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ORIGINAL RESEARCH

Short sleep duration is associated with teacher-reported inattention and cognitive problems in healthy school-aged children

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Purpose: Pediatric, clinical, and research data suggest that insufficient sleep causes tiredness and daytime difficulties in terms of attention-focusing, learning, and impulse modulation in children with attention deficit hyperactivity disorder (ADHD) or in those with ADHD and primary sleep disorders. The aim of the present study was to examine whether sleep duration was associated with ADHD-like symptoms in healthy, well-developing school-aged children.

Patients and methods: Thirty-five healthy children (20 boys, 15 girls), aged 7–11 years participated in the present study. Each child wore an actigraphic device on their nondominant wrist for two nights prior to use of polysomnography to assess their typical sleep periods. On the third night, sleep was recorded via ambulatory assessment of sleep architecture in the child's natural sleep environment employing portable polysomnography equipment. Teachers were asked to report symptoms of inattention and hyperactivity/impulsivity on the revised Conners Teacher Rating Scale.

Results: Shorter sleep duration was associated with higher levels of teacher-reported ADHD-like symptoms in the domains of cognitive problems and inattention. No significant association between sleep duration and hyperactivity symptoms was evident.

Conclusion: Short sleep duration was found to be related to teacher-derived reports of ADHD-like symptoms of inattention and cognitive functioning in healthy children.

Keywords: ADHD-like symptoms, sleep duration, inattention, hyperactivity, impulsivity, healthy school-aged children

Introduction

A considerable proportion of elementary school-aged children sleep for less than the recommended 10–11 hours.[1] For example, a study conducted in 2004 found that 43% of boys aged 10–11 years slept for less than 9 hours per night.[2] Decreases in sleep time combined with increasingly delayed bedtimes suggest that sleep restriction is emerging as a preadolescent problem. A poll conducted by the National Sleep Foundation found that adolescents (6th–12th grade) averaged 0.5–2 hours less than the recommended amount of sleep each night.[3] This finding is a major problem, given the negative impact of restricted sleep on the mental and physical health of children and adolescents.

Mounting evidence indicates that sleep has beneficial effects on learning, memory, attention, emotional regulation, and academic success. Conversely, fatigue and insufficient sleep can negatively affect academic performance, self-regulation, and attention, all of which are necessary for success in school (for a review see Gruber et al).[4] The aspects of human behavior most affected by fatigue and insufficient sleep are the executive functions, learning, and memory; these are also the key functional

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domains required for academic success. Sleep loss impairs performance on tasks requiring abstract thinking, creativity, integration, and planning,[5] and is associated with a decrease in the efficiency of learning and memory.[6–13]

Furthermore, pediatric, clinical, and research data suggest that insufficient sleep causes tiredness and daytime difficulties in terms of attention-focusing and impulse modulation.[14–17] In 1991, Dahl et al[18] observed that such difficulties were very similar to the core symptoms of attention deficit hyperactivity disorder (ADHD), the most commonly diagnosed neuropsychological disorder in children. Subsequently, several researchers have studied the association between sleep and neurobehavioral functioning in children with ADHD with or without sleep-disordered breathing and in children with both ADHD and restless leg syndrome/periodic leg movement disorder.[14,19–22] The cited studies consistently demonstrated that, in such populations, sleep disruption was associated with hyperactivity and inattention.[22]

Although the cited works provide convincing evidence that sleep and attention interact in children with ADHD, or in those with ADHD and any or all of sleep apnea, sleep-disordered breathing, restless leg syndrome, and periodic leg movement disorder, it is not clear whether this is true of typically developing children that do not suffer from any such problems. The few survey- or actigraphy-based studies that have examined the association between short sleep duration and ADHD-like symptoms in typically developing children have yielded conflicting results.[23–28] Inconsistent data were evident in both types of studies, with some reports finding associations between short sleep duration and inattention[23,24,26,29,30] and hyperactivity,[25,27,28] whereas others did not.[23–25,31,32] Reasons for such inconsistencies could be related to methodological differences in the way that sleep was measured. Polysomnography (PSG) was not employed, and no study employed an objective measure of breathing symptoms, and no prior study has measured restless leg syndrome or periodic leg movement disorder using either objective or subjective measures. Breathing symptoms, restless leg syndrome, and periodic leg movement disorder are common conditions, but relatively underdiagnosed in pediatric populations[33] and have been frequently associated with inattention and hyperactivity.[34–38]

Therefore, the presence of such comorbidities may have confounded prior study results, contributing to inconsistent findings. It is therefore impossible to draw firm conclusions in terms of an association between short sleep duration and symptoms of inattention and hyperactivity/impulsivity in healthy children based on the data of the cited works. This is important because if short sleep duration is indeed associated with ADHD-like symptoms in typically developing children who do not have primary sleep disorders, identification of such an association would support the use of interventions aimed at reducing sleep deprivation. These interventions could therefore help otherwise healthy children to fulfill their potential.

The goal of the present study was to determine whether shorter sleep duration was related to symptoms of inattention and hyperactivity/impulsivity, which are commonly used in the diagnosis of ADHD, in typically developing children. It was hypothesized that shorter sleep duration would be associated with higher teacher ratings of inattention and hyperactivity/impulsivity.

Material and methods

Participants

Thirty-five children (20 boys, 15 girls) aged 7–11 years (mean 8.60 years; standard deviation [SD] 1.12 years) participated in the present study. Psychiatric status was assessed using the Diagnostic Interview Schedule for Children;[39] which was administered to parents. Medical information was obtained via a detailed health screening form. Participants were excluded if they had an intelligence quotient (IQ) <80 (measured using the Wechsler Intelligence Scale for Children, 4th edition[40]), or any medical or psychiatric conditions. In addition, children with a saturation nadir lower than 90%, with paradoxical breathing, or with periodic limb movements associated with five or more leg movements per hour of sleep were excluded from the study.

Participants were recruited from elementary schools located in districts of middle socioeconomic status. The study was approved by the Research Ethics Board of the Douglas Mental Health University Institute. All enrolled children completed the study. Each child received compensation of CAD75. Parents signed consent forms permitting research team members to contact teachers. In addition, parents sent teachers information on the study, and informed them that team members would be in contact seeking completion of questionnaires. All teachers were contacted by a research assistant and subsequently completed the revised Conners Teacher Rating Scale (CTRS-R).[41]

Procedure

Children were first screened for eligibility. During initial contact, over-the-phone assessment was conducted using the Pediatric Sleep Questionnaire[42] which assesses sleep-disordered breathing, snoring, and sleepiness. In addition, the Chervin and Hedger tool,[43] which investigates leg restlessness, experience of growing pains in bed, insomnia, and morning headache, was administered to exclude those with restless leg syndrome. Children scoring 0.33 or higher (ie, replying positively to 33% or more of the 22 questions of either scale) were excluded. Health-related conditions and use of medication were assessed using a health screening form that included a detailed list of questions about each child's health status. Children who passed over-the-phone screening next visited the laboratory, where both IQ and potential psychological diagnoses were evaluated in a quiet room. After initial screening, children meeting inclusion criteria were invited to participate in the study and their parents received a package that included a sleep assessment battery, a demographic questionnaire, and a consent form. Sleep assessment included use of the morningness–eveningness questionnaire,[44] actigraphy, and a sleep log. Parents were asked to complete and return the questionnaire. Teachers were requested to complete the CTRS-R[41] based on the week of sleep evaluation. Each child wore an actigraphic device on their nondominant wrist for a period of two nights prior to use of PSG, to assess their usual sleep period. On the third night, sleep was recorded using ambulatory assessment of sleep architecture employing portable PSG equipment. On the scheduled night, a sleep technician arrived at each child's home 1.5 hours prior to habitual bedtime and connected the sleep recording apparatus. Recording commenced at the child's habitual bedtime. Sleep pattern and architecture were recorded in the natural home environment because such data afford greater ecological validity than do records logged in sleep laboratories.[45–47] For a visual representation of the study design, please see Figure 1.

Measures

Questionnaires/scales for neurobehavioral assessment

ADHD-like symptoms were evaluated using the CTRS-R, a well-validated and reliable instrument used to screen for ADHD in children.[41] The CTRS-R has internal consistency ratings of 0.86–0.95 and high test-retest reliability.[41] Teachers rated several behaviors on a scale from zero (not true at all) to three (very true), yielding four indices; data from the hyperactivity-impulsivity and cognitive problems/inattention domains were focused on.

The Full Scale IQ score of the Wechsler Intelligence Scale for Children, 4th edition[40] was used to estimate general cognitive functioning.

Sleep assessment PSG

An in-home recording procedure was used to assess child sleep architecture, to allow children to sleep in their natural environment. PSG recordings were performed in the children's homes using a digital ambulatory sleep recorder

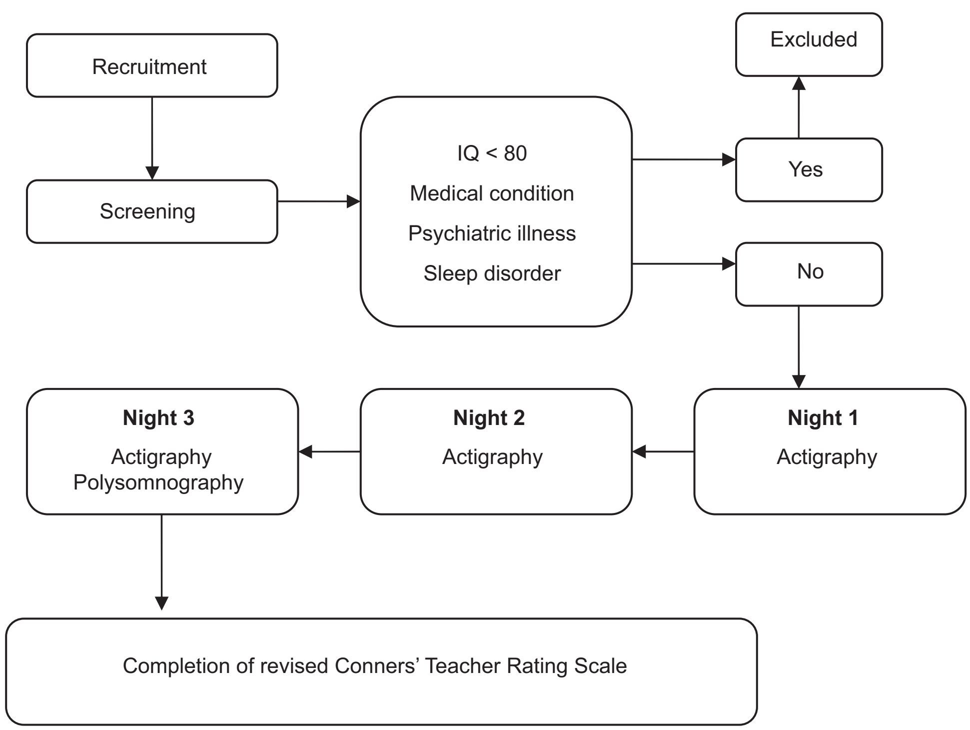

Figure 1 Study design.

(Vitaport-3; TEMEC Instruments BV, Kerkrade, the Netherlands), measuring electroencephalography, submental electromyography, electrooculography, and finger pulse oximetry. Electroencephalography electrodes were placed bilaterally along the anteroposterior axes at locations F3, F4, C3, C4, P3, P4, O1, and O2. To assess respiration, two respiratory belts, measuring both chest and abdominal movement, were fitted to detect hypopnea and apneas, respectively, and pulse oximetry was used to measure oxygen saturation. The decision not to use cannula was based on the fact that, whereas the electrooculography, electromyography, and electroencephalography electrodes could be easily twisted together and attached to the recording equipment located close to the child's head, the use of nasal cannula would interfere with the child's sleep and would impact the ecological validity of the study.

Electromyography leg electrodes were used to identify leg-movements. Sleep stages were scored visually onscreen (LUNA; Stellate Systems, Montreal, Canada) using the C3 derivation (referential derivation: linked ears) according to standard criteria,[48] but employing 20-second epochs.

Various PSG sleep measures were analyzed, but, in the present study, sleep duration was focused on.

Actigraphic measurements

Actigraphs (Actiwatch® 64; Mini Mitter Company Inc, Bend, OR) were used to assess sleep patterns in the natural home environment. These computerized wristwatch-like devices collect data generated by movement. Their use is minimally invasive and the devices therefore allow sleep to be reliably recorded without interfering with family routine. Each actigraphic sleep interval was manually marked with sleep log bedtime and rising time. For each 1-minute epoch, a total activity count was computed. If a threshold value was attained, then the epoch was considered to be wakefulness. If the value fell below that threshold, then the epoch was considered to be sleep. Actigraphic data were analyzed using Actiwatch 64 sleep software (Mini Mitter). The actigraphic parameter of interest was sleep period, representing the amount of time between sleep commencement and wakening. Sleep start and sleep end were automatically determined as the first and last 5-minute periods, respectively, in which no more than a single epoch was scored as mobile.

Circadian preference measure

The Children's Morningness–Eveningness Preferences Scale,[49] a ten-item multiple-choice scale adapted from the Horne–Ostberg morningness–eveningness questionnaire,[44] was used to determine circadian preference. The scale ranges from ten (extreme evening preference) to 42 (extreme morning preference).

General evaluation and confounders

To characterize the profiles of the children and reconfirm that the psychological profiles of the study children were within the normal range, the Child Behavior Checklist was used, a frequently utilized dimensional measure of child psychopathology.[50,51] Numerous studies have confirmed the stability of the instrument in terms of psychometric properties; the test shows good reliability and validity in both clinical and nonclinical populations.[52,53]

Body mass index was calculated by dividing weight in kilograms by height in meters squared.

Statistical analyses

Descriptive statistics on demographics, physical, and intellectual characteristics of participants were computed. To determine whether sleep duration on the PSG night was similar to those on the weeknights preceding PSG, Student's *t*-test for related samples was used to compare the mean time in bed obtained in the two consecutive nights prior to PSG to the time spent in bed in the PSG night. Multiple linear regression analyses, adjusted for age, IQ, body mass index, and circadian tendency, were used to assess the strength of potential relationships between teacher reports of inattention/cognitive problems or hyperactivity (dependent variables) and total sleep duration as measured by PSG (independent variable). All analyses were performed using IBM SPSS (v 15.0 for Windows; SPSS Inc, Chicago, IL). $P < 0.05$ was considered significant.

Results

Demographic and sleep characteristics of all enrolled participants are presented in Table 1. The age range was 7–11 years (mean 8.60 years, SD 1.12 years). Twenty (57%) of the children were male. Caucasian children represented 68.6% of enrolled participants, 2.9% had an African-American background, 8.6% were Asian, and 8.6% of mixed race. The average total score on the Child Behavior Checklist[50–53] was 49.77 (SD 9.2), thus confirming that all participants were within the normal range (T score < 60) on all subscales pertaining to child behavior. All of the participants who were included in the study were below the cutoff score on the Pediatric Sleep Questionnaire,[42] had no indication of desaturation, and no paradoxical breathing at the thoracic and abdominal channels (Table 1).

The average time slept in bed on the first two nights of actigraphic measurement was 539.64 minutes (SD 59.96 minutes)

Table 1 Sleep, demographic, and clinical characteristics (frequency or mean ± standard deviation) of the sample (n = 35)

Variable	Mean ± SD (or frequency)
Sleep characteristics	
Actigraphy	
Sleep period (first two nights)	539.64 (minutes) ± 59.96
Sleep period (third night)	533.54 (minutes) ± 59.65
PSG	
Sleep duration (third night, PSG data)	523 (minutes) ± 54.69
Stage 1%	3.45 ± 1.80
Stage 2%	43.56 ± 7.03
Stage 3%	13.19 ± 3.70
Stage 4%	21.66 ± 5.54
REM %	18.14 ± 3.28
Sleep efficiency	95.88 ± .302
Oxygen saturation (minimum)	94.3 ± 1.7
Oxygen saturation (mean)	97.8 ± .62
PLM index	1.83 ± 1.42
MES chronotype score	31.06 ± 3.75
Demographic characteristics	
Gender (male/female)	20/15
Age	8.6 ± 1.12
BMI	18.44 ± 4.05
Ethnic background	
Caucasian	24
African	1
Asian	3
Multiethnic	3
Unknown	4
Clinical characteristics	
IQ	104.54 ± 17.99
CBCL score	49.77 ± 9.2
CTRS-R cognitive problems/inattention T score	48.46 ± 5.65
CTRS-R hyperactivity-impulsivity T score	48.32 ± 6.04

Abbreviations: BMI, body mass index; CBCL, Child Behavior Checklist; CTRS-R, revised Conners Teacher Rating Scale; IQ, intelligence quotient; MES, Morningness–Eveningness Preferences Scale; PLM, periodic limb movement; PSG, polysomnography; REM, rapid eye movement; SD, standard deviation.

Table 2 Results of regression analyses studying main effects of sleep duration on cognitive problems/inattention and hyperactivity-impulsivity on the revised Conners Teacher Rating Scale

Measure	Cognitive problems/inattention	Hyperactivity-impulsivity
	β	β
Control (model 1)		
Age	–0.22	–0.12
BMI	–0.02	–0.21
MES score	0.20	0.20
WISC-IV IQ score	–0.43*	–0.29
Gender	0.22	0.18
Total R^2 (adjusted)	0.28*	0.10
ΔR^2	0.38*	0.25
Main effect (model 2)		
Age	–0.25	–0.04
BMI	–0.034	–0.40
MES score	0.23	0.35
WISC-IV IQ score	–0.31	–0.34
Gender	0.11	0.17
Sleep duration	–0.49*	–0.47
Stage 1%	0.29	0.08
Stage 2%	0.08	0.01
Stage 3%	–0.03	0.35
Stage 4%	0.03	–0.05
REM %	0.09	0.58*
Sleep efficiency	0.15	0.05
Total R^2 (adjusted)	0.49*	0.17
ΔR^2	0.27*	0.23

Notes: *$P \leq 0.05$; β represents standardized partial regression coefficients; R^2 values refer to the variation accounted for by the model; ΔR^2 refers to R^2 change.
Abbreviations: BMI, body mass index; IQ, intelligence quotient; MES, Morningness–Eveningness Preferences Scale; REM, rapid eye movement; WISC-IV, Wechsler Intelligence Scale for Children, 4th edition.

and 533.54 minutes (SD 59.65 minutes) on the PSG night. Sleep duration measured by PSG was 528 minutes (SD 54.69 minutes). No gender or racial difference was evident in average sleep period or average sleep duration.

No significant difference between the sleep period in the two nights preceding PSG evaluation and the sleep period of the PSG night measured by PSG (t [27] = –0.16; $P > 0.05$) was evident. In addition, significant correlation between sleep period, as measured by actigraphy on the PSG night, and sleep duration measured by PSG was found ($r = 0.74$, $P < 0.005$).

To explore whether sleep duration contributed to ADHD-like symptoms in healthy well-developing children, multiple linear regression analyses were performed (Table 2). Multiple linear regression analysis revealed that the addition of sleep duration, percentage of sleep stages, and sleep efficacy to the model significantly increased the R^2 value, contributing 27% to the explained variance ($R^2 = 0.65$; $P < 0.05$) ($\Delta R^2 = 0.27$) (F_{change} [1,29] = 3; $P < 0.05$) after controlling for body mass index, circadian tendency, and IQ in predicting cognitive problems/inattention. Sleep duration was found to be a significant predictor in the model predicting scores on teacher-reported cognitive problems and inattention; individuals with shorter sleep duration received higher scores on this scale.

Sleep variables measured by PSG did not contribute significantly to the prediction of teacher-derived data on hyperactivity.

Discussion

The aim of the present study was to explore whether objective measures of sleep duration are associated with teacher ratings of inattention and hyperactivity/impulsivity in healthy, well-developing preadolescent school-aged children who do not suffer from sleep-disordered breathing, restless leg syndrome, or periodic leg movement disorder. The results showed that shorter sleep duration was associated with higher levels of teacher ratings of cognitive problems and inattention. Specifically, short sleep duration, objectively measured using PSG, was significantly related to teacher reports of difficulties in the realms of learning or memory, in organizational skills, and the ability to be attentive when required. However, no significant association between sleep duration and hyperactivity symptoms was evident.

Several previous reports have found that short sleep duration was related to poorer academic performance when measures such as the Standard Achievement Test scores or school grades were employed (for reviews, see Gruber et al,[4] Dewald et al,[54] and Wolfson and Carskadon[55,56]). The present findings add to such data by demonstrating a strong association between sleep duration and the day-to-day functioning of children in the school environment, as reported by teachers, who were blind to the sleep status of participants. Both lines of investigation converge to show that shorter sleep is associated with the manifestation of inattention and poorer school-related outcomes. However, the mechanisms underlying these associations remain unclear, which is an important question that needs to be addressed in future research.

The findings are consistent with previous data from studies conducted in healthy adults, which found that deficits resulting from sleep deprivation resemble those seen in patients with prefrontal cortex damage.[57] The prefrontal cortex plays a significant role in executive functions,[58,59] and sleep loss preferentially impairs functions governed by the prefrontal cortex. Considering that a deficit in executive functions and prefrontal cortex activity is a core feature associated with ADHD,[60–64] it is not surprising that short sleep duration in healthy children is associated with ADHD-like symptoms. However, because the present study was correlational in nature, the causes and effects were unable to be determined.

In contrast to the conclusions of previous reports,[27,28] short sleep duration was not associated with the manifestation of higher levels of hyperactivity in the present sample of typically developing, non-ADHD school-aged children. Although this is not consistent with previous suggestions regarding the potential impact of sleep deprivation on self-regulation,[65–67] the data are in line with those of recent studies showing that different functional domains are differentially affected by sleep deprivation.[68] The variations in the association between sleep duration and ADHD-like symptoms emphasize the need to better explore these relationships, as well as to better understand the underlying mechanisms.[68]

Sleep duration contributed 27% to the explained variance in inattention and cognitive problems even after IQ was considered. If sleep duration is so significantly associated with the manifestation of such ADHD-like symptoms in otherwise healthy children, it is possible that increasing sleep duration might offer an effective and inexpensive opportunity to optimize the school functioning of healthy children. Sleep does not cost money and does not have any negative side effects. A potential practical path to this end is to incorporate sleep education into the practice of health care providers and pediatricians, and into the health curricula of elementary schools, similar to Cain et al's efforts at establishing motivational school-based interventions.[69] In addition, it is critical to educate parents, students, educators, and clinicians on the importance of sleep and to develop tools aimed at preventing sleep deprivation.

The present study extends prior research in various ways. First, sleep was objectively assessed and an ecologically-based measure of ADHD-like symptoms at school was employed. In addition, healthy school-aged children were studied, excluding those with symptoms of primary sleep disorders or ADHD. Further, sleep parameters were measured at home, increasing the ecological validity of the results.

Limitations

Some limitations of this work are apparent. First, the participants were below the cutoff score on the Pediatric Sleep Questionnaire, had no indication of desaturation, and no paradoxical breathing at the thoracic and abdominal channels; however, the presence of sleep-disordered breathing cannot be completely excluded because of the lack of nasal cannula or thermistor. Second, even if a statistical power analysis indicated that the sample size was sufficient for detection of significant effects, the sample size was still relatively small and the results are thus preliminary in nature.

The data support an association between sleep duration and school cognitive performance; however, the mechanisms and potential causes and effects of such association require further exploration. Although sleep duration explained 27% of variance, there are, clearly, additional variables that affect inattention and cognition in healthy children. Future studies are needed to further identify such variables.

Sleep is also affected by the physical and emotional environment of the child/adolescent. Exposure to light or to an uncomfortable temperature in the evening, a high level of stimulation around bedtime, and a noisy environment have all been shown to compromise the ability to obtain sufficient sleep. In addition to physical features, the emotional environment, affected principally by family interactions (eg, marital conflict), also has a significant impact on sleep processes.[70] In the present study, interference with regular sleep habits and the sleep environment was minimized by using at-home measurement of sleep parameters. However, environmental factors that might impact child sleep were not able to be identified. Future studies should further delimit the physical and environmental factors contributing to shortening of preadolescent sleep duration.

Conclusion

The findings suggest that short sleep duration is related to teacher-derived reports of ADHD-like symptoms of inattention and cognitive functioning in healthy children. The negative impact of sleep deprivation emphasizes the need to provide children and their parents with education on healthy sleep and tools that assist in achieving such sleep.

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Disclosure

The authors report no conflicts of interest in this work.

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