New Research

JCSM
Journal of Clinical Sleep Medicine

SCIENTIFIC INVESTIGATIONS

Delaying School Starting Time by One Hour: Some Effects on Attention Levels in Adolescents

Dubi Lufi, Ph.D.[1]; Orna Tzischinsky, Ph.D.[1,2]; Stav Hadar, M.A.[1]

[1]*Emek Yezreel College, Emek Yezreel, Israel;*
[2]*Sleep Laboratory, Faculty of Medicine, Technion-Israel Institute of Technology, Haifa, Israel*

Study Objective: The purpose of the study was to assess the attention level of middle-school students by providing a group of students with the opportunity for an additional one hour of sleep in the morning by delaying school starting time by one hour, as compared to another group received no additional sleep.

Method: For the first week of the study, the school starting time was delayed 1 h for the experimental group (N = 26). In the second week, these students returned to their regular school schedule. A control group (N = 21) remained on their regular schedule for these 2 weeks. Both groups were tested at the end of each week with 2 measures to assess their attention.

Results: The results showed that in the first week the experimental group slept an average of 55 minutes longer each night, for 5 nights (total 275 minutes). Students who slept longer performed better in measures of attention as assessed by the "Mathematics Continuous Performance Test" and the "d2 Test of Attention," indicating better performance in attention level, impulsivity, and the rate of performance.

Conclusions: The study strongly recommends that middle schools should consider delaying the school starting time by at least one hour. Such a change could enhance students' cognitive performance by improving their attention level, increasing rate of performance, as well as reducing their mistakes and impulsivity.

Keywords: Adolescent, short night sleep, delayed school, attention

Citation: Lufi D; Tzischinsky O; Hadar S. Delaying school starting time by one hour: some effects on attention levels in adolescents. *J Clin Sleep Med* 2011;7(2):137-143.

While there are various theories about the functions of sleep, researchers agree that sleep serves multiple purposes.[1] Some researchers have emphasized physical and psychological restoration and recovery,[2] memory consolidation,[3] the discharge of emotions and brain functioning,[4] while others have emphasized biological functions, including the immune system.[5] However, one major question, so far not investigated, is: What is the effect of sleep deprivation on attention, especially during adolescence.[6,7]

Many adolescents suffer from a lack of sleep, resulting from the combination of biological and environmental factors including changes in school starting times, homework load, social and extracurricular activities, employment, parental influence, and constant use of electronic media. The developmental change during adolescence is a shift to a later sleep phase, indicated by a preference for later bedtimes and later waking-up times. This tendency is often accompanied by curtailed sleep during weekdays and by distinct differences between weekday and weekend sleep timing and duration.[8-12]

Previous research has shown a relationship between behavior and cognitive performance among adolescents.[12-16] More specifically, several studies have indicated that the duration and the efficiency of sleep affect the cognitive performance of attention, memory, learning, and concentration[17-19]; while partial sleep deprivation affects cognitive function and academic success in school.[18] To date, numerous studies have examined sleep duration and academic and cognitive performances and the relationship with school starting time among adolescents.

BRIEF SUMMARY

Current Knowledge/Study Rationale: The purpose of the current study was to examine the impact of delaying school starting time by one hour on sleep duration and attention performance among 14-year-olds. The aim of this study was to assess the effect of sleep duration upon attention level with two different instruments.

Study Impact: The present study strongly suggests that administrators of middle schools should consider a change in the time when school starts. Such a change could increase sleep duration by approximately one hour, improve sustained attention, reduce the number of mistakes (of both: attention and impulsivity), and increase the rate of performance.

The present study aims to fill a gap in the research by exploring the lack of sleep in adolescents and its effect on their attention at school.

Two researchers studied the relationship between sleep-wake patterns and daily academic and behavioral performance among some 13- to 19-year-old students.[20] They found that students who slept less and had later sleep onset hours produced low academic and behavioral performance; in addition, they suffered from depressed moods and sleepiness during the day. Another study compared performances of younger adolescents (10-14 years old) after 5 hours in bed in contrast to a control group with 11 hours in bed. The control group scored better in creativity and cognition.[7] Research indicated that sleep deprivation among children and adolescents leads to lower cognitive performance; this was manifested in their lack of attention, concentration, memory and learning, as well as lower motivation, more absences from school, moodiness, and depression.[6,20,21]

Few standardized measures of normative sleep-wake patterns, and cognitive performances in healthy children or adolescents have been reported. One such study investigated the effects of the school starting time on sleep duration and fatigue among 572 fifth-grade students; it was based on a self-report questionnaire.[24] Sleep duration was significantly shorter for early risers who complained significantly more than the late risers of daytime sleepiness and poor concentration at school. Yet another study sought to establish normative developmental data of sleep patterns in Israeli children in the second, fourth, and sixth grades using actigraphy, sleep diaries, and questionnaires based on parent and child reports.[23] Questionnaire data revealed that, with increasing age, there was increased morning drowsiness and a tendency for daytime napping.

One study reported that 35 more minutes of sleep affected memory, attention, and reaction time among children 9-12 years old.[19] Similarly, other studies[24] found a similar relationship among 14-year-olds in their natural environment when their sleep was monitored by actigraphy. This preliminary study indicated that during the experimental week, when subjects went to sleep earlier and slept an average of 38 minutes more than during the baseline week, their attention improved. These results clearly demonstrated that an earlier bedtime, resulting in a longer sleep time, positively affected cognitive functioning. O'Malley and O'Malley[25] found that after a whole high school delayed its starting time, high school students slept 40 minutes longer during school nights, without appreciably delaying their bedtime. The students in that study reported lower levels of daytime sleepiness after the schedule had been changed.

The goal of the current study, therefore, was to examine the impact of delaying school starting time one hour on sleep duration and attention performance among 14-year-olds, using 2 measures of attention. The unique contribution of this study was a careful scrutiny of the effect of sleep duration upon attention level with 2 different instruments. The hypothesis of the study was that a delay in school starting time by one hour would increase time in bed and sleep duration, and improve performance on tasks of attention.

METHODS

Participants

The study was conducted on a group of eighth-grade students from the Northern Israel public school of Jezreel Valley. Prior to the research, permission was granted by the Ministry of Education to conduct the procedures described below. The study was approved by the school. All the parents gave written consent for their children to participate in the research. Forty-seven students (mean 13.78 years, SD = 0.28), including 20 boys and 27 girls participated in the study. Most students arrived at school by transportation organized by the regional council. Most schools in Israel operate 5 days a week, from Sunday to Thursday. As a rule, school starts daily at 07:30. One class was chosen at random to be the experimental group (N = 26), while the other class, also chosen at random, served as a control group (N = 21). The school reported that none of the participants had suffered major illness or had known attention deficit hyperactivity disorder.

Instruments

Actigraph – (Mini-Act, AMA-32, AMI, Ardsley, NY)

An actigraph is a small device, like a wristwatch, worn on the wrist of the non-dominant hand. The device records movements of the wrist; data are collected (in 1-min epochs) and analyzed by a computer.

The actigraph was used for objective assessment of sleep over a 5-day period; during these 5 days the participants completed daily sleep logs to verify use of the actigraph. Use of the actigraph for sleep research under natural conditions has been found in previous studies to have adequate reliability and validity for research.[27] Actigraphs were worn throughout the 5 school nights. Activity data were downloaded and analyzed using the ActionW software (Version 2, using Sadeh algorithm #20). The actigraph was used to determine the onset of sleep (the first min of ≥ 3 consecutive min of sleep as recorded by the algorithm) and the end of sleep (the last min of ≥ 5 consecutive min of sleep just before the end of the sleep period). Measures also included sleep efficiency and duration of sleep.

MATH-CPT

The MATH-CPT (Mathematics Continuous Performance Test)[28] is a CPT-type computerized test designed to assess sustained attention. The test had 450 simple mathematical problems of addition, subtraction, multiplication, and division with a solution ≤ 10. There were right and wrong answers in the test, (e.g., 1 + 3 = 4, or 4 × 2 = 7). The participants were shown one problem at a time on the computer screen and had to decide whether the solution to the problem was correct or incorrect by pressing '1' for a correct answer or '2' for an incorrect answer. The test had no time limit and took between 10 to 20 min. The test recorded response time, accuracy of response, standard deviation of the response time (a measure of variability of the response rate), anticipatory-impulsive responses, and included a final overall attention level formula to assess the overall attention level of the participant. This formula was the most important item as it estimated sustained attention. In this formula a score above '0' indicated difficulty in attention, while a score < 0 was considered within the normal range. During the construction of this instrument, test-retest reliability after one week of testing showed correlations of 0.85 to 0.48 for the main measures of the MATH-CPT. During development of the MATH-CPT, stepwise discriminant function analysis was used to compare a control group with a group of people with ADHD. The results showed that the test could identify 91.60% of the subjects in both groups.

d2 Test of Attention

The d2 Test of Attention[29] is a graphic-motoric test of cancellation aimed to assess attention. The test included a task of cancelling specific designated letters (*p* or *d*) with small vertical lines above and/or below the letters. The test had 14 rows of 47 characters in each row—a total of 658 characters. The participants were allowed 20 sec to cancel the designated letter (the letter *d*) on each row, with 2 small vertical lines below and/or above the letter. The task lasted 4 minutes 40 seconds. Before starting the test, each student was given a full explanation and a chance to practice the task in a one-line trial. The test assessed attention through using rate of cancellation, accuracy, consistency of the work, and the number of mistakes. The d2 Test of Attention has been used in many studies to assess attention. Qualities of the test included a test-retest reliability > 0.90 in numerous studies.[29] The validation of the d2 test has shown significant correlations with other measures of attention. Several studies have shown that a population of ADHD scored lower than one without ADHD in various measures of the d2 Test of Attention.[30,31]

Procedure

The experiment lasted 2 weeks. During these 2 weeks, the participants wore an actigraph to record sleep and kept a diary of sleep onset, wake-up time, and actigraphic activity. Sleep diaries were used by the participants only to validate sleep measured by the actigraph and were not used in the statistical analysis. Actigraphic data and sleep diaries served as a measure to assure that the experimental group slept longer and woke up later during the experimental week, while the control group maintained normal sleep habit during the 2 weeks the experiment lasted.

The subjects were instructed to go to bed at their normal time during the experiment and to be exact about going to sleep at the same time, regardless of their waking time. Falling asleep time and wake-up time were monitored by actigraphy. Actigraphic data were collected for 5 days each week (from Saturday night until the following Thursday morning). At the conclusion of each week, on Thursday morning, all the participants performed the attention level tasks.

The experimental manipulation was conducted only in the experimental group in the following way: during the first week, transportation from the various settlements was organized according to the new timetable (1 h later); this enabled the students to start their school day at 08:30 (1 h later than normal). During the second week, the experimental group arrived at school at the normal time and started school at the regular time, i.e., 07:30. Apart from this change, the students were instructed to keep to their normal daily routines, as well as going to bed at their regular time; this was done to ensure that they gained an extra hour of sleep. In addition, the experimental group finished school one hour later; this was done in order not to lose school study time and to maintain their regular schedule.

The second class served as a control group; there were no changes in their daily routine. These students kept their normal daily schedule; they started school at 07:30 and kept sleep onset on the regular time during the 2 weeks of the experiment. The classroom teacher of both groups was responsible for seeing that each group kept its planned schedule.

On the last day of each week, (Thursday morning) all students completed the 2 attention tasks. The tests were performed in 2 classes—the MATH-CPT took place in the school computer class, and the d2 Test of Attention was carried out in a different classroom. Administration of attention tests was counterbalanced between groups and across weeks. Each student performed the tasks on his or her own without talking or seeing what the other students did. During the second week, the test order was reversed to avoid possible order effects.

RESULTS

A 2 × 2 repeated analysis of variance (ANOVA) (by time: week 1 vs. week 2; and by group: experimental group vs. control group) was used to evaluate the effect of the 2 independent variables: regular sleep v. longer periods of sleep, on the dependent variables: various measures of attention. It was found that throughout the first week the experimental group woke up significantly later (mean time = 07:07, SD = 0:16) than the control group (mean time = 06:27, SD = 0:23), while in the second week, there were almost no differences in the waking hours. In addition, the experimental group slept significantly longer in the first week (mean = 8 h 26 min, SD = 0:13) than the control group (mean = 7 h 29 min, SD = 0:11), while in the second week, there were much smaller differences between the 2 groups. These results reflected the purpose of the study: to have a longer period of sleep (the experimental group slept in the first week on average 55 minutes longer each night, for 5 nights as compared to the second week) and waking up later in the morning (by 55 minutes) for the experimental group during the first week of the experiment. No significant differences were found between the 2 groups in the measures of the time when sleeping began and in sleep efficiency. These results are shown in **Table 1**, **Table 2**, and **Figure 1** (**Table 2** is a continuation of **Table 1**, presented separately because of space limitations, and the figure presents only the results of the most conspicuous variables).

A 2 × 2 repeated ANOVA of the results of the MATH-CPT and the length of time the students slept showed that both groups improved their performance in the MATH-CPT main measure of attention (Overall attention level) due to the practice effect; this can be seen by the "within" F scores in **Table 2** ("within F" refers to the changes from first trial to second trial within each group). However, when the experimental group slept more, they performed much better than the control group (see **Table 3**, **Table 4**, and **Figure 2**). These results can be seen in the significant interaction between the overall attention level score and the length of time they slept (mean overall attention level = −1.13, SD = 0.64 for the experimental group, mean −0.17, SD = 1.03 for the control group, $F_{1,47} = 6.54$, $p < 0.05$; in this measure, a lower score indicated better sustained attention). Almost no differences were found when both groups started school at the same time in the second week of the experiment (mean overall attention level = −1.37, SD = 0.53 for the experimental group, mean −1.18, SD = 0.77 for the control group). No significant interaction was found in any of the other variables of the MATH-CPT and the length sleep (although the experimental group had better performance in 3 other MATH-CPT variables: these results can be seen in "between subjects F," which refers to the differences between the 2 groups resulting from experimental manipulation).

Assessing the results of the d2 Test of Attention showed significant interaction of 5 d2 variables with the time the participant slept. The 5 variables showing significant interactions were: total signs marked, total mistakes, missing correct mistakes (considered mistakes of "inattention"), marked wrong (considered mistakes of "impulsivity"), and the percentage of

Table 1—Sleep means (SD) of experimental and control groups measured by actigraphy

	Experimental Group				Control Group			
	First Week		Second Week		First Week		Second Week	
Variable	X̄	SD	X̄	SD	X̄	SD	X̄	SD
Sleep Onset Time[1,2]	22:41	0:21	22:42	0:35	22:58	0:23	23:04	0:35
Sleep Offset Time[1]	7:07	0:16	6:13	0:13	6:27	0:23	6:22	0:19
Sleep Duration[1]	8:26	0:13	7:31	0:19	7:29	0:11	7:18	0:19
Sleep Efficiency[3]	95.72	2.57	96.94	1.60	92.43	6.65	94.50	3.69

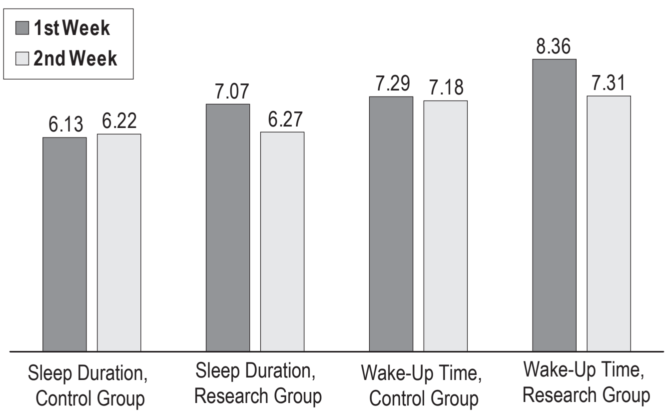
[1]In hours and Minutes HH:MM; [2]24 hour clock; [3]Sleep efficiency is reported in percentages, using the following formula: (sleep time/time in bed × 100).

Table 2—Continuation of Table 1, with statistical analysis of: sleep measures of the experimental and control groups, measured by actigraphy: F-values, F-interaction, partial eta squared, and observed power (experimental group, control group)

Variable	F-Within Subject	Partial Eta Squared	Observed Power	F-Between Subjects	Partial Eta Squared	Observed Power	F-Interaction	Partial Eta Squared	Observed Power
Sleep Onset	0.28	0.02	0.08	2.44	0.13	0.31	0.21	0.01	0.07
Sleep Offset	60.93**	0.78	1.00	5.46*	0.24	0.60	41.18**	0.71	1.00
Sleep Duration	16.14**	0.49	0.97	14.43**	0.50	0.95	6.85*	0.29	0.69
Sleep Efficiency	5.14*	0.23	0.57	2.87	0.14	0.36	0.35	0.02	0.09

*p < 0.05, **p < 0.01.

Figure 1—Comparison of sleep duration and wake-up time of experimental and control groups during the two weeks of the experiment (in hours and minutes)



errors. Four of these 5 variables were connected to the number of mistakes while performing the test, and one assessed rate of performance. These results are shown in **Table 3**, **Table 4**, and **Figure 2** (**Table 4** is a continuation of **Table 3**, presented separately because of space limitations, **Figure 2** presents only the results of the most conspicuous variables of the MATH-CPT and the d2 Test of Attention).

DISCUSSION

The purpose of this study was to assess the effects of longer sleep duration (i.e., one additional hour of sleep for five nights) on attention levels among adolescents; this was achieved by delaying school start time by an hour. Estimated by actigraphy, students obtained more sleep—on average 55 minutes longer each night—for 5 nights following the delay in school start time. The distinctive contribution of the study to sleep research was a careful measure of the effect of sleep duration upon attention level using two different instruments assessing attention.

The hypothesis of the study was accepted; when the students (i.e., the experimental group in the first week) slept longer, they performed better than the control group on tests requiring attention. The meaning of the six significant interactions found in the study is the same: while the experimental group performed better during the first week when they slept longer, their improvement in the second week, due to practice effect, was marginal. In contrast, the control group performed poorer in the first week and improved a great deal in the second week due to practice effect.

The differences between the two groups were found in the main measure of a computerized test (MATH-CPT): the overall attention level, which assesses sustained attention. In the d2 Test of Attention there were differences in five variables, indicating that the experimental group marked more signs and made fewer mistakes. This was seen in four measures of the number of mistakes: (1) total mistakes; (2) missing correct answers, which measures attention; (3) marking wrong sign, which measures impulsivity; and (4) the percentage of errors. In the fifth variable of the d2 Test of attention, assessing speed of responses, there was also better performance of the experimental group in total signs marked. These results coincide with another study,[19] which found that sleep quantity influences the reaction time.

It is important to note that in both groups there was an improvement on most variables of both tests due to practice effect, i.e. being tested twice within one week (a phenomenon found in many cognitive tests). Nonetheless, the changes reported here were beyond this practice effect.

Other studies using a procedure of limiting the period of sleep[6,7] suggested that a slight lack of sleep could be detected

Table 3—Mean (SD) effect of sleep on cognitive measures used in the study

	Experimental Group				Control Group			
	First Week		Second Week		First Week		Second Week	
Variable	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
MATH-CPT								
Total Time (Sec)	767	141	628	111	948	335	822	315
SD Total Time	0.84	0.29	0.58	0.30	1.10	0.55	0.97	0.68
Anticipatory-Impulsive	0.11	0.32	0.16	0.38	0.24	0.56	0.38	0.88
Correct Responses	433	8.21	437	8.10	427	13.87	435	10.68
Overall Attention Level[a]	-1.13	0.64	-1.37	0.53	-0.17	1.03	-1.18	0.77
d2 Test of Attention								
Total Signs Marked	396	58	461	74	382	50	422	67
Marked Minus Mistakes	381	55.48	444	76.40	359	43.81	408	65.04
Correct Responses	153	22.22	182	34.72	141	16.96	165	25.98
Total Mistakes	14.47	8.61	17.47	11.65	23.30	15.51	13.95	8.94
Missing Correct	12.94	8.52	13.94	9.26	19.80	13.77	12.60	8.56
Marked Wrong	1.53	1.07	3.53	6.06	3.50	3.91	1.35	1.69
Percentage Errors	3.61	2.18	3.92	2.76	5.91	3.66	3.03	2.08
Concentration Performance	151	21.97	179	37.51	138	17.32	163	26.35

[a]A lower indicates of a better attention level.

Table 4—Continuation of Table 3 with statistical analysis of effect of sleep on cognitive measures used in the study: F-values, partial eta squared, and observed power

Variable	F-Within Subject	Partial Eta Squared	Observed Power	F-Between Subject	Partial Eta Squared	Observed Power	F-Interaction	Partial Eta Squared	Observed Power
MATH-CPT									
Total Time (Sec)	28.22**	0.45	1.00	5.99*	0.15	0.66	0.07	0.02	0.06
SD Total Time	9.71**	0.22	0.86	5.11*	0.13	0.59	1.04	0.03	0.17
Anticipatory-Impulsive	0.55	0.16	0.11	1.70	0.05	0.25	0.12	0.03	0.12
Correct Responses	15.41**	0.31	0.97	1.97	0.06	0.28	1.41	0.04	0.21
Overall Attention Level	17.38**	0.37	0.98	6.67*	0.18	0.71	6.54*	0.18	0.70
d2 Test of Attention									
Total Signs Marked	105.00**	0.75	1.00	1.70	0.05	0.25	6.30*	0.15	0.68
Marked Minus Mistakes	93.95**	0.73	1.00	2.25	0.06	0.31	1.37	0.04	0.21
Correct Responses	88.44**	0.72	1.00	3.54	0.09	0.45	1.15	0.03	0.18
Total Mistakes	2.64	0.07	0.35	0.65	0.02	0.12	9.97**	0.22	0.87
Missing Correct	4.58*	0.12	0.55	0.82	0.02	0.14	8.01**	0.19	0.79
Marked Wrong	0.08	0.00	0.05	0.02	0.00	0.05	5.80*	0.14	0.65
Percentage of Errors	5.84*	0.14	0.65	1.17	0.03	0.18	9.36**	0.21	0.85
Concentration Performance	62.45**	0.64	1.00	3.37	0.09	0.43	0.08	0.02	0.06

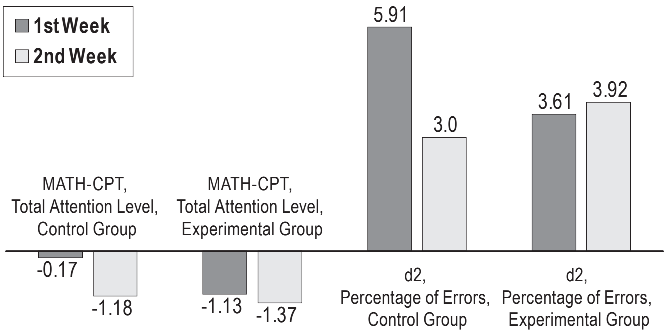
*$p < 0.05$, **$p < 0.01$.

by searching for specific measures of cognitive-behavioral variables that were more sensitive to a lack of sleep. The results of the present study indicate that such measures were within the realm of attention.

Consequently, the present school schedules can lead to insufficient sleep and disturbed sleep patterns and are followed by a worsening in health, daytime functioning, and academic performance, as well as daytime sleepiness and fatigue (especially during the morning). The long-term solution would be to change school start time, as suggested by some studies. Wolfson et al.[26] reported that middle-school adolescents who started school later, reported waking more than an hour later on school days and obtained 50 minutes more sleep each night; they showed less sleepiness and tiredness than adolescents who started school early.

The results of the present study are more striking because it was performed within the natural environment of the students and with the regular daily schedule of the participants. The manipulation of the study was one additional hour of sleep—something that could be achieved in many schools by changing the time at which the school starts in the morning. This allows the researchers to assume that middle-school students who are

Figure 2—Comparison of MATH-CPT total attention level[a] and d2 percentage of errors[b] of experimental and control groups during the two weeks of the experiment



[a]Lower score indicates higher attention level. [b]Higher score indicates more mistakes.

given a chance to sleep an additional hour in the morning could perform better in school because of better attention levels. The present study could not distinguish whether the positive effect of the manipulation was due to extra sleep (lasting on average 55 minutes longer each night for five nights), or whether these results reflected waking up 55 minutes later than usual. The answer to this question was beyond the scope of the present study. Practically, it is difficult to make adolescents go to bed earlier; but an additional hour of sleep in the morning is more easily attainable and coincides with biological changes during adolescence. This aspect should be investigated in future research.

The above results raised the question: Will starting school later enhance school performance? Our study joins some other research in an attempt to answer the question. In a study performed in Minnesota, it was arranged for a school to start after 8:30 a.m.[32-34] It was reported that the students, their parents, and superintendents claimed that delaying the starting time positively influenced students' study habits. In addition, it was found that extracurricular activities after school did not suffer from the change. A follow-up study of the program indicated a benefit from the change regardless of the administrative effort and time devoted that such a change requires.[35]

The present study strongly suggests that middle schools should consider a change in the time when school starts, i.e., at least one hour later. Such a change could improve the attention level of the students and increase the rate of performance, possibly without interfering with extracurricular activities performed after school. Another byproduct of the present study was a suggestion to investigate the potential of additional sleep on the attention level among students with attention deficit hyperactivity disorder (ADHD).

The study is not without some limitations. Technical limitations of the school did not allow the study to continue longer and include more participants. There was also a lack of a measurement of pubertal development. This was a field study performed in school during school time, a reality that caused several practical difficulties. In particular, a baseline of sleeping habits, intellectual ability, and the level of attention of both groups before the study started were not established. Probably an ABA design would have been a preferable method for such research. Although the procedure of selecting the groups at random was used to reduce these possible effects, it is suggested that in future research a baseline of cognitive abilities should be obtained. In future studies, there should be more subjects with different age groups and an assessment for gender differences.

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ACKNOWLEDGMENTS

The research was carried out at Yezreel Valley College.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication August, 2010
Submitted in final revised form November, 2010
Accepted for publication November, 2010

Address correspondence to: Dubi Lufi, Kibbutz Yifat 36583, Israel; Tel: 972-4-6548880; Fax: 972-4-6548600; E-mail: dubilufi@gmail.com, dubil@yvc.ac.il

DISCLOSURE STATEMENT

This was not an industry supported study. The authors have indicated no financial conflicts of interest.