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CLINICAL REVIEW

Understanding adolescents' sleep patterns and school performance: a critical appraisal

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Summary The present paper reviews and critiques studies assessing the relation between sleep patterns, sleep quality, and school performance of adolescents attending middle school, high school, and/or college. The majority of studies relied on self-report, yet the researchers approached the question with different designs and measures. Specifically, studies looked at (1) sleep/wake patterns and usual grades, (2) school start time and phase preference in relation to sleep habits and quality and academic performance, and (3) sleep patterns and classroom performance (e.g., examination grades). The findings strongly indicate that self-reported shortened total sleep time, erratic sleep/wake schedules, late bed and rise times, and poor sleep quality are negatively associated with academic performance for adolescents from middle school through the college years. Limitations of the current published studies are also discussed in detail in this review.

INTRODUCTION

Sleep researchers and clinicians, as well as parents and teachers have had a hunch for years that children and adolescents do not seem to function well in school or at home after a slumber party, a late night out to see a hockey game or movie, or without getting enough sleep for a variety of other reasons. In 1913, researchers Terman and Hocking argued that the key question was, "What is the optimal amount of sleep for physical and mental efficiency?" [1]. Although sleep medicine practitioners have long had a strong sense that irregular sleep schedules or inadequate sleep may lead to poor school performance, the current database has reached a level that makes it useful to draw research-based conclusions about the impact of sleep on school performance.

The availability of data on factors affecting school performance is important because conclusions are sometimes drawn based on "experience" rather than "experiment". As Meehl articulated in *Clinical Versus Statistical Prediction* [2] and has been demonstrated empirically, clinical observations, judgments, and experiences are inherently unreliable measures of human behavior [3, 4]. Meehl, in particular, argued that the place of clinical observation in the behavioral sciences is only as a source of hypotheses that may be built into a theory, not the substance of conclusion. Until quantitative data establish an acceptable level of scientific support, clinical observations are hunches and not facts. Meehl also argued that one must acknowledge when a methodology is flawed, and therefore, findings may not be meaningful regardless

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of statistical significance [2]. Furthermore, Meehl made it clear that data collection should not stop after completing one study (i.e., "significant" or "not significant"), as only the accumulation of data can be informative [2]. Phenomena such as school performance that are highly complex need aggregation on many levels to reveal reliable processes.

The sleep research field has utilized reliable and valid methodologies for studying sleep–polysomnography, the Multiple Sleep Latency Test (MSLT), actigraphy, and other procedures. The sleep field has been less systematic, however, in attempts to understand sleep's relations to other aspects of human functioning, such as school performance. Although a clear theoretical basis exists for analyzing the associations between sleep habits and academic performance, certain investigators (ourselves included) have made assumptions about how to measure school performance in their attempts to understand the impact of poor sleep habits on school performance. Such assumptions may lead to inadequate appraisal of the phenomenon.

Behavioral scientists use various approaches to assess school performance, however controversy has existed regarding the best method. Academic performance has been assessed through such modalities, grade point average (based on self-report or actual records), self-reported average grades, teacher comments or behavior ratings, school behavior, and parent report. Moreover, a variety of time frames and outcome measures have been utilized: quarterly or semester reports, weekly evaluations, pop quizzes, final exams, standardized tests, tardiness/absenteeism records, graduation, and retention rates. School systems also have varied ratings systems. For example, 68 in one school district may be equivalent to a "D", whereas it may reflect an "F" in another system. On the one hand, the variety of outcome measures may cloud relationships and make it difficult to compare results across studies. Yet, at the same time, use of multiple measures for assessing school performance within a specific study may strengthen the findings.[1]

Much of the behavioral sciences research in this area of school performance has stemmed from a concern by school administrators, teachers, school nurses, parents, and researchers with the relation between children's and adolescents' health (e.g., nutritional lunches, physical education, etc.) and school performance [5, 6]. For example, investigators have shown that the US Department of Agriculture School Breakfast program reduced tardiness and absenteeism, particularly for those students at greatest risk [7]. Other health researchers have looked at the relationship between school-based health clinics and adolescents' school performance. Specifically, McCord and colleagues examined the effect of health clinic use on at-risk high school students' absences, suspensions, withdrawals, and graduation or promotion rates [8]. They found that students who used the clinic were significantly more likely to remain in school and to graduate or be promoted in comparison to students who were not registered for the clinic.

A number of researchers have also attempted to evaluate the association of sleep habits and academic performance. Since the 1980s, six studies of sleep habits and some aspect of academic performance have been published as abstracts, eight peer-reviewed articles, and one professional report/book (see Table 1). These studies were based almost entirely on self-report for grades and sleep habits; sample sizes ranged from approximately 100–6000 participants; participants' ages (grade in school) ranged from 5th grade through first year in college; and the educational setting varied (i.e., public, independent schools, universities, and variety of countries). The majority of these studies operationally defined academic performance as self-reported Grade Point Average (GPA); however, a few researchers looked at other aspects of school performance, such as concentration/attention, achievement motivation, and attendance/tardiness. While most of the studies focused on self-reported sleep/wake habits, such as bedtime, rise time, and total sleep, others focused more on self-reported sleep quality. All of the studies to date relied on self-reported sleep/wake habits rather than actigraphically estimated sleep and/or polysomnography. It is noteworthy that our lab recently demonstrated the validity of self-report survey estimates of sleep patterns in adolescents through a comparison of retrospective survey descriptions of usual sleep habits with diary-reported and actigraphically estimated sleep behaviors [9].

Moreover, the hypotheses and theories driving the studies have varied. For example, the first studies discussed below assumed that the key relationship is between sleep patterns and school performance,

[1]This review focuses primarily on school performance operationalized as academic grades, in-school tests, etc. as opposed to laboratory performance. Other researchers have focused on laborabory models of performance. For example, Fallone and colleagues provide a thorough review of children's sleepiness and performance (e.g., attention, motor skills, problem-solving, cognitive ability, etc.) in laboratory studies [47].

Table 1. Sleep habits, sleep quality and school performance studies in preadolescents, adolescents, and college-age students

Study	Publication type	Sample size	Age	Sex	Location	Sleep variable(s)	School performance variable(s)	Other variables to explain school performance	Key findings
Sleep/wake patterns and grades									
Link & Ancoli-Israel (*Sleep Res*, '95)	Abstract	150	15–18 ($M = 16.2$)	63% female	Public HS, Southern CA	Self-report BT, RT, TST, # naps, sleepiness	Self-report GPA		More TST, dec. sleepiness, higher GPA
Kahn *et al.* (*Pediatrics*, '89); Blum *et al.* (*Sleep Res*, '90)	Peer Rev. Journal; Abstract	972	8–10	46% female	5 Belgium schools	Parent report Poor sleepers vs Good sleepers	Unclear how school achievement defined	Parental education	Poor sleepers more school problems than good; Fatigue and parent educ. best predictors for school failure
Hofman & Steenhof (*Sleep/Wake Res*, Netherlands, '97)	Peer-Rev. Journal	604	12–18		6 high schools, Utrecht, Netherlands (3 levels of education, not clearly explained)	Self-report BT, RT, sleep lag, time in bed (TIB), alertness, sleep quality	Self-report (not explained)	Drug use, level of educ	School perf. related to sleep quality, inc. TIB, small sleep lag
Wolfson & Carskadon (*Child Dev*, '98)	Peer-Rev. Journal	3120	13–19	52% female	4 Public HS in So. New England, 3 Districts	Survey TST, BT, RT (school/ weekend) Weekend delay, oversleep	Self-report survey of usual grades		A/B students earlier BT, RT, inc. regularity than C, D, F students
Trockel *et al.* (*J Amer College Health*, '00)	Peer Rev. Journal	185	1st yr. college, living in dorms	Not reported	University	Survey/tel. Interview: BT, RT, TST	Semester GPA from student records	Exercise, eating, mood, stress, social support, religious habits	Regression: sleep habits (later RT) assoc. low GPA vs other var ($B = -0.37$).
Kelly *et al.* (*College Student Journal*, '01)	Peer Rev. Journal	148	18–42 ($M = 19.9$)	51% female	University Intro. Psych. class	$\leq$6 h (23), 7–8 h (107), $\geq$9 (18) compared	Self-report overall college GPA	Sex	Short sleepers lower GPA than long

Table I *continued*

Study	Publication type	Sample size	Age	Sex	Location	Sleep variable(s)	School performance variable(s)	Other variables to explain school performance	Key findings
School start and phase preference									
Allen (*Sleep Res*, 1992)	Abstract	102	Grade 12 (age not specified)	Not reported	2 schools SST: 7:40 SST: 8:30 Human behavior classes, but diff. years	Self-report: sleep latency, TST, BT, RT	Self-report grades, but question not published	# parties, work hours, alcohol consumed	Students with aver. grades later BT than A & B+; parties & wk hrs correl. with late BT & lower grades
Epstein *et al.* (*Sleep*, '98)	Peer Rev. Journal	811	10–12 ($M = 10.6$)	Not reported	18 schools Israel	Self-report 3 SST (7:10, 7:20–7:55, 8:00) BT, RT, TST sleepiness (Epstein *et al.*, '97; Zomer *et al.*, '84)	Self-report: attention, concentration in school (likert scales from Epstein *et al.*, '97; Zomer *et al.*, '84)	Morningness/ Eveningness (Horne & Ostberg, '76)	Inc. complaints re: attn./conc. early start students
Wahlstrom (*CAREI*, 2001)	Technical report, volume II	7168	10–12	Not known	3 districts	Self-report 3 SST (8:30, 7:25, 7:15) BT, RT, TST, sleepiness, sleep/ wake behavior prob. (questionnaire, Wolfson & Carskadon, '98)	Self-report on survey of usual grades	Depressed mood, work hours, other daytime functioning questions	Students with better grades: earlier school-night BT, later RT, more TST, fewer sleep prob., later SST district
Cortesi *et al.* (*Sleep Res*, 1997); Giannotti *et al.* (*Sleep Res*, 1997)	Abstracts	3040	13.8–20.2	60% female	Students in Italy	Revised, translated Sleep Habits Questionnaire (Wolfson & Carskadon, '98) TST, BT, RT, sleepiness, sleep problems	Self-report of usual grades	M/E scale (not defined)	E-types: poor school achievement, fell asleep in class, later BT, RT, less TST; Dec. TST & inc sleepiness assoc. poor school achievement

Lack (*College Health*, 1986)	Peer Rev. Journal	211	1st yr. College students (16–50, $M = 23$)	65% female	1st year Psych. Students, Univ. So. Australia	Self-report: BT, RT, sleep quality, sleep difficulties; criteria for DSPS	Self-report final first-yr psych. course grade		DSPS group lower grades vs other sleep disturbance group & rest of sample
Wahlstrom (*CAREI*, 2001; book chapter, in press)	Exec. Report; Book Chapter	Approx. 18000	grades 9–12	Not known	Minneapolis School District	Self-report (Wolfson & Carskadon, '98)	Attendance, enrollment, grades from school records		SST change: improved attendance, enrollment, slight improv. grades, & increased TST
Sleep, classroom performance, and other outcome measures									
Horn & Dollinger (*J School Psychol*, 1989)	Peer Rev. Journal	239	grades 6 & 7 ($M = 12.0$)	49% females	Rural midwestern school	Self-report sleep latency, TST, sleep complaints, restedness	Examination grades	Self-report anxiety scale, vigilence test	More restedness assoc. better perf. on no-exam day vs exam-day
Meijer *et al.* (*J Sleep Res*, 2000)	Peer Rev. Journal	449	grades 7 & 8 9.4–14.4 ($M = 11.25$)	46% female	7 schools, Amsterdam	Self-report (measure pub. with study) TIB, get up time, BT, quality of sleep scale (alpha = 0.72)	Concentration: (Bourdon-Vos, '92) school funt: School Perception Q. (Van der Wolf, '95)	Controlled for sex, age, mental health symptoms	Sleep quality assoc, school function, particularly achiev. motivation; TIB, BT, get up time not related to school funct.

whereas other studies attempted to look at school start times, sleep, and grades or circadian rhythms factors (e.g., comparing grades of owls vs larks), sleep and academic performance. This literature is reviewed in the sections that follow. Table 1 provides a summary of the papers under discussion.

SLEEP AND ACADEMIC PERFORMANCE

Sleep–wake patterns and grades

We focus here principally on studies in which survey data on sleep habits and academic performance was collected from middle school, high school, or first-year college students. In an abstract report, Link and Ancoli-Israel assessed the sleep and grades of high school students in a survey study of 150 high school students [10]. Students were asked to report their GPAs and sleep/wake schedules. Students with higher GPAs reported later school rise times, earlier rise times on weekends, shorter sleep latencies, fewer night wakings, and fewer school day naps. The study included a comparison of sleep habits for students with GPAs $\geq$ 3.5 and those with GPAs $<$ 3.5. The students with lower GPAs reported signs of daytime sleepiness (falling asleep or fighting to stay awake while riding bus/car) more frequently; the students with better grades woke up later on school mornings, woke up less often during night, and took fewer naps. Another noteworthy finding was a trend for the students who reported better grades to report sleeping longer on school nights (7.4 vs 7 h).

In another study, Kahn and colleagues reported data on 972 older children and preadolescents in Belgium [11]. In this study, participants' parents completed a questionnaire focused on quantity and quality of sleep, family background, children's daytime behavior, and school achievements. Poor versus good sleepers were compared (e.g., poor sleep was defined as the report of sleep latency longer than 30 min plus more than one arousal per night on at least 2 nights per week). Fourteen percent of the participants were classified as poor sleepers. Although it was not clear how school performance was assessed in this study, it seemed to be based on whether or not the study participant met academic requirements for their grade (e.g., failed or behind in school) as reported by the parent. Among these poor sleepers, 21% failed at school and were behind in grade by one or more years. School achievement difficulties were significantly more frequent among the poor sleepers than among youngsters without sleep difficulties. In a later abstract report [12] based on the same sample, a regression analysis showed that the best predictors of school failure were the children's fatigue (operationalized as difficulty to arouse in the morning and need for at least one daytime nap) as well as the parents' educational level.

In another study of European adolescents, Hofman and Steenhof surveyed about 600 Dutch high school students [13]. The survey queried sleep habits, sleep quality, and school performance, and the following sleep variables were derived: weekday bedtime, rise time, weekend bedtime, rise time, sleep lag (difference) between weekday and weekend bedtimes and rise times), time of peak alertness, sleep quality, and total time in bed. It is unclear how school performance was operationalized in this report. Using a multiple regression analysis, these investigators found an association of better school performance with more time in bed, better sleep quality, and a shorted sleep lag. They pointed out that better school performance was also related to reduced reported drug use (e.g., alcohol, caffeine, nicotine).

The report of Wolfson and Carskadon [14] supported and extended findings from a number of these studies. About 3000 high school students in southern New England completed a Sleep Habits Survey. The survey included items for usual bedtimes, rise times, and total sleep times and a number of other questions about sleep habits. The Survey also asked the students to select a category that represents his/her usual grade (e.g., mostly As, As & Bs, mostly Bs, etc.). The study found that high school students with self-reported higher grades reported significantly more total sleep and earlier bedtimes on school nights than did students with lower grades ($p < 0.001$). These sleep habits differences distinguished students reporting Cs and worse from those reporting mostly Bs or better. Specifically, students reporting mostly Bs or better reported getting, on average school nights, 17–33 min more total sleep and going to bed 10–50 min earlier than C and D/F students. Students' weekend sleep habits also differed according to self-reported grades: A and B students reported earlier bedtimes and earlier rise times than did C and D/F students; however, self-reported grades did not distinguish the students on reported weekend total sleep. Finally, students with worse grades reported greater weekend delays of their sleep schedules than did those with better grades. Thus, C and D/F students reported going to bed on average about 2.3 h later on weekends than on

school-nights versus a difference of about 1.8 h for the A and B students.

A few studies examined the relationship between sleep/wake patterns and academic performance in older adolescent college students. Trockel and colleagues [15] either interviewed or surveyed a total of 200 randomly selected first-year college students regarding sleep/wake habits, exercise, eating, mood, perceived stress, social support and religious habits. With permission from the participants, they also obtained their GPAs from the university registrar. Of all the variables considered, sleep habits, particularly wake-up times, accounted for the largest amount of variance in grade point averages. Later weekday and weekend wake up times, later weekday and weekend bedtimes, and greater numbers of work hours (paid/volunteer) were associated with lower grade point averages. For each hour of delay in reported average weekday rise time, the predicted GPA decreased by 0.13 on a standard grade scale of 0–4.0. Eating habits, mood, stress, time management, and social support were not associated with these first-year college students' grades. Strength training and study of spiritually oriented material were somewhat correlated with higher grade point averages. According to the authors, the relationship between earlier bedtimes and wake times and higher GPA was the most significant study finding, lending moderate support for the hypothesis that sleep habits account for variance in first-year college students' academic performance [15].

In another recent study of college students, investigators found that short sleepers reported significantly lower overall grade point averages than did long sleepers [16]. The researchers surveyed nearly 150 introductory psychology students regarding their backgrounds, average sleep length, and overall college GPAs. Although there were no age or sex differences, long sleepers ($\geq$9 h/night) reported significantly higher GPAs than short sleepers ($\leq$6 h/night) (GPA = 3.24 vs 2.74). Grades of average sleepers (7–8 h/night) were not significantly different from those of long or short sleepers. These results support the hypothesis that long sleepers or those who obtain more total night time sleep tend to report better or higher grades (GPAs) than short sleepers.

These studies demonstrate a number of strengths and shortcomings. It is striking that although a cause-and-effect relationship has not been established, these studies collectively suggest that self-reported diminished total sleep quantity, delayed and/or erratic sleep schedules, later weekend rise times, longer sleep latencies, and increased daytime sleepiness contribute to older adolescents' poor school performance for preadolescents through first-year college students. Moreover, although these studies relied on a variety of measures for assessing both sleep patterns and academic grades; their overall results are comparable. On the other hand, there are several shortcomings. First, data are difficult to compare across studies because of the differences in sleep variables, grading systems, and lack of information on the participants' backgrounds, living situations, and school environments. Second, a few of these studies were published only in an abstract format, which limited the amount of detail on methods, measures, background on participants and so forth [10, 12]. Third, some of the studies provided minimal information on how school performance or achievement was measured or operationally defined [11, 13].

School start and phase preference

A small number of studies has approached the issue of sleep and school performance from a school schedule or circadian rhythm perspective. These studies compared sleep/wake patterns and academic performance for early versus late starting schools or for students with a morning-type phase preference versus those with an evening-type phase preference.

In a small-scale study, Allen [17] compared 12th graders with a 7:40 am school start time ($n = 72$) to 12th graders attending a high school with an 8:30 am start ($n = 30$). These students completed a sleep–wake questionnaire in human behavior class. Items covered school and weekend sleep patterns, work hours, average grades, weekend social habits, and alcohol use. Compared to students attending the later starting school, the students with the earlier start time reported shorter school-night total sleep times, more sleep problems, and sleeping in later on weekends. For all students, later weekend bedtimes were associated with poorer grades, later weekend parties, and later employment hours. The investigators pointed out that 15% of students reporting highest grades (A–B+) described going to bed after 2:30 am on weekends, whereas 35% of the students with "average grades" reported such late bedtimes. Although this brief report indicated a relationship between sleep patterns and school performance, average grades did not differ for students with early versus late school start times [17].

In the report of Epstein and colleagues [18] school start times, sleep habits, and performance were examined in a large number of Israeli children and teenagers ($n = 6495$) from 40 schools: 2764 were elementary school students; 607 were attending junior high schools; and 3122 were in high schools. These investigators reported significant correlations of reported total sleep time with ability to concentrate in school, tendency to doze off during classes, and frequency of school tardiness. In another study reported by the same researchers [19], just over 800 Israeli fifth graders were surveyed. These preadolescents attended schools with starting times that ranged from 7:10–8:30 am. The investigators compared those that started at least two days per week at 7:15 am or earlier with those that started regularly at 8:00 am. Mean total sleep times of the students attending the schools with early start times were significantly shorter than those students at the later starting schools. The former group expressed more frequent complaints of daytime fatigue and sleepiness throughout the school day, a greater tendency to doze off in class, and attention/concentration difficulties in school. It is noteworthy that these complaints were not associated with their total sleep times. Moreover, average school night total sleep time for the early group was 8.7 vs 9.1 h for the later-starting group. Students with the earlier school start also reported feeling most tired during their first class of the day. Epstein and colleagues concluded that early start times negatively influence sleep and, therefore, have a negative impact on daytime functioning in school [19].

Wahlstrom and colleagues [20] also examined differences among districts with different high school start times. These researchers compared sleep habits and daytime functioning of high school students ($n = 7168$) from three school districts in the Minneapolis/St Paul, Minnesota area. District A started classes each day at 8:30 am, whereas Districts B and C started at 7:25 am and 7:15 am, respectively. Similar to Wolfson and Carskadon [14], they found that students who get better grades tend to go to bed earlier and get more total sleep on school nights. This was particularly true for A and B students versus D/F students. Furthermore, high school students in District A reported similar bedtimes to students in Districts B and C; however, they reported getting up about one hour later and obtaining about an hour more sleep on school nights ($p < 0.0001$). Weekend sleep habits did not differ among students in these districts. Students in District A reported fewer sleep/behavior problems than students in the other two districts. Finally, District A students reported that they earned higher grades than did District B and C students.

Other studies have examined at the relationship between circadian phase preference (morningness/eveningness) and school functioning. Cortesi and colleagues [21] utilized a self-report sleep habits questionnaire [14] and a morningness/eveningness scale (not defined), to assess these issues in just over 3000 Italian teenagers. Evening types reported poorer school achievement and a greater tendency to fall asleep in school. Also, evening types reported later bedtimes on school and weekend nights, later rise times, longer sleep latencies, and slept less on school nights (455 vs 481 min), but more sleep on weekend nights (545 vs 520 min). In another abstract report, these investigators [22] also compared sleep patterns and academic performance for late versus early starting schools (8:00 vs 8:30 am) for the same sample of teenagers. Students at the earlier starting school had significantly more irregular sleep schedules, complained of increased daytime sleepiness, used more stimulants, and reported poorer school performance than those at the later starting school. It is noteworthy that these researchers attempted to relate their findings to parents' socioeconomic status (SES), family background, and geographic region; however, it was unclear how these variables were assessed or accounted for in the analyses [22]. They acknowledged that SES was not associated with the students' sleep patterns, but that students from "not intact" families had more irregular sleep patterns.

Another researcher [23] examined delayed sleep phase, sleep loss and academic performance in 211 university students in Australia. Participants were all first-year psychology students who attended a voluntary test-administration session as part of their psychology course experience. The students completed a questionnaire that queried about sleeping times and other sleep habits, frequency of sleep difficulties (e.g., difficulty falling asleep, early morning wakings), and a variety of daytime symptoms (e.g., drug use, napping, depressed mood). Academic performance was operationalized as the final grade in the first-year psychology course, with final exams given at the student's preferred times. This study also attempted to identify students with delayed sleep phase syndrome (DSPS), defined as late lights-out time and/or long sleep-onset latency, little difficulty maintaining sleep, and late wake-up time on weekends [22]. The investigator compared a DSPS group ($n = 35$) with two other groups of students, a group who reported frequent or more sleep difficulties ($n = 19$) but no

daytime sleepiness, and a control group with no sleep problems selected at random from the remaining sample ($n = 35$). Both the control group and the sleep difficulty groups had significantly higher mean final psychology course grades than the DSPS group and did not differ from each other. Lack concluded that the sleep/wake pattern associated with DSPS and chronic insufficient sleep might result in lowered academic performance [23].

The final study that looked at associations as a function of timing issues examined school start times, sleep/wake habits and academic performance. This project was unique because it utilized a naturalistic design to study of the impact of changing school start times in a large metropolitan school district on sleep patterns and school functioning [24, 25]. Wahlstrom and colleagues compared over 18,000 high school students in the Minneapolis School District before and after the district's school start time change from 7:15 am in the 1996–97 school year to 8:40 am beginning with the 1997–98 school year [24, 25]. The researchers compared attendance, enrollment, grades obtained from official school records, and sleep patterns acquired from a self-report survey. The following statistically significant results were reported by the investigators: (1) attendance rates for students in grades 9 through 11 improved over the period from 1995 to 2000; (2) percentage of high school students continuously enrolled in the district or the same school also increased over this time period; (3) grades showed a slight but not statistically significant improvement following the school start time change; and (4) Minneapolis high school students reported bedtimes similar to students in schools that did not change start times and the Minneapolis students obtained an hour more sleep on school nights during the 1999–2000 school year in comparison to students attending high schools that began an hour earlier [24]. The positive impact of the later school start was most prominent in the African American students, who accounted for 40% of the student population [24, 25].

Wahlstrom and her colleagues, whose chief area of expertise is educational policy, acknowledged that comparing grades between schools or districts and within schools across several academic years raises a number of methodological concerns [24, 25]. First of all, the titles of classes differed from school to school, so that comparisons of similar classes were very difficult to make. For example, there were 642 differently named mathematics classes over the five years among the seven high schools. Second, the length of class periods (four periods of 90 min on the block schedule, versus a 6- or 7-period day) and number of grading periods (semesters versus trimesters) varied markedly from school to school. Third, students in this district tended to be somewhat transient, and the schools kept the grades. Thus, if a student began a semester in one school and then moved at mid-semester to another school, the class entries in the first school could be left blank for the listed courses, with the same student showing up in a different set of classes in the second school. Finally, a number of schools did not have records for some of the students who were supposedly attending that school [24, 25].

Taken together, a few preliminary conclusions may be drawn from these studies regarding the complex relationship between school start time, phase preference, and adolescents' school performance. The studies suggest that self-reported eveningness, delayed sleep schedules, and early school start times seem to be associated with daytime sleepiness, dozing in class, attention difficulties, and poorer academic performance [20–23]. Such conclusions need to be carefully evaluated, however, because study designs, methodologies, measures, study locations, sample sizes, and other factors varied markedly across the studies. Specifically, the following shortcomings need to be examined: (1) school performance and/or attention/concentration levels were not clearly operationalized in several of the studies [17–22]; (2) morningness/eveningness was measured in a few of the studies, but the specific measurement tool is not described [21]; (3) reliability of self-reports in younger children or preadolescents (i.e., 5th–6th graders) is problematic and parent and/or teacher reports might be more accurate for such variables as school performance; and (4) the studies rarely examined other possible mediating and/or moderating variables such as SES, school type, parental involvement, and other background characteristics.

Sleep, classroom performance, and other outcome measures

A few studies have examined aspects of school functioning or performance other than grades in relationship to adolescents' sleep habits. In an atypical study, test anxiety, sleep, and performance were examined middle school students [26]. As part of this study, the researchers measured sleep and anxiety through self-report, vigilance performance on the Digit Symbol Substitution Test, and school performance

with examination grades. Students' performance, sleep behaviors, and anxiety levels were compared on an examination day (high stress) to a day without tests (low stress day). Three test anxiety level groups (i.e., high, moderate, low) were formed based on subjects' responses to the Test Anxiety Scale [27, 28]; the groups did not differ in their reports of sleep complaints. No significant correlations were reported between any of the sleep variables and vigilance task scores on the stress day; however, vigilance scores on the non-stress day were significantly related to the students' ratings of how rested they felt on that morning (i.e., restedness). In other words, reports of greater restedness on the no-test day were associated with better performance on the vigilance task [26]. These findings are difficult to compare with those from studies that focused on sleep patterns and academic grades; however, we included this study because it hinted at complex association between sleep or perceptions of daytime sleepiness and school anxiety. Thus, sleep habits and/or levels of sleepiness might be more significant on a "regular" school day than on days where exams are given, as anxiety and/or motivation might supersede sleepiness in affecting test performance.

Meijer and colleagues focused more on the relationship between sleep/wake patterns and young adolescents' perceptions of their school functioning than on academic achievement [29]. These investigators assessed nearly 450 Dutch young adolescents at several schools. Sleep behaviors were obtained using a self-report questionnaire that included a sleep quality scale (created from questions regarding sleep latency, frequency of wakings, subjective sleep perception); concentration or selective attention was measured by a time-limited pencil and paper test; and children's school functioning was evaluated with the School Perception Questionnaire [30]. The later measure is noteworthy, as it apparently attempted to assess the young person's own sense of how they are performing at school. Meijer and colleagues found that 43% of these young adolescents had trouble getting up in the morning, 15% complained of sleep problems, and 25% did not feel rested during school; however, neither time in bed nor quality of sleep was associated with differences in concentration [29]. On the other hand, participants who noted having difficulty waking up in the morning reported less motivation to do their best at school; whereas children who reported higher quality sleep and feeling more rested reported greater receptivity to their teacher's influence, a more positive image of themselves as students, and higher motivation to do their best in school. The authors concluded that quality of sleep has a substantial impact on preadolescents' school functioning such as achievement motivation and student self-image [29].

These two studies of sleep quality, sleep habits and classroom performance in middle school students [26, 29] both found that feeling rested and ease of getting started in the morning were associated with school motivation, performance, and student self-image. On the other hand, variables more reflective of sleep habits (such as time in bed or sleep latency) were not associated with these school factors [26, 29]. Similar to the findings of Epstein and colleagues, Meijer and colleagues also found no association between the length of time in bed and difficulty concentrating and paying attention [19, 29]. These studies indicated that particular moderating and mediating variables (e.g., anxiety levels, school motivation, level of self-confidence, etc.) might influence the complex relationship among adolescents' sleep habits, sleep quality, daytime sleepiness, and school performance.

DISCUSSION

In the majority of studies described here, the investigators did not take into account other variables that may account for differences in school performance among children and adolescents. Trockel and colleagues, by contrast, examined the influence of sleep habits, exercise, eating habits, mood, perceived stress on first-year college students GPAs and were able to conclude that certain sleep habits contributed the largest amount of variance in predicting GPAs [15]. Without accounting for the other factors, however, these researchers could not have drawn the same conclusions. The work of developmental psychologists, educators and other social scientists in assessing factors that contribute to differences in school performance have highlighted the importance of a more comprehensive approach than most sleep scientists have used. Likewise, Dornbusch, a distinguished social scientist, recently acknowledged that researchers that study adolescent functioning (e.g., psychologists, sociologists and others) need to examine the impact of sleep on adolescents' deviant behavior, school difficulties, and psychological well-being [31]. In the section below, we discuss some of the past research regarding variables associated with school success, particularly for adolescents.

Hidden confounds in school performance research

Very few developmental periods are characterized by so many changes at so many different levels as adolescence. Risk factors with regard to school failure or changes in school performance seem to increase during early adolescence as students transition from elementary school to junior high or middle school. For example, studies have found a noticeable decline in adolescents' grades as they transitioned into junior high school [32, 33]. This decline may be exaggerated for young adolescents who report erratic sleep/wake schedules, for example. Researchers have tried to understand school performance among both middle school and high school age adolescents from a variety of perspectives such as motivational changes, self-concept, ethnic and social class, parental style and involvement, family structure, teenage employment, stressful life events or multiple life changes, social support/relationships, as well as school environment and size. According to Wigfield and colleagues studies have looked at both the role school environments might play in school performance, a General Environmental Influences Model, or at the relationship between the adolescent's needs and his/her environment, a Person-Environment Fit Model [32].

Studies using the general environmental influences model or design have found that students attending smaller schools or in smaller school districts tend to have higher achievement and more consistent attendance; these findings are particularly strong for lower SES, ethnic minority, and students with prior school difficulties [32, 34, 35]. Higher teacher salaries, greater teacher self-efficacy, and better school facilities have also been shown to have a positive influence on student performance [32, 36]. In several well-cited studies with a total sample size of 7664, Dornbusch and colleagues found that community SES predicted grades for both African American and Non-Hispanic white students as well [37, 38].

The other model examines school performance from the perspective of a person-environment fit. In this context, studies have looked more at how certain aspects of the adolescent's daily functioning (for example, grade, parenting styles, parental involvement, high school employment, sports (exercise) involvement, self-concept, and/or stress) may be associated with school success [38–43]. Most studies from this theoretical approach examine one factor, such as whether student employment hours predicted grades, while controlling for other factors, such as parents' occupations, education levels, and income.

Briefly, Dornbusch and colleagues found that both authoritarian and permissive parenting styles were negatively associated with grades, whereas authoritative parenting was positively associated with grades, particularly for white students [38]. Other factors, such as sex, age, parent education, ethnic background, and family structure did not influence these findings. Students with pure authoritatively oriented parents reported the best grades, and inconsistent parenting styles were correlated with the lowest grades [38].

Social scientists (i.e., psychologists, educators) have also looked at school performance in relation to family structure and parental participation [39, 40]. One study, for example, found that lack of a parent, either mother or father, increased children's behavioral problems and lowered school performance [40]. However, although children from two-parent households performed significantly better in school than those living in single-mother or single-father homes, the strengths and shortcomings of each situation may affect school performance and behavior differently.

In the last two decades, studies have also reported that long hours of employment and cumulative stressful life events are negatively associated with high school performance [41–44]. For example, Quirk and colleagues surveyed 15,552 students in grades 8–12 regarding employment hours and GPA along with the following control variables: parents' education, occupation, income, ethnic background, and previous school achievement [42]. They found that hour of work accounted for a moderate significant negative effect on high school grades. In particular, students who reported working fewer than 12 h/week earned similar or better grades than their peers who did not work at all. Yet, grades dropped significantly for students who worked 12–35 h/week. Steinberg and colleagues reported similar findings in an earlier study [43].

Measurement of school performance

Assessment of school performance itself has proved challenging, and social scientists have struggled with the best way of defining and then operationalizing school performance. The construct "school performance" has been variously defined and measured. Dornbusch and colleagues, among the most established adolescent development researchers, have

summarized a consensus from consulting with educators about the use of grades as a measure of school performance [37, 38]. In comparison to intelligence and standardized achievement tests, grades by consensus provide the more appropriate measure of school performance [38]. Thus, although grades, undoubtedly, represent a relatively arbitrary and even subjective assessment by a teacher, the "typical", "usual", or "average" grade is the summation of many judgments about the student's response to the curriculum. Furthermore, grades appear to be more likely to change as a result of learning, because they are more closely tied to a student's curriculum and are a more sensitive measure of learning per se than are achievement tests [42].

The issue of school report versus self-report of grades was examined in over 5,000 high school students [44]. Dornbusch and his colleagues found that self-reported (i.e., on a survey) and school reported (i.e., student transcripts) grades were correlated ($r = 0.79$), and there was no tendency for students to overstate or understate grades except for a slight tendency of students near the bottom of the distribution to report better grades [37, 44]. Other studies have supported this finding [45].

A final point that Dornbusch and colleagues make is that it may be useful to adjust average grades based on students' tracks, arguing that adjusted grades better reflect the actual performance of students, since an A in an honors class, for example, usually represents a higher level of performance than the same grade in a basic or remedial course [37]. Others have argued that it is more reliable and, perhaps, more valid to rely on grades reported (by school or student) only for major subjects such as, English, Math, Science, and Social Studies, rather than including other subjects such as, art, music, and physical education [42].

In contrast, some social scientists [34, 46] recommend using achievement tests as a measure of school performance for the following reasons: (1) individually administered tests tend to be more reliable for children with learning problems; and (2) test content is more representative of what was being taught in the schools in comparison to individual teachers' tests. On the other hand, these researchers, themselves, point out that since most students spend considerable time on seat-work assignments, teacher-made tests or essays as opposed to standardized tests, may make just as much sense to evaluate school performance based on these types of tasks (i.e., rely on academic grades) [34, 46].

Other measures, such as graduation, dropout, absenteeism, and tardiness rates may also serve as indexes of school performance, though each taps different aspects of so-called school performance. Thus, graduation rates provide a measure of students satisfactorily completing educational requirements; whereas, absenteeism and dropout rates offer a measure of student participation in classes, and perhaps provide clues regarding interest in learning.

Unmistakably, although the self-report studies of school performance have limitations, the implications of the data that we have just reviewed seem undeniable. Sleep researchers have much to learn from this fairly large and historical body of research on predictors of school performance. In the section below, we outline recommendations for future research.

Conclusions and future recommendations regarding sleep and school performance

Although the current published studies on sleep and school performance have limitations, findings strongly point out that self-reported shortened total sleep time, erratic sleep/wake schedules, late bed and rise times, and poor sleep quality are negatively associated with academic performance for adolescents from middle school through the college years. We note the importance of these findings; however, certain caveats pertain. First, the results of these studies are based almost entirely on the adolescents' self-reports and suffer limitations because data tend to be retrospective and subjective. Although the studies used a variety of measures of both sleep and academic performance, future studies should use multiple sources of measurement within the same study, such as parent and teacher ratings, school record data, standardized test batteries, and sleep laboratory and/or actigraphy recordings. A multi-measure approach will provide a more comprehensive and possibly more reliable assessment than studies conducted, to date.

Second, this review focused specifically on adolescents' sleep and school performance; however, other largely in-lab, experimental studies have examined the impact of sleep deprivation, sleep restriction, and sleepiness on laboratory measures of motor skills, attention, memory, and problem-solving [47, 48]. For example, several studies of children have reported decrements in verbal creativity, attention, and psychomotor performance following either sleep restriction or sleep deprivation [48–50]. Fallone and colleagues

concluded in their recent review of research on sleepiness and daytime behavior in children that cognitive flexibility and abstract reasoning abilities may be impaired as a result of sleepiness [47]. Evidence of difficulty in other aspects of learning, such as motor skills, memory, and attention is far less consistent [47]. One could argue that verbal creativity, attention skills, and a range of other cognitive and behavioral skills are intricately related to school performance. We recommend that future studies look at sleep/wake patterns, school performance and in-lab measures of attention, verbal creativity, and other tasks in the same sample of adolescents to expand our understanding of the impact of erratic sleep habits and shortened total sleep on overall grades, as well as specific school-related tasks (e.g., learning a second language, English vs math classes, etc.).

Fourth, as emphasized in this review, assessing sleep along with a variety of other variables that influence school performance, such as SES, parent involvement, school size, employment hours, levels of anxiety and motivation, sex, age, and other factors, will provide a more thorough understanding of the mediating and moderating factors that influence the relationship between sleep/wake patterns and school performance and predict academic performance itself.

Fifth, because the studies reviewed here were performed in specific geographic areas and particular school systems, caution should be taken in generalizing the findings. Large-scale, multi-site studies will be important to make such generalizations. Since the studies were cross-sectional, no conclusions about long-term ramifications of inadequate sleep can be drawn. Future investigations need to gather longitudinal data across several weeks, months, as well as years of school performance, behavioral, and sleep data.

Researchers, clinicians, and educators also need to be concerned about the impact of sleep disorders, particularly DSPS and psychophysiological insomnia, on adolescents' ability to function and achieve in school [51–53]. Insomnia and DSPS both interfere with an adolescent's ability to fall asleep at night, resulting in increased difficulty with getting up for school in the morning, and reduced sleep. Although clinicians and researchers have concluded that insomnia and DSPS produce daytime sleepiness, poor academic performance, and behavioral problems, well-designed studies to establish these associations and the impact of interventions are lacking [23, 51–53]. Similarly, studies of young children with sleep apnea and other sleep disorders that contribute to excessive daytime sleepiness suggest that these children may be at risk for absenteeism and lower academic performance [54].

In conclusion, although self-report data have clear limits, the implications of the studies reviewed here seem unambiguous. Schools, parents, and pediatricians need to take an active role to consider sleep and sleep disorders in the context of academic grades, test scores, absenteeism, emotional difficulties, and other aspects of daytime functioning and adolescent development. Likewise, just as sleep researchers need to consider other factors besides sleep in relation to school performance, behavioral scientists in other fields concerned with adolescent development and school functioning need to add the insights regarding adolescents' sleep into their studies and clinical work.

At a more individual level, clinicians, parents, and teachers need to assess the teen who consistently falls asleep in class, is routinely late or absent from school, and take note that insufficient or ill-timed sleep or a sleep disorder may be involved. In Meehl's well-cited article, "When shall we use our heads instead of a formula?" he argued certain issues cannot be studied with statistical prediction [55]. Undeniably, the best behavioral science research and clinical practice requires shuttling back and forth between innovative theory and practice based hypotheses and subsequent empirical studies [55]. Finally, it is essential for researchers, practitioners, and educators to take interdisciplinary approaches to understanding and promoting the academic, health, and behavioral well being of adolescents- middle school, high school, and college students. Likewise, clinical researchers should develop and evaluate the impact of intervention programs for adolescents that promote earlier bedtimes, increased total sleep time, and other sleep hygiene practices on both sleep/wake patterns as well as academic performance. This overall review and recommendations are particularly important at a time when educators, health care practitioners, policy makers, and the general public are focused on increasing students' (particularly teenagers) performance and overall well-being, as well as focused on improving the performance of schools.

Practice Points

1. Adolescents who report inadequate sleep, irregular sleep patterns and/or poor sleep quality as a group tend to do poorly in school in comparison to other adolescents.

2. Health care practitioners (e.g., physicians, psychologists, nurses, social workers) should carefully assess for sleep disorder(s) and/or poor sleep habits in adolescents who:
   (a) Consistently fall asleep in class;
   (b) Are routinely late or absent from school;
   (c) Are doing poorly academically, particularly without a known or previously diagnosed learning disorder or health problem(s).
3. Health care practitioners should consider insufficient, ill-timed, and irregular sleep when evaluating adolescents for these types of behavior and complaints that may suggest insomnia, delayed sleep phase syndrome, or clinical depression.
4. Adolescents and their parents should be advised that inadequate sleep and irregular sleep schedules might lead to poor school performance.

Research Agenda

1. Explicit operational definitions of school performance need to be provided when reporting results.
2. Performance outcomes need to be assessed in the context of overall base rates or overall distribution of grades by district and type of school.
3. The relative contribution of sleep patterns to school performance should be examined along with other variables that predict academic performance (e.g., SES, parent education, gender, parent–child relationships (parenting style), marital status, etc.).
4. Studies need to examine students over several weeks with multiple measures of sleep (e.g., parent and self-report or survey and actigraphy) and school functioning (e.g., self-reported grades, school records, and absenteeism rates).
5. Longitudinal studies are needed to evaluate developmental changes and possible sequelae of inadequate sleep over time.
6. The impact of such sleep disorders as insomnia and DSPS on adolescents' school performance and related outcome measures needs to be more thoroughly examined.
7. Assessment techniques and intervention strategies that improve adolescents' sleep habits need to be developed and tested. Evaluation of these programs should include changes in sleep habits, school performance, and other behavioral outcomes.
8. Statistical power, effect-size estimates, and ultimately sample size should be derived based on previous research and theory (e.g., from school performance studies).

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