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Reut Gruber, PhD, Jamie Cassoff, BSc, Sonia Frenette, PhD, Sabrina Wiebe, MSc, and Julie Carrier, PhD

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AUTHORS: Reut Gruber, PhD,[a,b] Jamie Cassoff, BSc,[a,b] Sonia Frenette, PhD,[c] Sabrina Wiebe, MSc,[a,b] and Julie Carrier, PhD[c,d]

[a]Attention, Behavior and Sleep Laboratory, Douglas Mental Health University Institute, Verdun, Quebec, Canada; [b]McGill University, Quebec, Canada; [c]Centre du Sommeil et des Rythmes Biologiques, Quebec, Canada; and [d]Université de Montréal, Quebec, Canada

KEY WORDS

sleep extension, sleep restriction, school, emotional regulation, impulsivity

ABBREVIATION

CGI-T—Conners' Global Index-Teachers

Dr Gruber made substantial contributions to conception and design; Drs Gruber, Frenette, Carrier and Ms Wiebe made substantial contributions to acquisition of data; Drs Gruber, Carrier, and Ms Cassoff made substantial contributions to analysis and interpretation of data; and all authors have made substantive intellectual contributions to this article.

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Address correspondence to Reut Gruber, PhD, Attention, Behavior and Sleep Laboratory, Douglas Mental Health University Institute, 6875 LaSalle Blvd, Verdun, Quebec H4H 1R3, Canada. E-mail: reut.gruber@douglas.mcgill.ca

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WHAT'S KNOWN ON THIS SUBJECT: Healthy sleep is essential for supporting alertness and other key functional domains required for academic success. Research involving the impact of modest changes in sleep duration on children's day-to-day behavior in school is limited.

WHAT THIS STUDY ADDS: This study shows that modest changes in sleep duration have significant impact on the behavior of typically developing children in school. Modest sleep extension resulted in detectable improvement in behavior, whereas modest sleep restriction had the opposite effect.

abstract

OBJECTIVE: To examine the impact of moderate sleep extension and restriction on child behavior in school.

METHODS: We conducted a randomized parallel group study to determine the impact of an experimental sleep extension (addition of 1 hour of sleep relative to baseline habitual sleep duration on weekdays) and experimental sleep restriction (elimination of 1 hour of sleep relative to baseline habitual sleep duration on weekdays) on child behavior in school. The primary outcome measures were scores on the Conners' Global Index Scale, as determined by teachers blinded to sleep status of the participants. A sample of 34 typically developing children aged 7 to 11 years with no reported sleep problems and no behavioral, medical, or academic issues participated in the study.

RESULTS: Our main findings were that (1) a cumulative extension of sleep duration of 27.36 minutes was associated with detectable improvement in Conners' Global Index–derived emotional lability and restless-impulsive behavior scores of children in school and a significant reduction in reported daytime sleepiness; and (2) a cumulative restriction of sleep of 54.04 minutes was associated with detectable deterioration on such measures.

CONCLUSIONS: A modest extension in sleep duration was associated with significant improvement in alertness and emotional regulation, whereas a modest sleep restriction had opposite effects. *Pediatrics* 2012;130:1–7

Academic success plays an important role in improving future lifetime opportunities. As successful adjustment to school impacts child success and well-being, the identification of modifiable factors that can improve such adjustment, or conversely, increase the risk of poor adjustment, is an important public health issue. Factors relevant to successful adjustment to school have been identified, but the role of sleep has been largely ignored. The features of behavior most affected by sleepiness and insufficient sleep are behavioral/emotional regulation[1,2] and cognitive functioning[3–8] and are key functional domains required for academic success.[9] If the relationship between sleep duration and academic performance were better understood, educators and parents would be able to optimize child academic performance by identifying strategies maximizing the benefits of sleep.

With 1 controversial exception,[10] existing data suggest decreased sleep time and increasingly delayed bedtimes result in sleep restriction as an emerging problem in preadolescents. A recent study[11] found that 43% of boys aged 10 to 11 years slept for less than the recommended duration each night, and a recent poll revealed that 64% of school-aged children (ie, 6–12 years old) went to bed later than 9:00 PM.[12]

Previous research examining the associations between sleep and school function of school-aged children used naturalistic and correlational design,[13–22] rendering it impossible to assess cause and effect.[9] Seven experimental studies on the impact of sleep on the daytime functioning of school-aged children have been conducted[23–29]; these studies showed that sleep restriction resulted in an increase in daytime sleepiness and poorer performance on vigilance and memory tasks. No study has examined the effect of sleep restriction on the actual day-to-day function of children in school. Only 2 reports explored the impact of extended sleep on child daytime functioning.[26,27] In 1 study, vigilance and memory were improved compared with baseline after sleep extension.[27] The other study[26] did not provide baseline information, making it impossible to determine what changed after sleep extension. These limited data emphasize that the effects of sleep extension on daytime function have yet to be thoroughly investigated in children. No study has examined the impact of sleep restriction on the actual day-to-day function of children in school.

In the current study, we tested the effects of a 1-hour extension or restriction of sleep over 5 consecutive nights on day-to-day functioning of children in the school environment, as reported by teachers blinded to the sleep status of participants. We examine the effects of moderate cumulative changes in sleep duration because this resembles the sleep variations that occur naturally. We hypothesized, first, that an intervention aiming at sleep extension would be associated with decreased daytime sleepiness and improved behavioral functioning, and second, that sleep restriction would increase daytime sleepiness and impair school functioning.

METHODS

Participants

This study included 34 typically developing children between 7 to 11 years of age. Children were recruited through school advertisements. The study was approved by the hospital's research ethics board. Parents signed informed consent forms, and all of the children assented to participation in the study. Inclusion criteria were as follows: (1) children were free of medical conditions, as established by clinical history and questionnaires, and did not present any psychiatric or sleep issue; (2) children's reported habitual nightly sleep durations were between at least 8.5 to 9.5 hours, with no evidence of habitual napping or sleep disturbance; (3) children were capable of understanding and following the study instructions; and (4) children spent weekdays in a school setting in which the same teacher was able to assess behavior both at baseline and at the end of the experimental week.

A total of 53 parents responded to the advertisements, and their children were assessed for study eligibility. Fifteen children did not meet inclusion criteria, and 2 refused to participate. Thirty-six children met inclusion criteria and were enrolled in the study. Seventeen children were randomly assigned to the sleep-extension group, and 17 were randomly assigned to the sleep-restriction group. One child in the sleep-restriction group dropped out of the study.

Design

The current randomized parallel group study featured 2 experimental sleep conditions: sleep extension and sleep restriction. The primary outcome measure was the teacher-rated daytime functioning as determined by teachers blinded to participant sleep status both at baseline and during intervention. The secondary outcome measure was parents' rating of daytime sleepiness.

Procedure

Participant eligibility was determined before enrollment by screening for the absence of sleep disorders by using the Children's Sleep Habits Questionnaire.[30] This sleep-screening instrument is commonly used to identify behavioral and medical sleep problems in school-aged children. In addition, the Child Behavior Checklist[31] was used to confirm that behavioral problems were lacking. Open questions were used to explore child health status. In addition, during the screening visit, the National Institutes of Mental Health Diagnostic Interview Schedule for Children Version 4.0[32] was used to determine if any psychiatric condition was present. Only children with no reported sleep problems and no behavioral, medical, or academic issues were invited to participate in the study. Eligible participants were told to avoid products containing caffeine (eg, chocolate or cola) and to avoid napping for the duration of the study. They completed a baseline protocol involving objective sleep evaluation, employing actigraphy, in the natural home environment for 5 consecutive nights. On the last day of the baseline period, the participants were randomly assigned (at a 1:1 ratio) to 1 of 2 experimental conditions. These conditions consisted of experimental sleep extension (addition of 1 hour of sleep relative to baseline habitual sleep duration on weekdays) and experimental sleep restriction (elimination of 1 hour of sleep relative to baseline habitual sleep duration on weekdays).

At the beginning of each experimental period (baseline, restriction/extension), each participant received a package that included an actiwatch, a daily log allowing parents to assess sleep, and a sleepiness questionnaire for completion by parents. Data on pubertal and socioeconomic status and BMI, which are potential confounders of sleep behavior, were collected from participants. Actiwatches were worn on the nondominant wrist, commencing shortly before bedtime and terminating shortly after awakening. On the last days of both the baseline and experimental weeks, teachers blinded to child sleep status completed the Conners' Global Index-Teachers (CGI-T, 3rd edition), and parents completed the sleepiness scale.

Measures

Daytime Function

The CGI-T[33] is a tool that allows teachers to score behavior in a school setting. The instrument is designed to record difficulties that may be experienced by youth aged 6 to 18 years. Two behavioral domains are explored; the first is "emotional lability," which assesses moodiness and emotionality. For example, a child scoring highly in this domain may cry, lose his or her temper, or become easily frustrated. The other domain explored is "restless-impulsive behavior." Raw total and factor scores are transformed into normalized T-scores. A score of $\geq$60 is considered clinically significant. The internal reliability coefficient of the CGI-T is high; the test-retest reliability coefficient over a 6- to 8-week interval is typically 0.8. The validity of the revised Conners' Teacher Rating Scale (CTRS–R) and the revised Conners' Parent Rating Scale (CPRS–R) also has been established.[34,35]

Sleep

Nighttime sleep was monitored by using actigraphy; the technique employs a wristwatch-like device (AW-64 series; Mini-Mitter Co, Inc, Bend, OR) to evaluate sleep via measurement of ambulatory movement. Actigraphy has been shown to be a reliable method of sleep evaluation, and the Actiware Sleep algorithm for scoring of sleep indices has been previously validated, displaying a high degree of correspondence with polysomnographic data.[36–39] The actigraphic data were analyzed in 1-minute epochs, and Actiware Sleep 3.4 (Mini-Mitter) served as the sleep-scoring software. The total number of activity events was computed for each 1-minute epoch, and if the threshold sensitivity value of the mean score during the active period was exceeded, the epoch was considered to be waking in nature. Otherwise, the epoch was considered to be sleep. Actigraphic sleep measures included an estimate of sleep duration (sleep time; the time between sleep start and sleep end, scored as sleep by the algorithm) and sleep quality (fragmentation index; the sum of the percentage of time spent sleeping when the subject is moving and the percentage of immobile periods that last a minute or less).

Sleepiness

The Modified Epworth Sleepiness Scale[40] was completed by parents to explore the propensity of each child to fall asleep in various situations.

Confounders

BMI was calculated by dividing weight (kg) by height (m) squared. A modified version of Petersen's puberty development scale[41] was used to assess pubertal development; participants were asked to report on physical changes associated with puberty. A 4-point scale was used. Information on parental educational level, marital status, income, and profession was collected via questionnaire, and a socioeconomic score was calculated based on the 4-factor index of Hollingshead.[42]

Statistical Analysis

Demographic and physical characteristics were considered to be dependent variables and were compared between the 2 sleep manipulation groups (extension and restriction) by using either 1-way analysis of variance or the χ^2 test, depending on the nature of the data.

To assess the effects of experimental manipulation on sleep measures and sleepiness parameters, we conducted 3 sets of multiple analysis of variance tests, with group (sleep restriction or sleep extension) as the between-subject variable and time (weekly average at baseline versus weekly average

TABLE 1 Demographic Characteristics of Participants

Variable	Sleep-Extension Group, n = 17	Sleep-Restriction Group, n = 16
Age at first session, y	8.39 (0.92)	8.68 (1.30)
Gender, no. (%)		
Male	10 (58.8)	10 (58.8)
Female	7 (41.2)	7 (41.2)
Race, no. (%)		
White	11 (64.7)	13 (76)
Asian	3 (17.6)	0
Multi-ethnic	3 (17.6)	2 (11.8)
Other	0	2 (11.8)
BMI	17.83 (3.88)	18.78 (4.17)
SES	53.11 (10.64)	51.72 (10.93)
PDS score	6.13 (1.46)	6.93 (2.12)

Data are given as mean (SD), unless indicated otherwise. PDS, pubertal development score; SES, socioeconomic status.

at intervention) as the within-subject independent variable. Sleep, sleepiness, and CGI-T score were used (separately) as dependent variables. Post-hoc power analyses also were conducted. SPSS version 20.0 for Windows (SPSS Inc, Chicago, IL) was used for all statistical analysis, and $P < .05$ was considered to indicate statistical significance.

RESULTS

Study Population

Analysis of data from the sleep-extension group includes 17 children (mean age = 8.68 years, SD = 0.92) and from the sleep-restriction group includes 16 children (mean age = 8.39 years, SD = 1.3). Means and SDs of the demographic and physical characteristics of children in either interventional group are shown in Table 1. No significant between-group difference was evident when age, BMI, extent of pubertal development, socioeconomic status score, gender, or race distribution was examined.

Effects of Experimental Manipulation on Sleep

Table 2 shows the means and SDs of sleep and sleepiness scores of children both at baseline and after sleep manipulation. Significant time × intervention interactions were found when actigraphic sleep measures were examined ($F_{2,32}$ = 17.98, $P < .001$, β = .95). Univariate analysis revealed that, after intervention, sleep time was shorter in the sleep-restriction group but longer in the sleep-extension group compared with baseline values ($F_{1,\ 33}$ = 34.7, $P < .00$, β = .65]. This difference in sleep duration indicates that sleep was significantly extended (by an average of 27.36 minutes) in the sleep-extension group but was significantly shortened (by an average of 54.4 minutes) in the sleep-restriction group. After intervention, sleep fragmentation was significantly reduced in the sleep-restriction group ($F_{1,\ 35}$ = 5.11, $P <$ .03, β = .59) but did not change in the sleep-extension group.

The Effects of Experimental Manipulation on Sleepiness

A significant time × intervention interaction was evident when sleepiness scores were compared between the 2 groups ($F_{1,\ 33}$ = 5.1, $P < .05$, β = .59). Univariate analysis revealed that the level of sleepiness after intervention increased, compared with baseline, in children in the sleep-restriction group, but decreased in children in the sleep-extension group (Table 2).

The Effect of Experimental Manipulation on Teacher CGI-T Ratings

A significant group × period interaction was found when CGI-T measures were examined ($F_{3,\ 30}$ = 3.75, $P <$ .05, β = .76). These data, confirmed by post-hoc testing, indicated that both emotional lability and restless-impulsivity scores improved significantly from baseline in children in the sleep-extension group, whereas these measures deteriorated in children experiencing sleep restriction. Table 3 includes means and SDs of teacher-reported CGI-T scores before and after sleep manipulation in both groups.

DISCUSSION

The present work constitutes the first experimental study to evaluate the impact of experimental sleep extension and restriction on the day-to-day functioning of typically developing children in the school environment. The strengths of this study are that we (1) implemented experimental restriction and extension of sleep duration; (2) assessed day-to-day functioning based on standardized observations,

TABLE 2 Sleep and Sleepiness Scores of Children at Baseline and After Sleep Manipulation

Sleep Variables	Sleep-Extension Group		Sleep-Restriction Group	
	Baseline	After Sleep Extension	Baseline	After Sleep Restriction
Sleepiness	4 (2.70)	3.06 (2.86)	3.94 (4.01)	6.06 (4.34)
Actigraphy				
Sleep duration (min)	558.46 (38.75)	585.82 (48.23)	556.71 (34.67)	502.35 (33.72)
Sleep fragmentation[a]	35.35 (9.55)	35.39 (9.34)	35.39 (7.55)	29.35 (10.83)

Data are given as mean (SD).

[a] Sleep fragmentation is denoted by the sleep fragmentation index.

TABLE 3 Teacher-Reported CGI-T Scores of Children After Baseline and Sleep Manipulation

CGI-T T-Scores	Sleep-Extension Group		Sleep-Restriction Group	
	Baseline	After Sleep Manipulation	Baseline	After Sleep Manipulation
Emotional lability subscale	50.33 (8.29)	47.33 (4.65)	47.93 (6.23)	51.5 (7.85)
Restless-impulsive behavior subscale	49.94 (9.32)	47.05 (5.94)	51.94 (9.64)	55.06 (10.52)
Total score	49.89 (8.15)	46.67 (5.36)	50.44 (8.83)	54.19 (9.93)

Data are given as mean (SD).

at school, by teachers blinded to child sleep status; (3) examined the impact of moderate changes in sleep duration that are common in everyday life; and (4) used objectively measured sleep parameters.

The principal goal of the current study was to determine the effects of modest changes in sleep duration on teacher perceptions of behavior in a nonclinical sample of school-aged children, by using a standardized detailed questionnaire. Our main findings were that (1) a cumulative extension of sleep duration of 27.36 minutes was associated with detectable improvement in (CGI-T–derived) emotional lability and restless-impulsive behavior scores of children in school and a significant reduction in reported daytime sleepiness, and (2) a cumulative restriction of sleep of 54.04 minutes was associated with detectable deterioration on such measures.

Consistent with the data of previous studies,[27,29] we found that sleep restriction lowered the sleep fragmentation index. These findings indicate that a decrease in sleep duration did not override any improvement in sleep continuity. Our study participants exhibited poorer behavior after sleep restriction despite the fact that sleep quality, as measured by the fragmentation index, was better.

Our finding that emotional lability and restless-impulsive scores were sensitive to both sleep extension and restriction is consistent with clinical and observational data supporting the view that inadequate sleep creates a low threshold for expression of negative affect (irritability and frustration) and is associated with difficulty in the modulation of impulse and emotion. Previous research has shown that short sleep duration and sleep disruption are associated with emotional dysregulation and development of psychiatric disorders in children. This previous work was conducted with children presenting with both internalizing and externalizing behavioral problems.[43] In the current study, however, we provide evidence that sleep and emotional and behavioral functioning interact in typically developing children. In addition, all previous studies were correlational in nature and did not allow cause-and-effect conclusions to be drawn, which is important given the potential bidirectionality of the interplay between sleep and emotion. Sleep disruption in children with clinical disorders may form an element of the clinical problem (eg, anxiety or depression). Sleep disruption also can impair emotional regulation.[14,44] Our present findings afford preliminary evidence that moderate changes in sleep duration could have positive (with sleep extension) or negative (with sleep restriction) effects on the ability of healthy children to regulate emotion.

The findings of the current study are consistent with those of 2 recent reports.[45,46] In the cited works, sleep duration was experimentally manipulated in typically developing toddlers[45] or adolescents.[46] Examination of the effects of this manipulation on emotional functioning revealed that reduced sleep duration increased negative affect and impaired emotional regulation.

The idea that daytime alertness and performance can be improved by increasing sleep duration is controversial.[47–49] In addition, the extent of change in sleep duration necessary to create a measureable impact on daytime alertness and performance is unclear. In a previous study of 3120 high-school students,[50] those who averaged 25 minutes' more weeknight sleep than others obtained better school grades. In the current study, we found that an extension of 27.36 minutes of sleep for 5 consecutive nights beneficially affected child daytime behavior in school. Our present work and the cited studies provide initial support for the idea that cumulative small additions to sleep duration potentially improve child functioning in school. Additional studies examining the impact of moderate cumulative sleep extensions on grades and alertness in class are needed.

Our findings contribute to the discussion on the physiologic benefits afforded by sleep extension, particularly improved daytime functioning and alertness, as well as the feasibility of this type of intervention. The findings of the present work show that a moderate sleep extension is both feasible and beneficial.

Although statistical power analysis indicated that our sample size was sufficient to permit detection of significant effects, the size of our sample was nonetheless relatively small, and we suggest that our results be considered preliminary in nature. It is important to note that our sample size is in the same range of previous experimental sleep studies conducted with children.[9,23–25] Although large studies are desirable, such studies are difficult, from both practical and financial perspectives, given the nature of the protocol, the need to use objective methodology, and the elaborate screening process required. Second, although actigraphy allows reliable recording of child sleep in the home environment, the technique does not record sleep architecture. Future studies would benefit from the use of polysomnography, in conjunction with actigraphy, to investigate associations between sleep and behavior in school-aged children. We used a convenience-based sample, as have other experimental sleep studies on children. This method of convenience sampling is pragmatic and cost-effective, but samples may be unrepresentative and biased.

Parents of participants were not blinded to the nature of the intervention, which may have biased parent-recorded child sleepiness levels. Future work using objective measures of sleepiness (such as the Multiple Sleep Latency Test) are needed to objectively determine the impact of intervention on sleepiness levels in children at baseline and after intervention.

Although the CGI-T is a commonly used, validated standardized questionnaire allowing reliable teacher reports on child behavior, the instrument does not deal with all aspects of day-to-day functioning in the school environment that could be affected by sleep. Additional studies featuring additional outcome measures, including the extent of participation in class discussion and the ability to socialize with peers, are needed to fully capture the impact of sleep on the daily life of children in the school environment.

CONCLUSIONS

Findings from this study have important practical and clinical implications. First, given the positive impact of moderate sleep extension and the negative impact of moderate sleep restriction, it is important that parents, educators, and students are provided with sleep education featuring data on the critical impact of sleep on daytime function. Sleep must be prioritized, and sleep problems must be eliminated. Sleep tools may aid children in making the small modifications in daily routine that are needed if a small sleep extension is to follow. In addition, our work supports the utility of actigraphy as a sensitive and objective method to explore the impact of inadequate sleep on the daytime functioning of school-aged children.

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