents mediated the effects of fluctuations in each adolescent's previous night's sleep duration predicting corresponding fluctuations in their reports of depressive symptoms at the end of each day.

Multistage mediation

Having the parent-reported levels of bedtime rule enforcement and school start time as level 2 predictors allowed us to test a

multi-stage mediational model linking both of those parent-reported variables to adolescent depressive symptoms at a between-family level. The results of these analyses suggested that both bedtime rule enforcement (indirect effect = −.04, SE = .02, p < .07; 93% CI: LL= −.086, UL = −.001) and school start times (indirect effect = −.04, SE = .02, p < .05; 95% CI: LL= −.092, UL = −.003) influenced adolescents' depressive symptoms via the mediating variables of adolescent sleep duration and daily energy levels. Thus, between-family differences in enforcing bedtime rules were indirectly predictive of between-family differences in adolescent depressive symptoms via its links to both adolescent sleep duration and corresponding levels of daily energy reported across the diary period.

Discussion

Building upon previous work that has linked parent-set bedtimes, adolescents' daytime functioning, and mental well-being [11, 27], the current study sought to provide a more rigorous test of the influence of parental limit-setting around bedtime and the mechanisms that might ultimately lead to better psychosocial outcomes for adolescents. Given that within and between-person differences are typically confounded within longitudinal models and can therefore generate spurious results [49, 50], the current study made use of multilevel modeling to distinguish those two distinct sources of variance. Our model was therefore able to demonstrate both between- and within-person associations for a process in which adolescent sleep duration indirectly influenced their daily levels of depressive symptoms through their daytime energy levels. We also provided strong support for the use of parental enforcement of bedtimes above and beyond the environmental impediments to longer sleep durations for adolescents (i.e. earlier school start times). This model capitalized on an adolescent-reported 7-day daily diary that could capture the short-term longitudinal impact of sleep duration (morning assessment) on daytime energy levels (evening assessment), which were ultimately associated with adolescents' depressive symptoms (evening assessment). Furthermore, given the interval between the baseline assessment and the 7-day daily diary, our results suggest that both the enforcement of bedtimes and school start times do have a prospective association with adolescents' daily sleep duration and indirectly impact adolescents' depressive symptoms. Building on the extensive links between adolescents' insufficient sleep and their mental health [4], the current results provide another avenue through which both adolescents' sleep and its subsequent impact on their mental health can be addressed. Specifically, parents that can appropriately create and maintain bedtimes for their adolescent-aged children increase not only the opportunity for more sleep but also for greater daytime alertness and mental well-being for these children.

First articulated in the "Perfect Storm" model originally developed by Carskadon [13, 14], the biological and psychosocial factors that serve to ultimately decrease adolescents' sleep durations continue to be a source of risk for their mental health functioning. Fortunately, despite the challenges of parenting adolescents, parents and caregivers are still available to exert influence over their teenage children. Relatively few parents, however, actively enforce parent-set bedtimes or rules related to sleep hygiene (e.g. ceasing use of electronic media in the

hours before bedtime, restrictions on the consumption of caffeinated beverages in the afternoon/evening) [12]. Although our results support the use of parent-set and enforced bedtimes, it is interesting that neither the enforcement of rules related to prebedtime electronic media usage nor the enforcement of afternoon/evening caffeine consumption predicted longer sleep durations or other constructs in our models. There are perhaps at least two reasons why these links did not emerge. First, sleep hygiene related to prebedtime media usage and caffeine consumption provides a guide for improving sleep, but not everyone responds to the light emitted from screens or caffeine similarly. For instance, for individuals with high enough sleep pressure, the effects of screen-emitted light might be negligible. Second, although there is extensive evidence supporting the negative consequences of prebedtime electronic media usage on sleep latency and duration [15, 51, 52], nuances within this body of literature suggest that the level of interaction with electronic media (e.g. watching television vs. playing videogames) might have differential effects [53]. For example, multiple studies have shown that the use of prebedtime electronic media did not impact sleep onset latency or duration for both adolescents and emerging adults [30, 34, 54, 55]. The lack of significant findings for rules limiting technology's usage impacting sleep in the current study is therefore consistent with these findings and suggests that once other factors are controlled, the negative association between technology use and poor sleep might be more limited than originally envisioned. Screen-related bedtime rules, whereas a critical component of proper sleep hygiene, appear to not have the same level of effect as setting a bedtime for adolescents. Similarly, given the relative independence adolescents are afforded, parents might have little control over what their children are consuming after school despite their beliefs in maintaining rules in this domain. As the "Perfect Storm" model suggests [13, 14], it may ultimately be the interplay of multiple sleep hygiene factors and not just the enforcement of one that will yield the same results as parent-set bedtimes.

In an attempt to provide an ecologically valid depiction of adolescent sleep, we included both school start times and parent–child disagreements about bedtime in our models. Consistent with the literature on school start times [6], earlier start times predicted shorter sleep durations and were indirectly linked with adolescents' depressive symptoms. Although the paths linking school start times emerged as slightly more robust than the paths linking bedtime rule enforcement to adolescents' depressive symptoms, it is important to note that parents continue to provide a key source of an intervention despite the negative influence of earlier school start times.

In addition, in our bivariate correlations, the frequency of bedtime disagreements was associated with both bedtime and screen-related rule enforcement. These results speak to the complexity of the family environment as well as to other contextual influences when it comes to adolescents getting enough sleep. Adolescence is a period marked by increasing autonomy and independence, and setting limits, such as a bedtime, can be considered a direct provocation to one's teenage child. However, unchecked autonomy may put adolescents further at risk for insufficient sleep. For instance, research suggests that adolescents with greater bedtime autonomy in addition to higher frequencies of cell phone usage were most at risk for insufficient sleep when compared to those adolescents who used their cell phones less frequently [56]. In this light, intervening with

adolescents to promote better and longer sleep might be best served through a framework that draws on the principles of motivational interviewing and other individually tailored strategies in order to simultaneously meet the needs of both adolescents and their caregivers [57]. Furthermore, any parental limit-setting on bedtimes needs to account for the developmental shifts in adolescents' sleep schedules. The sleep phase delay associated with pubertal development, a hallmark of adolescence, remains an integral factor of the "Perfect Storm" model and an essential consideration when imposing bedtime limits [13, 14]. One could expect that forcing a teenager to get to bed before they were biologically ready might result in longer sleep onset latencies and even to the development of insomnia. Although our sleep duration measure assessed the net time asleep (and not simply in bed), the current study did not include sleep latency as a predictor in its models due to its lack of association with either bedtime or screen-related rule enforcement. However, previous research has suggested that parent-set bedtimes are not associated with longer sleep onset latencies [27].

The current findings add to a growing body of literature examining links between sleep difficulties and depressive symptoms. As daytime fatigue or sleepiness represents a symptom of both depression and insomnia, a growing body of work has begun to conceptualize daytime energy levels as a distinct construct in models—isolating that one facet as a pivotal mechanism that potentially links sleep problems and depression [4, 5, 36, 58, 59]. Thus, although daytime fatigue is considered a symptom of depression, the current study built on this growing body of work and distinguished daytime energy levels as meaningfully distinct from other depressive symptoms. The current results therefore suggest that low-daytime energy levels might represent the most proximal symptom of depression linked to lack of sleep, highlighting a potential underlying process linking these two domains of functioning that warrants further study.

We must acknowledge several of the current study's limitations. First, despite efforts to improve on previous studies that included assessments of parents' enforcement of bedtime (e.g. [11, 27]), our measure was also a participant to desirability bias. Future studies should collect detailed information on bedtime practices from all family members to triangulate agreement. With that said, based on parents' and children's diary reports of whether a bedtime limit was given (yes/no), parents and children agreed that no specific bedtime limit was sent on 74% of the nights surveyed. Second, all measures of adolescent sleep, daytime functioning, and mental health symptoms were self-reported, and thus may be confounded by response-biases. Although we tried to limit such response-bias by employing separate assessments for sleep and daily functioning (i.e. energy levels and mood), future studies would benefit from augmenting self-report surveys with additional methods (e.g. actigraphy). Likewise, only one parent reported on bedtime-related limit-setting in their household, which provides only a limited portrayal of the family environment. Second, although comparable to other samples recruited primarily via the internet [60], the sample was predominately Caucasian, well-educated, and economically advantaged, and findings may only generalize to a similar population. In addition, given that adolescent participants were required to be living 7 days a week in the participating family's household, our results might not generalize to youths who split time between two households. Future

studies should seek to examine these questions in more nationally representative samples with a more diverse range of family structures to ensure broad generalizability of the findings. Finally, our mediational model employing the daily diary assessments supports a direction of effects from adolescent sleep to daytime functioning to adolescent depressive symptoms. Although the temporal spacing of our diary assessments (i.e. morning to evening diary entries) supports the directionality of our findings linking sleep duration to daytime energy levels, it is entirely possible that the opposite direction of influence could also emerge. Furthermore, the link between daily energy levels and depressive symptoms was assessed concurrently in our model as both of those constructs were assessed in the evening diary, leaving the directionality of that association unclear. Thus, although the current model offers partial longitudinal support to the mediation model tested, future work (e.g. using experiential momentary assessment) is needed to determine the true directions of causality. Much support exists for the bidirectional links between adolescent sleep and mental health functioning [61, 62], and future investigations of this topic will ideally include models that can test reciprocal associations between these constructs.

Despite these limitations, the current study extends research on the positive influence of parent-set bedtime by including reports from both parents and children, by minimizing autocorrelation through the use of separate assessments of sleep and functioning, by distinguishing between- and within-person differences within our models, and by controlling for critical factors (i.e. school start times, bedtime disagreements) within adolescents' sleep environments. In the decade that has passed since some of the seminal research on parent-set bedtimes first emerged [11, 27], the epidemic of adolescent insufficient sleep has still not abated [6]. Some would say that with the increasing prevalence of teenagers' use of electronic media, the problem has worsened [63]. Fortunately, supported by both the current findings and other recent studies (e.g. [26, 39]), parents and their enforcement of appropriate bedtimes should still be considered an effective frontline intervention in the effort to afford adolescents their much-needed sleep.

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