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Nonsignificance of Sleep Relative to IQ and Neuropsychological Scores in Predicting Academic Achievement

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Abstract

Objective—The goal of the study was to determine the relative importance of sleep, IQ, neuropsychological, and attention-deficit/hyperactivity disorder (ADHD) scores in predicting academic achievement.

Method—Objective overnight polysomnograph sleep scores, parent ratings of sleep problems, IQ, neuropsychological test scores, and parent ratings of ADHD were used to predict academic achievement in a general population sample of 412 elementary schoolchildren, 6 to 12 years of age with IQs of 71 to 147.

Results—Using stepwise linear regression analysis, IQ was the best single predictor of reading and math achievement test scores. The most powerful combined predictors of achievement were IQ and some of the neuropsychological test scores. Subjective parent-reported sleep problems and objective polysomnograph scores (apnea-hypopnea index, mean oxygen saturation and lowest saturation percentage during sleep, snoring frequency and severity, sleep latency, minutes to rapid eye movement (REM) sleep, arousal index, number of awakenings, sleep efficiency, and percentage of stage 1, 2, 3, 4, and REM sleep) did not contribute significantly more to the prediction of achievement. Children with and without sleep problems did not differ from each other in achievement. IQ, neuropsychological test scores, and ADHD ratings were all significantly related to achievement, but correlations between achievement and objective and subjective sleep scores were all nonsignificant.

Conclusions—There may be individual children for whom sleep problems affect achievement, but for a large group of community children, sleep was not significantly related to academic functioning. In contrast, IQ and neuropsychological test scores were powerful predictors of achievement.

Index terms

sleep; academic achievement; neuropsychological functioning; attention-deficit/hyperactivity disorder; IQ

Sleep disturbances (difficulty falling or staying asleep) and sleep-disordered breathing together affect up to 50% of children in the general population[1–3] and are common in

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children with neuropsychiatric disorders.[4] Significant associations between sleep disturbance and impaired neuropsychological, behavioral, emotional, and academic functioning have been reported in some studies, though findings are inconsistent and often contradictory. These findings have been interpreted as indicating that sleep problems cause daytime deficits, including low academic achievement.[5–8] For example, the DSM-IV-TR states that children with sleep disordered breathing may have "learning difficulties, poor attention, and hyperactive behavior."[4] The National Institutes of Health state that the extent of sleep disturbances in children is far greater than previously believed and "the consequent impact on mood, neurobehavioral and academic functioning, safety, and health is considerable."[9]

It is certainly reasonable to hypothesize that sleep problems have a negative impact on daytime functioning for some children. However, it is premature to state that sleep problems are a primary cause of academic (or attention, neuropsychological, behavioral, or emotional) problems because existing studies are purely correlational (not causal) and do not consistently support this position. Alternative hypotheses must be considered. The association may not be unidirectional (i.e., mood and behavior problems may cause sleep problems) or causal (i.e., sleep and daytime deficits may be comorbid and have a common neurophysiologic etiology). Further, they may both be related to something else accounting for the association, such as attention-deficit/hyperactivity disorder (ADHD). The majority of children with ADHD have learning, behavior, and neuropsychological deficits,[10–13] and parent-reported sleep problems are common in ADHD.[14–17] These hypotheses are not mutually exclusive and may all be accurate to some degree. Studies specifically designed to test these hypotheses have not yet been conducted.

ACADEMIC ACHIEVEMENT AND SUBJECTIVE SLEEP DISTURBANCE

Studies show significant associations between parent-reported sleep problems and parent-reported academic difficulty.[18–23] However, when achievement is objectively measured using standardized achievement tests, the relationship between sleep and achievement is nonsignificant.[7,24,25] Two studies using grades from school records showed a significant association with parent report of snoring,[8,26] but another did not.[27] Using adolescent self-report, shorter sleep duration was associated with lower grades in one study,[28] but not in another.[29]

Two studies used a control group and analyzed academic functioning before and after adenotonsillectomy in children treated for sleep-disordered breathing. Gozal[30] reported an increase in grade point average from 2.4 to 2.9 following surgery in the treated group and from 2.4 to 2.5 in the control group. However, Montgomery-Downs et al[31] did not find a change in reading readiness scores before and after surgery in preschool children. Because it is not possible to conduct blind, placebo-controlled surgical studies, it is not known whether reported improvement in pre-post studies is the result of placebo response, halo effect, or regression to the mean and not treatment effects.

STUDY PURPOSE

The purpose of our study was to determine the relative importance of sleep, IQ, neuropsychological test scores, and ADHD symptoms in predicting academic achievement in a large community sample of children. It is known that IQ is strongly related to achievement[32–38] and that some neuropsychological test scores are significantly correlated with achievement.[39] It is also well established that ADHD and learning problems have high comorbidity.[11,12] Studies using subjective sleep and achievement measures suggest a significant relationship between sleep problems and low achievement, but the relationship is generally nonsignificant when objective measures are used. No study has yet examined the relative importance of all these variables in predicting academic achievement. Our study includes both subjective and objective measures of sleep and achievement, including (1) overnight polysomnography yielding 14 objective sleep variables, (2) parent-reported sleep problems, (3) standardized academic achievement test scores, (4) parent ratings of school problems, and (5) learning disability diagnosis. As noted by Curcio et al,[40] published studies investigating sleep and academic functioning have relied heavily on subjective report of school problems without using a multimeasure approach that includes individually administered achievement tests. We hypothesize that IQ, neuropsychological test scores, and ADHD ratings will be significantly related to achievement (based on previous research), but that objective and subjective sleep scores may not be associated with achievement, given equivocal findings published to date.

METHODS

Sample

The sample comprised 412 kindergarten through fifth grade students in three school districts who were subjects in a general population epidemiologic study of the prevalence of sleep disorders in children. Questionnaires were sent home to the parents of every elementary student in these districts (n = 7312), with a 78.5% response rate. From this sample, students were invited (using stratified random sampling so that the sample matched the original survey sample on age, gender, race, and risk of sleep-disordered breathing) for further evaluation in the sleep laboratory. Seventy percent of the invited families agreed to participate. The 412 children in our study are all of the children from the larger study who completed the sleep, neuropsychological, and achievement measures of interest in our study. No data were missing for any children in our study. Sixteen children with major medical and neurological conditions (epilepsy, autism, juvenile rheumatoid arthritis, diabetes, and hemophilia) were excluded from the study so that sleep and achievement scores were not confounded by these neuromedical problems. Children diagnosed with mental health or learning disorders (e.g., attention-deficit/hyperactivity disorder ADHD], learning disability, and anxiety disorder) were not excluded from the study. No medication changes were made for any children in the study. The mean age of the sample is 8.6 years (range, 6–12, SD = 1.7), and the mean IQ is 106.6 (range, 71–147, SD = 13.5). Fifty-two percent of the children are male, 74% are white, 20% are black, 5% are Asian, 1% is Hispanic, and 53% have a parent with a professional or managerial occupation. Our study was approved by the Institutional Review Board at Penn State College of Medicine. Informed consent was

obtained from parents of all participants and assent was obtained from all children prior to participation.

Polysomnography

All children underwent a full-night polysomnography with a parent present in a sound-attenuated and light- and temperature-controlled room in our research center. Each child was monitored with an infrared video and a computerized system using Gamma software that includes an electroencephalogram, two-channel bilateral electroculogram, and chin and anterior tibial electromyogram. Respiration was measured throughout the night with a thermocouple at nose and mouth, nasal pressure monitor, and thoracic and abdominal respiratory effort gauges. Snoring sounds were measured by a throat sensor. All night hemoglobin oxygen saturation was obtained by pulse oximeter attached to the finger. A single-channel electrocardiogram was recorded. An apnea event was defined as a cessation of airflow for a minimum of 5 seconds and an out-of-phase strain gauge movement. Hypopnea was defined as a reduction in airflow with an associated decrease in oxygen saturation of at least 3% or an associated arousal.

Fourteen objective polysomnograph sleep scores were used in the data analyses: apnea-hypopnea index (number of apnea or hypopnea events per hour of sleep), sleep latency in minutes, minutes from sleep onset to rapid eye movement (REM) sleep, sleep efficiency (time asleep divided by total time in bed), awakenings (number of wake periods >30 seconds after sleep onset), mean oxygen saturation percentage during sleep, lowest oxygen saturation percentage during sleep, arousal index (mean number of arousals ≥3 seconds per hour), frequency of snoring (none, intermittent, and continuous), snoring severity (none, mild, moderate, and severe), and percentages of stage 1, 2, 3, 4, and REM sleep.

Parent-Reported Sleep, Attention-Deficit/Hyperactivity Disorder, and School Problems Ratings

Parents rated their children on a 4-point scale from “not at all a problem” to “very often a problem” on the 165 items on the Pediatric Behavior Scale (PBS),[41] which yields norm referenced T scores for several clinical subscales. The PBS measures sleep disturbance (difficulty falling and staying asleep), sleep duration relative to the norm, parasomnias (nightmares, sleep walking, and talking in sleep), and daytime sleepiness, and it yields a total sleep problems T score based on norms for the child’s age and gender. Parents also completed the Children’s Sleep-Wake Scale[42] and the Pediatric Sleep Questionnaire. The PBS was chosen as the primary parent report measure because it yields a norm-referenced standard score, unlike the other two measures. In our sample, the PBS total sleep problems score correlated significantly with the total sleep disturbance score on the Children’s Sleep-Wake Scale ($r = .76$, $p < .0001$) and the Pediatric Sleep Questionnaire ($r = .72$, $p < .0001$).

The PBS ADHD subscale consists of 15 ADHD symptoms, and the School Problems subscale comprises seven items (e.g., “has trouble learning even when tries hard” and “gets low grades on school papers or tests”). The PBS significantly differentiates between diagnostic groups and has been used to evaluate ADHD and behavior, mood, sleep, school, and health problems in several published studies.[10–12,41,44,45]

Psychological Tests

Children completed the following tests: (1) Wechsler Abbreviated Scale of Intelligence; (2) Wide Range Achievement Test–Third Edition Reading and Arithmetic subtests; (3) Vigilance and Distractibility subtests from the Gordon Diagnostic System,[46] a computerized continuous performance test that measures attention; (4) Wechsler Intelligence Scale for Children–III (WISC-III) Digit Span subtest (requiring the child to repeat numbers after the evaluator in forward and reverse order to assess attention and working memory); (5) Developmental Test of Visual-Motor Integration,[47] an untimed test on which the child copies geometric forms with a pencil; (6) WISC-III Coding subtest, a timed test requiring the child to quickly copy geometric forms; (7) Animal Naming Test[48] measuring verbal fluency by having the child name as many animals as possible in 1 minute; and (8) California Verbal Learning Test,[49] on which children recall as many words as possible from a list of 15 fruits, clothes, and toys read by the evaluator across the five trials.

Data Analyses

Stepwise linear regression analysis (with the effect size statistic R^2) was used to determine explained variance and the most powerful predictors of reading and math standard scores using intelligence, neuropsychological, ADHD, and sleep scores. Pearson correlation coefficients and the effect size statistic r^2 were calculated to determine the degree of relationship between variables and the proportion of explained variance. The significance of differences in variable frequencies between groups was calculated using χ^2. Independent t tests and Cohen's d effect size determined differences between groups. In analyses based on parent report, ADHD ratings were covaried using analysis of covariance because ADHD is associated with both learning problems[11] and parent-reported sleep problems.[14–17,50,51] A probability level of .01 was chosen for statistical significance because of the large number of comparisons.

RESULTS

Reading Predictors and Correlates

IQ, the six neuropsychological test scores, parent attention-deficit/hyperactivity disorder (ADHD) rating, parent ratings on the three sleep subscales (sleep disturbance, parasomnias, and total sleep problems), and 14 objective sleep laboratory scores were entered in stepwise linear regression analysis to predict reading test scores. The most powerful predictors were IQ, Digit Span, and Developmental Test of Visual-Motor Integration scores. Explained variance for IQ alone was 31% ($R = .56$), which increased to 39% ($R = .62$) with the addition of Digit Span, and 42% ($R = .64$) for IQ, Digit Span, and Developmental Test of Visual-Motor Integration. The four remaining neuropsychological test scores, the parent sleep and ADHD ratings, and the 14 objective sleep scores did not add significantly more to the prediction of reading achievement. Correlations between reading scores and the 14 objective sleep scores and the parent ratings of sleep problems (−0.12 to 0.12) were all small and nonsignificant at 0.01. Parent ratings of ADHD were significantly negatively related to reading achievement ($r = -.25$, $p < .0001$), indicating that reading achievement scores decreased as parent-reported ADHD symptoms increased. All psychological test scores were significantly related to reading scores ($r = .19–.56$, $p < .0001$), with the exception of the

Animal Naming Test (r = .08, p = .09). Correlations between achievement, IQ, sleep, and neuropsychological scores are reported in Table 1.

Math Predictors and Correlates

When stepwise linear regression analysis was used to predict math achievement test scores from the IQ, six psychological test scores, parent ratings of ADHD and sleep problems, and 14 objective sleep scores, the most powerful predictors were IQ, Developmental Test of Visual-Motor Integration, Digit Span, Coding, Gordon Diagnostic System, and California Verbal Learning Test scores. Explained variance for IQ alone was 27% (R = .52), which increased from 33% to 40% (R = .57 to .63) with the addition of the other significant predictors. The remaining neuropsychological test score (Animal Naming Test), the ADHD score, and the 14 objective and three subjective sleep scores did not add significantly to the prediction of math achievement. Correlations between math scores and the 14 objective sleep scores and the parent ratings of sleep problems (−0.11 to 0.12) were all small and nonsignificant at .01. An increase in parent-reported ADHD symptoms was significantly related to a decrease in math achievement (r = −.25, p < .0001). All psychological test scores were significantly related to math (r = .18 to .52, p < .0001).

Sleep Problems and Achievement

There were no statistically significant differences in math achievement scores between children with and without objectively and subjectively measured sleep problems (Table 2). Results were similar for reading, with the exception of a difference for parent-reported sleep problems. However, this was nonsignificant when the parent ADHD rating was covaried. The clinical significance of all differences was small (d = 0.04 to 0.37, mean d = 0.16). For children with apnea-hypopnea indexes >5, four had average to above average IQs and achievement and no diagnosis of ADHD. The remaining child had below average IQ and achievement scores and a previous diagnosis of ADHD. Four children had exceptionally high parent ratings of sleep problems on the Pediatric Behavior Scale. Three had average to above average IQs and achievement and no diagnoses of ADHD or learning disability. One had previous diagnoses of both ADHD and learning disability and performed overall in the low average range on the IQ and achievement tests. None of the children with exceptionally high parent ratings of sleep problems had apnea-hypopnea indexes >5 and vice versa.

Learning Problems and Sleep

As shown in Table 3, objective sleep scores did not differ significantly between children identified by their schools as having a learning disability (n = 29) versus not having a learning disability (n = 383) and between children with (n = 94) and without (n = 318) parent-reported academic problems (Pediatric Behavior Scale School Problems T score ≥65). Differences in the frequency of children who did and did not snore were not significant between children with and without a learning disability (χ^2 = 1.4, p = .23) and between children with and without parent-reported academic problems (χ^2 = 0.0, p = .98). Greater parent-reported sleep problems were found in children with (versus without) academic problems, but this difference was not significant when parent ratings of ADHD were covaried.

Sleep, Attention-Deficit/Hyperactivity Disorder Symptoms, and Achievement

Correlations between achievement scores and parent ADHD ratings were significant ($p < .0001$), whereas relationships between achievement and subjective and objective sleep scores were all nonsignificant at .01. Parent ADHD ratings correlated significantly with parent ratings of total sleep problems ($r = .48$, $p < .0001$), but not with any of the 14 objective sleep measures ($p > .01$).

DISCUSSION

Our study is the first to comprehensively analyze the relationship between academic achievement and sleep using extensive objective and subjective measures of sleep and achievement and the first to determine the relative importance of sleep, IQ, neuropsychological scores, and attention-deficit/hyperactivity disorder (ADHD) symptoms in predicting achievement. When IQ, six neuropsychological test scores, parent ADHD ratings, and 14 objective and three subjective measures of sleep were entered as predictor variables, IQ was the best single predictor of reading and math achievement test scores, explaining 31% and 27%, respectively, of the variance. The primary importance of IQ in determining achievement is consistent with findings from other studies.[32–38] The most powerful combined predictors of achievement in our study were IQ and some of the neuropsychological test scores, explaining 42% of the reading variance and 40% of the math variance. The 14 objective polysomnograph and three parent-reported sleep problems scores did not contribute significantly more to the prediction of achievement.

Correlations between achievement and IQ, neuropsychological test scores, and ADHD parent ratings were all significant, whereas correlations between achievement and objective and subjective sleep scores were all nonsignificant. This is consistent with previous studies demonstrating that achievement measured by standardized achievement tests is not significantly related to sleep problems.[24,25] Further, studies have also shown that severity of sleep-disordered breathing does not correspond with severity of ADHD symptoms,[16,52] neuropsychological test scores,[25,53–55] and parent ratings of mood and behavior problems.[54–56]

Urschitz et al[26] found a nonsignificant association between academic grades and hypoxia events, but a significant relationship between math grades and the child's lowest nighttime oxygen saturation percentage.[57] In our study, none of the sleep-disordered breathing indices, including lowest oxygen saturation percentage, were significantly related to any of the achievement measures. However, a limitation of our study is the small number of children with severe sleep-disordered breathing. Future research will need to assess the relationship between achievement and sleep using a sample that has sufficiently large numbers of children representing all levels of sleep-disordered breathing and other sleep problems. Another limitation of our study is that the Wide Range Achievement Test Reading and Arithmetic subtests assess only word reading and math computation skills. Future studies should include measures of reading comprehension and writing, as well as teacher ratings of achievement.

Earlier studies suggest that when achievement and sleep are both subjectively measured, the relationship between the two is significant.[18–23,58,59] In our study, children with versus without parent-reported academic problems did not differ on objective sleep dimensions, but did on parent-reported sleep problems, perhaps in part because of common source variance (i.e., both sleep and academic problems were ratings by the same parent using the same rating scale). However, this difference was nonsignificant when the effects of parent-reported ADHD symptoms were removed.

The relationship between ADHD and sleep is in need of much further study. Studies report contradictory findings on differences in apnea-hypopnea indexes between children with ADHD and controls.[60–62] Parent-reported sleep problems are common in ADHD.[14–17] In contrast, objective polysomnograph sleep data generally do not show differences between children with ADHD and controls in terms of sleep latency and efficiency, nighttime awakenings, and sleep stages,[60–65] and the relationship between severity of ADHD symptoms and severity of sleep-disordered breathing is nonsignificant.[16,52] Our study is consistent with the preponderance of previous research and showed a significant association between parent-reported ADHD symptoms and parent-reported sleep problems, but not between ADHD symptoms and 14 objective polysomnograph sleep measures. The correlation between parent ratings of ADHD and sleep problems may be inflated somewhat by common source variance, which would not be a factor when objective sleep measures are used. Further, the relationship between parent report of ADHD symptoms and sleep problems may partially be because both are to some degree behavioral.

Findings in previous studies regarding the relationship between sleep and academic achievement and between sleep and ADHD symptoms differ depending on whether sleep is subjectively or objectively defined. This suggests that the two methods of evaluation are measuring different sleep dimensions. Parent-reported sleep problems may primarily reflect observable, behavioral aspects of sleep, whereas objective sleep laboratory data may primarily reflect physiologic aspects of sleep.

Some previous studies show an association between sleep and daytime deficits, though findings are inconsistent and contradictory. These studies demonstrate a possible correlation, but not causation. The relationship between subjective report of sleep problems and subjective report of achievement[18–23,58,59] may be because both sleep and academic problems are related to behavior, mood, parenting, or other problems common to both and not because of a direct causal relationship between sleep and achievement. Sleep and daytime deficits, including low achievement, may have a common neurophysiologic etiology or they may both be related to something else, accounting for the association. For example, children with (vs without) sleep problems have parents with lower educational levels and professional status,[21] which may account for the lower school achievement. Similarly, lax parenting discipline style has been associated with sleep disturbance,[66] and this style may also be associated with low child achievement.

In conclusion, our study showed that parent report of sleep problems and objective polysomnograph sleep scores did not contribute significantly to the prediction of reading and math achievement in a general population of 412 elementary schoolchildren. IQ was the best

single predictor of achievement, and IQ and some neuropsychological test scores were the most powerful combined predictors of achievement. Further, IQ, neuropsychological test scores, and ADHD parent ratings were all significantly related to achievement, but correlations between achievement and objective and subjective sleep scores were all nonsignificant. There certainly may be individual children for whom sleep problems affect academic achievement, but for a large group of community children, sleep was not significantly related to academic functioning, whereas IQ and neuropsychological test scores were powerful predictors of achievement.

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Table 1

Correlations Between Achievement, IQ, Sleep, and Neuropsychological Scores (n = 412)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Reading													
2 Math	0.55												
3 FSIQ	0.56	0.52											
4 Apnea-hypopnea Index	−0.05	−0.04	0.00										
5 Sleep efficiency	−0.12	−0.00	−0.09	−0.00									
6 Sleep problems rating	−0.12	−0.09	−0.09	0.07	0.07								
7 ADHD rating	−0.25	−0.25	−0.22	−0.00	0.12	0.48							
8 Digit Span	0.49	0.40	0.44	−0.05	−0.09	−0.12	−0.17						
9 Animal Naming Test	0.08	0.18	0.28	−0.03	0.05	−0.04	−0.02	0.15					
10 Coding	0.19	0.32	0.24	0.00	0.01	−0.13	−0.23	0.18	0.19				
11 Visual-Motor Integration	0.41	0.44	0.45	−0.01	−0.07	−0.13	−0.29	0.24	0.07	0.20			
12 Gordon Diagnostic	0.28	0.34	0.40	−0.04	−0.13	−0.07	−0.18	0.24	0.19	0.15	0.23		
13 California Verbal Learning	0.20	0.26	0.28	0.06	−0.04	−0.06	−0.11	0.12	0.33	0.22	0.15	0.15	

FSIQ, Full Scale IQ.

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Table 2

Mean Achievement Standard Scores for Children with and without Sleep Problems (n = 412)

	Reading Scores			Math Scores		
	Sleep Problem	**No Problem**	***t* (*p*)**	**Sleep Problem**	**No Problem**	***t* (*p*)**
Apnea-hypopnea index ≥1 (n = 87)	106	108	0.8 (.40)	104	104	0.3 (.76)
Apnea-hypopnea index ≥5 (n = 5)	103	108	0.7 (.47)	99	104	0.8 (.42)
Snores (n = 110)	106	108	0.9 (.37)	103	105	0.8 (.40)
Parent-reported sleep problems *T* ≥ 65 (n = 116)	105	109	2.6 (.01)[a]	102	105	1.9 (.06)

[a]Nonsignificant covarying for parent attention-deficit/hyperactivity disorder rating (F = 0.1, *p* = .70).

Table 3

Mean Sleep Scores for Children with and without Learning Problems (n = 412)

	Learning Disability (LD)			Parent-Reported School Problems		
	LD	**No**	**F (*p*)**	**Yes**	**No**	**F (*p*)**
Apnea-hypopnea index	0.5	0.8	1.3 (.19)	0.9	0.7	1.0 (.33)
Mean oxygen saturation	97%	97%	0.8 (.45)		97%	0.4 (.68)
Lowest oxygen saturation	93%	93%	0.4 (.67)	93%	93%	1.0 (.33)
Snoring severity	0.2	0.3	1.3 (.20)	0.4	0.3	0.8 (.41)
Sleep latency, min	20.5	29.3	1.8 (.07)	28.0	28.9	0.3 (.78)
Arousal index	3.3	3.1	0.4 (.69)	3.4	3.1	1.1 (.27)
% Stage 1	2.3	3.5	1.9 (.06)	3.2	3.5	0.9 (.39)
% REM	22.3	19.8	2.4 (.02)	19.6	20.1	0.7 (.47)
Sleep efficiency	89%	86%	1.9 (.06)	87%	86%	1.5 (.13)
Parent-reported sleep problems *T* score	73	58	4.4 (.000)[a]	69	57	5.6 (.000)[b]

[a] Covarying parent ADHD rating F = 3.7, $p = .06$.

[b] Covarying parent attention-deficit/hyperactivity disorder rating F = 0.6, $p = .44$.