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School start time, sleepiness and functioning in Norwegian adolescents

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The study's aim was to investigate how school start time affects sleepiness and functioning in Norwegian 10th grade students ($N = 106$). The intervention school started at 0930 hours on Mondays and 0830 hours the rest of the week. A control school started at 0830 hours all schooldays. The students were assessed on a reaction time test as well as with self-report measures of sleepiness, mood and sleep. The intervention school obtained one hour longer total sleep time on Sunday nights compared to the control school and performed better on the reaction time test on Mondays than on Fridays, relative to the control school. Later school start times may both lengthen nocturnal sleep and increase students' alertness in early morning classes.

Keywords: school start time, sleepiness, functioning, adolescents

School start time, sleepiness and functioning in Norwegian adolescents

It is estimated that adolescents need between 8.3 and 9.2 hours of sleep per night (Carskadon, 1982; Carskadon et al., 1980). However, studies show that they obtain only 7.5 to 8.5 hours per night on average (Allen, 1992; Carskadon, 1990b). In a sample of over 3,000 students (age 13–19) not more than 15% reported that they obtained 8.5 hours or more, whereas 26.6% reported that they got less than 6.5 hours of sleep on school nights (Wolfson & Carskadon, 1998). The discrepancy between needed and obtained amount of sleep may be due to major physiological and psychosocial changes that occur during adolescence. In terms of the physiological changes, studies show that compared to pre-puberty, puberty is associated with a slower accumulation of sleep need following periods of wakefulness (Jenni, Achermann, & Carskadon, 2005). Hence the homeostatic sleep pressure builds up at a slower rate in mature adolescents than in children and less mature adolescents. In addition to the homeostatic factor, sleep is under influence from the circadian rhythm. This rhythm regulates several bodily processes showing a 24-hour oscillation, among them the timing of sleep and wakefulness (Bjorvatn & Pallesen, 2009). Several studies have shown that physical

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maturation in puberty appears to lengthen the endogenous circadian rhythm (Carskadon, Acebo, Richardson, Tate, & Seifer, 1997; Carskadon, Vieira, & Acebo, 1993; Hagenauer, Perryman, Lee, & Carskadon, 2009). As a consequence it may become more difficult for the adolescent to fall asleep at an appropriate time in the evening, and likewise more difficult for him or her to get up early in the morning. In modern societies, these biological changes often seem to interact with different psychosocial processes. For example, adolescents exert more control over their own bedtimes than younger children (Carskadon, 1990b), which permits the former group more access to evening activities (Carskadon, 2002). Recently studies have shown that the use of electronic devices in the bedroom are associated with later bedtime, increased sleep latency, decreased sleep duration and excessive daytime sleepiness (Calamaro, Mason, & Ratcliffe, 2009; Choi et al., 2009; Shochat, Flint-Bretler, & Tzischinsky, 2010; Van den Bulck, 2004, 2007). Furthermore, adolescents are more likely than younger individuals to engage in part-time work after school (Carskadon, 1990a, 1990b; Carskadon, Mancuso, & Rosekind, 1989). Studies have shown that part-time work in adolescents is associated with delayed bedtimes (Carskadon et al., 1989). All the above mentioned changes occur parallel with an increase in the workload at school (Manber et al., 1995).

One obvious consequence of delayed bedtime is excessive daytime sleepiness, cognitive and academic difficulties, and mood disturbances (Banks & Dinges, 2007; Fallone, Owens, & Deane, 2002; Hill, 1994; Wolfson & Carskadon, 2003). One study from Japan found that 33% of the boys and 39% of the girls reported excessive daytime sleepiness (Ohida et al., 2004). In a study by Carskadon et al. (1998) it was suggested that daytime sleepiness may be a consequence of early school start times. The investigators evaluated students in the transition from 9th grade in middle school to 10th grade in high school. Start times for the middle school and the high school were 0825 and 0720 hours, respectively. The study showed that early school start time was associated with significant sleep deprivation and daytime sleepiness compared to the later start time (Carskadon et al., 1998). The 9th graders obtained on average 7.15 hours of sleep and the 10th graders 6.8 hours (Carskadon et al., 1998). In another study by Wolfson and Carskadon (1998), 87% of the subjects ($N = 3\ 000$; aged 13-19) reported needing more sleep than they obtained. The result of the same study showed that adolescents with short sleep periods on weekdays (6 hours and 45 min) reported higher levels of depressed mood compared to students obtaining longer sleep periods (8 hours and 15 min). In line with this, studies show that when school start time is delayed the adolescents experience fewer mood disturbances, sleep longer on school nights and report less daytime sleepiness, and also obtain better grades (Allen, 1992; Dexter, Bijwadia, Schilling, & Applebaugh, 2003; Epstein, Chillag, & Lavie, 1998; Linck & Ancoli-Israel, 1995; Owens, Belon, & Moss, 2010; Wahlstrom, 2001, 2002). For example, Wahlstrom (2002) monitored 18,000 high school students when school opening times were changed from 0715 hours to 0840 hours in the morning. Following this change students achieved almost one more hour of sleep on school nights, class attendance and daily school enrollment improved, and the students' grades improved slightly (Wahlstrom, 2002). Several studies indicate that daytime sleepiness and reduced sleep quality and quantity in students are related to deteriorated neurocognitive functioning and academic performance (Curcio, Ferrara, & De Gennaro, 2006; Fallone et al., 2002; Kelly, Kelly, & Clanton, 2001; Meijer, Habekothé, & Van Den Wittenboer, 2000; Wolfson & Carskadon, 1998, 2003). In a recent meta-analysis the investigators separately looked at the effects of sleep quality, sleep duration and sleepiness on school performance (assessed by questionnaires, standardized tests or grade point average) (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010). The authors concluded that

the variables were significantly related to school performance. Performance was most affected by daytime sleepiness, followed by sleep quality and sleep duration (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010). In one recent experimental study, adolescents were sleep restricted for five nights (<6.5 hours in bed) before being tested in a simulated classroom setting. The result showed that, compared to a counterbalanced control session (five days with 10 hours in bed), sleep restriction reduced attentive behavior, diminished learning and lowered arousal in the simulated classroom (Beebe, Rose, & Amin, 2010).

All studies of delayed school start times have so far taken place outside Scandinavia and no study has investigated the effects of delayed school start time for only one day of the week. In Norway, most junior high schools start between 0800 hours and 0900 hours. In the present study, one junior high school (intervention group) had a conventional start time at 0830 hours, but had delayed school start time on Mondays to 0930 hours. The intervention school was compared with a control school that started at 0830 hours on all schooldays (control group). We investigated whether vigilance (simple serial reaction time) and self-reported sleepiness, sleep and mood would be affected by school start times by assessing these parameters in students in both schools at 0930 hours both on a Monday and a Friday.

Method

Participants

A total of 106 10th-grade students from two junior high schools (two classes at each school) in Norway participated in the study. The school that constituted the intervention group (*n* = 55) had delayed school start time to 0930 hours on Mondays and started at 0830 hours the rest of the week. This delayed start time at the beginning of the week was implemented two years before this study was conducted to give the teachers time for a weekly meeting. Of the 55 students from this school, 25 of them were boys (45.5%) and 30 girls (54.5%). Due to some missing data and students not showing up on both test days, the number of paired registrations available varied between 29 and 49 in the different analyses (Table 1). The control group comprised 51 students at another junior high school. In this group, 18 of the students were girls (35.3%) and 33 were boys (64.7%). Depending on

Table 1
Results from t-test for Independent Means (delta, Saturday–Sunday)

	<i>N</i> (intervention, control)	Intervention ΔM (<i>SD</i>)	Control ΔM (<i>SD</i>)	<i>Cohen's d</i>	<i>df</i>	<i>t</i> -value	<i>p</i> -value
Sleep diary							
– Total sleep time, TST	29, 44	77.2 (157.8)	152.5 (143.1)	0.50	71	–2.11	.04
– Bedtime	49, 46	–110.3 (73.2)	–127.5 (83.3)	0.22	93	1.07	.29
– Sleep onset latency, SOL	49, 45	–8.5 (25.9)	–23.0 (43.5)	0.41	92	2.00	.05

Mark: *Cohen's d* is given in absolute value.

the variable being analyzed, the number of paired registrations available varied from 36 to 46 (Table 1). The control group started at 0830 hours on all school days.

Instruments

Karolinska Sleepiness Scale (KSS). The Karolinska Sleepiness Scale (Åkerstedt & Gillberg, 1990) is a sleepiness scale where subjects rate their current degree of sleepiness. The scale is verbally anchored with the following steps: 1 = “very alert”, 3 = “alert”, 5 = “neither alert nor sleepy”, 7 = “sleepy, but no problem staying awake” and 9 = “very sleepy, fighting sleep, effort to stay awake”. The intermediate steps (2, 4, 6 and 8) are not anchored verbally. A score of 7 or more indicates excessive sleepiness.

Reaction time test (RT). Objective measures of vigilance were obtained with a 10-minute simple serial reaction time test administered on a Palm handheld computer (Palm Inc, Santa Clara, CA, USA). The RT is a modified version of similar tests developed by Lowden, Kecklund, Axelsson, and Åkerstedt (1998). The test task is validated and has shown good convergent validity when compared with other similar tests (Lamond, Dawson, & Roach, 2005). The test comprises 100 black squares appearing on the screen at squarely distributed intervals (4.75–7.25 seconds). The subjects’ task is to press any key immediately when a stimulus appears. If a response is made before stimulus appears or faster than 120 ms (false start), the response is rejected and a warning is displayed on the screen. If no response is given within 1750 ms, a new interval is initiated. The RT software has a time-resolution of at least 0.5 ms. Parameters derived from the RT comprise mean and median reaction time, and numbers of “lapses” (omissions, >500ms). The RT was administered on a Monday morning (0930) and on a Friday morning (0930).

Positive and Negative Affect Schedule (PANAS). PANAS is a reliable and valid scale (Watson, Clark, & Tellegen, 1988) measuring positive affect and negative affect. The questions related to positive affect are meant to give a numeric expression of the subject’s feelings of enthusiasm, pleasure and engagement. A high score reflects a high degree of positive affect. The questions regarding negative affect reflect distress and other unpleasurable states such as nervousness and anger. A high score indicates a high degree of negative affect. For Mondays, the Cronbachs alpha for positive and negative affect were .75 and .69, respectively. The corresponding figures for Fridays were .89 and .72.

Retrospective sleep diary. The retrospective sleep diary is a subjective rating instrument that respondents complete retrospectively for three foregoing days. It contains questions of bedtime, sleep-onset latency, wake after sleep onset, number of awakenings, early morning awakening (time spent in bed after final wake-up), final wake-up time, get-up time, and an overall rating of sleep quality (1 = “very restless”, 5 = “very sound”). Based on the diary, estimates of total wake time (sleep-onset latency + wake after sleep onset + early morning awakening), total sleep time, and sleep efficiency (total sleep time as a percentage of time in bed) were calculated.

Procedure

The junior high schools that participated in the study had about the same number of students in the 10th grade. Before the study was carried out the students received both written and oral information about the project. All students and their parents signed a written consent form. The data collection took place in February and March. All students were assessed in their classrooms

both on a Monday morning at 0930 hours and on a Friday morning at the same time. On Mondays the data collection took place during the first lesson for the students in the intervention group, and during the second lesson for the students in the control group. On Fridays the data collection took place in the second lesson for both schools. On the test days (both Monday and Friday), all students were first asked to complete the KSS before taking the RT, and then to complete the PANAS and the retrospective sleep diary. On each test day the data collection lasted about 30 minutes, and was done simultaneously for all students in each class. To rule out learning effects on the RT-test, the data collection was done in a counterbalanced way, where students in one class in each school (intervention and control) were first tested on a Monday and then on a Friday, while students in the other class from each school were tested in the opposite order. The two classes at each school were randomly assigned to the different orders. The study was approved by the Norwegian Social Science Data Services (NSD).

Statistics

Data were analyzed by PASW version 18 (PASW Inc, Chicago, IL). In order to retain as many participants as possible, the analyses were carried out individually for all the variables. We used t-tests for independent samples to compare the two groups on the relative change in the different outcome measures between Monday and Friday; and for the variables in the sleep diary between Saturday night and Sunday night. Each group’s changes between the two assessments are referred to as delta values. In all analyses the alpha level was set to .05.

Due to the high dropout rate over the test days and some missing data, the number of subjects included in the analyses deviates somewhat from the total number who participated overall. To preserve as many participants as possible in the analyses, some of the missing data in the sleep diary was replaced by estimates. This was just the case for the control group, where missing get-up time on Monday morning was replaced by mean get-up time for the remaining weekdays. The number of missing data that were replaced comprised 0.26% of the total number of data points. We also calculated effect sizes (*Cohens d*) for the difference between the intervention and the control group (Tables 1 and 2). As a benchmark for interpreting such effects, 0.2 is regarded as a small effect size, 0.5 is a moderate effect size and 0.8 is considered as a large effect size (Cohen, 1988).

Table 2
Results from t-test for Independent Means (delta, Monday–Friday)

	N (intervention, control)	Intervention ΔM (SD)	Control ΔM (SD)	Cohen’s <i>d</i>	<i>df</i>	<i>t</i> -value	<i>p</i> -value
Sleepiness, KSS	35, 45	-.5 (2.7)	.1 (2.2)	0.24	78	-1.09	.28
Positive affect, PANAS	31, 36	.7 (8.1)	-1.2 (6.9)	0.25	65	1.01	.32
Negative affect, PANAS	32, 41	-.4 (4.3)	-.5 (4.2)	0.02	71	.13	.90
RT-test							
- Lapses (>500 ms)	33, 45	-7.3 (18.2)	1.3 (12.5)	0.56	76	-2.48	.02
- Median RT	33, 45	-49.1 (129.0)	2.5 (58.8)	0.54	76	-2.37	.02
- Mean RT	33, 45	-73.7 (168.3)	2.1 (139.9)	0.49	76	-2.17	.03

Mark: *Cohen’s d* is given in absolute value.

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Results

Sleep variables. For the sleep variables, the result from the *t*-test is shown in Table 1, and Table 3 presents an overview of the mean values. When comparing the change in total sleep time (TST) between Saturday night and Sunday night, the intervention group’s delta values ($\Delta M = 77.36$; $SD = 157.8$) were significantly different from that of the control group ($\Delta M = 152.47$; $SD = 143.07$), $t(71) = -2.11, p = .04$. As shown in Table 3, the two groups had similar TST on Saturday, whereas the intervention group slept more than one hour longer compared to the control group on Sunday night. There were no differences between the groups in terms of bedtime delta values (Saturday–Sunday), $t(93) = 1.07, p = .29$. Nevertheless, a significant difference in sleep onset latency delta values was observed between the groups, $t(92) = 2.00, p = .05$. On average, the intervention group fell asleep 11 minutes faster than the control group on Sunday night (Table 3).

Reaction time test (RT). The findings from the RT-test are shown in Tables 2 and 4, and in Figures 1 and 2. A total of 78 students (73.6%) were included in the analyses (intervention, $n = 33$; control, $n = 45$). The intervention group showed significantly fewer lapses (>500 ms) on Mondays than on Fridays ($\Delta M = -7.27$; $SD = 18.23$), compared to the control group ($\Delta M = 1.33$; $SD = 12.47$), $t(76) = -2.48, p = .02$ (Figure 1). On median reaction time, the intervention group performed significantly better on Mondays than on Fridays ($\Delta M = -49.12$; $SD = 129.04$), compared to the control group ($\Delta M = 2.48$; $SD = 58.77$), $t(76) = -2.37, p = .02$ (Figure 2).

Subjective sleepiness (KSS) and mood (PANAS). In the analysis of KSS (Table 2), paired data between Monday and Friday were available for 80 students (75.5%) (intervention, $n = 35$; control, $n = 45$). No significant differences were seen between the groups’ delta values of subjectively reported sleepiness (intervention, $\Delta M = -.46$; $SD = 2.72$; control, $\Delta M = .13$; $SD = 2.15$), $t(78) = -1.09, p = 0.28$. Nor did we find significant differences in terms of delta values of positive or negative affect, respectively $t(65) = 1.01, p = .32$ and $t(71) = .13, p = .90$ (Table 2). Mean values are shown in Table 4.

Discussion

The present study further supports the notion that later school start times increase the amount of sleep obtained by adolescents (e.g. Danner & Phillips, 2008; Epstein et al., 1998; Owens et al., 2010; Wahlstrom, 2002). While one may expect adolescents to go to

Table 3
Variable Overview Saturday vs. Sunday Assessments

	Intervention		Control	
	Saturday <i>M (SD)</i>	Sunday <i>M (SD)</i>	Saturday <i>M (SD)</i>	Sunday <i>M (SD)</i>
Sleep diary				
– Total sleep time, TST	523.1 (123.4)	445.8 (84.8)	532.0 (106.8)	379.5 (101.9)
– Bedtime	0147 hours (100.2 min)	2357 hours (85.4 min)	0217 hours (81.4 min)	0009 hours (78.4 min)
– Sleep onset latency, SOL	14.6 (14.4)	23.0 (24.6)	11.0 (14.6)	34.0 (42.1)

Mark: The values are given in minutes if not stated otherwise.

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Table 4
Variable Overview Monday vs. Friday assessments

	Intervention		Control	
	Monday <i>M (SD)</i>	Friday <i>M (SD)</i>	Monday <i>M (SD)</i>	Friday <i>M (SD)</i>
Sleepiness, KSS	4.0 (1.8)	4.5 (5.2)	5.0 (1.8)	4.9 (2.2)
Positive affect, PANAS	26.9 (6.2)	26.3 (7.1)	27.4 (6.0)	28.6 (9.0)
Negative affect, PANAS	12.8 (3.4)	13.2 (3.1)	14.0 (3.7)	14.5 (4.7)
RT-test				
– Lapses (>500 ms)	7.3 (9.8)	14.6 (19.1)	11.1 (11.2)	9.7 (10.6)
– Median RT	273.0 (56.2)	322.1 (140.2)	273.1 (61.9)	270.6 (53.0)
– Mean RT	321.1 (97.7)	394.8 (176.4)	394.1 (119.2)	346.9 (120.8)

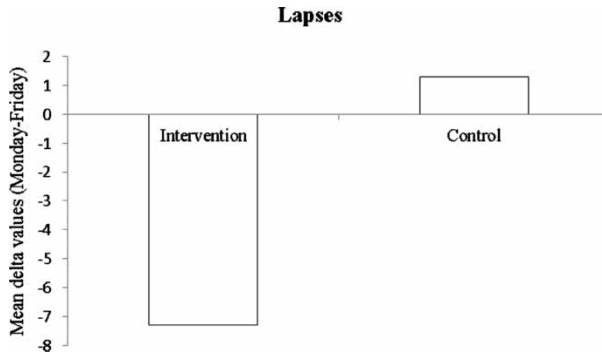


Figure 1. Mean delta values of numbers of lapses (Monday–Friday) as a function of group.

bed later when they start school later, a start time delay of one hour on Mondays actually caused the students to obtain more than one hour longer sleep duration on Sunday nights, compared to the control group. Longer total sleep time (TST) may also be the reason why students performed significantly better on the reaction time test (RT) on Mondays compared to Fridays, relative to the control group. The number of lapses (omissions) was significantly reduced on Mondays compared to Fridays for students in the intervention group relative to the control group, suggesting that they were less fatigued (Lee, Bardwell, Ancoli-Israel, & Dimsdale, 2010). This is in accordance with previous studies using both subjective (Dexter et al., 2003; Owens et al., 2010; Wolfson & Carskadon, 1998) and objective (Carskadon et al., 1998) measures of sleepiness. Thus, it was surprising that the self-report sleepiness scale (KSS) revealed no significant effects of the delayed school start time. The intervention seemed to have a significant facilitating effect on the adolescents’ reaction time. In adults and children, previous studies have demonstrated a slowing in response times as a result of both total and partial sleep deprivation (Peters et al., 2009; Van Dongen & Dinges, 2000). The reaction time test administered in the present study was a simple sustained attention task similar to other tests (e.g. psychomotor vigilance task) proven as valid predictors of performance and levels of fatigue (Dinges et al., 1997; Lim & Dinges, 2008). Sustained attention (intrinsic alertness) is probably a prerequisite to

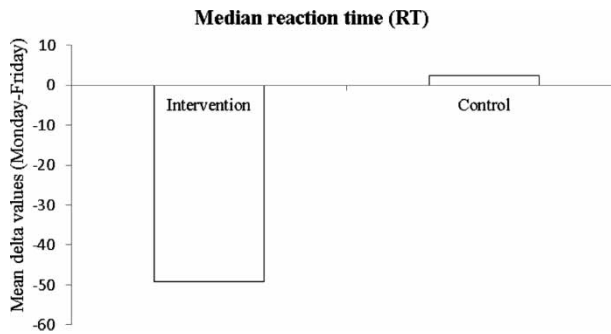


Figure 2. Mean delta values of median reaction time (Monday–Friday) in milliseconds as a function of group.

many higher aspects of cognition, which subsequently may decline if a subject is not able to sustain a sufficient level of alertness during task performance (Lim & Dinges, 2010; Sturm et al., 1999). Although vigilance appears to be more affected by sleep deprivation than more complex attention and cognition (Lim & Dinges, 2010), it is still reasonable to expect optimal academic performance to also require optimal alertness.

It is not clear why no effect of the intervention was observed in the self-reported sleepiness data. Similarly, the delayed start times did not seem to have any effect on the students' self-reported mood states, which is surprising considering the overwhelming evidence linking shorter sleep duration to affective complaints (Dahl & Lewin, 2002; Liu, 2004; Moore & Meltzer, 2008; Owens et al., 2010; Pilcher & Huffcutt, 1996; Wolfson & Carskadon, 1998). There may be several reasons why the mood and sleepiness assessments did not reveal any differences/changes. For one thing, studies show that when sleep duration is controlled for, adolescents still report higher daytime sleepiness compared to younger children (Carskadon et al., 2002). Also, as mentioned earlier, contrary to previous similar studies where the intervention often includes a delayed school start time throughout the whole week, the intervention in the present study pertained only to Mondays. We assessed the students on a Monday and on a Friday, where the Friday assessments served as a baseline measure for each group. It may be that later school start time at the beginning of the week gave the students a 'buffer' to gradually advance their weekend delayed sleep pattern (e.g. Hansen, Janssen, Schiff, Zee, & Dubocovich, 2005), which consequently had a facilitating effect on the intervention groups' assessments on Friday. Also, the students' ratings on the subjective measures may be sensitive to what day in the week they are assessed. It's easy to imagine students being more positive and alert on a Friday morning, knowing that the weekend is approaching, as opposed to a Monday morning, which is more often associated with the blues. This phenomenon has been demonstrated within experimental sleep deprivation studies and is denoted as end-effects (Haslam, 1983).

Another possible explanation for the discrepancy between objective and subjective measures is that some students may have felt more alert due to the fact that they were participating in an experiment, as opposed to taking part in a normal school lecture. The novelty of the situation might have stimulated the students' interest and affected their ratings on the subjective measures.

The fact that we did not find convergence between the different measures is in line with data on adults, showing that subjective and objective data on sleepiness and mood may be

unrelated (Franzen, Siegle, & Buysse, 2008). This underlines the complex nature of sleepiness where subjective and objective measures may address different aspects of the entity. Also, it further suggests that even if the students did not subjectively report being sleepy, their physiological sleepiness may still have been elevated, causing lapses in attention which may impede school performance and increase the risk of accidents.

In sum, the findings from the present study are similar to those of previous reports (Allen, 1992; Curcio et al., 2006; Dexter et al., 2003; Epstein et al., 1998; Fallone et al., 2002; Linck & Ancoli-Israel, 1995; Owens et al., 2010; Wahlstrom, 2002; Wolfson & Carskadon, 2003), and advocate the positive impact of adjusting school schedules to adolescents' sleep needs. It should be noted that most junior high schools in Norway already have relatively late start times (often close to 0830 hours) compared to the schools included in most of the studies referred to above. It would be reasonable to expect that the effect of delaying start times would at some point fall off. The positive effects of the intervention on the objective measures therefore convey an important message. Seen from a practical point of view, the problems related to functioning in school caused by too little sleep among adolescents can be solved either by delaying school start times so much that they are able to obtain the amount of sleep they need and/or by reducing the adolescents' sleep phase delay. Recently, investigators have successfully implemented educational programs to enhance students' awareness of sleep with the intention of improving their sleep habits (Brown, Buboltz, & Soper, 2006; Cortesi, Giannotti, Sebastiani, Bruni, & Ottaviano, 2004), although not all seem to have this effect (Moseley & Gradisar, 2009). Certainly, as the input from multimedia electronic devices will probably only increase, interventions like sleep hygiene education may be imperative to accommodate adolescents' sleep deficiency, either as an alternative or as a supplement to later school start times.

Study strengths and limitations

In this study we used a quasi-experimental design where the allocation of students to the two different groups was a non-random process. This precluded us from making clear conclusions about cause and effect. To compensate for the lack of randomization we carried out repeated measures and performed analyses to address each student's alteration over the two test days.

Previous reviews have long urged investigators to utilize objective measures of both sleepiness (Fallone et al., 2002) and daytime functioning (Wolfson & Carskadon, 2003). Few studies, however, have adhered to this appeal (Dewald et al., 2010). In the present study we accommodated this recommendation by the use of a neurobehavioral measure to assess daytime functioning.

A major limitation of the present study was that sleep was recorded by use of a sleep diary that the students completed retrospectively for the three foregoing days. This has drawbacks in terms of precision (Pallesen, Nordhus, Havik, & Nielsen, 2001). Another limitation pertains to the missing data and the high dropout rate between the two test days, which dramatically reduced the number of possible paired comparisons. The number of dropout students was higher for the intervention group than for the control group (intervention, $n_{\text{dropout}} = 16$; control, $n_{\text{dropout}} = 7$). This difference was due to a communication error with the administrators at the intervention school, where on one of the test days some of the students were sent off to the school kitchen to prepare a meal. This did however not affect the

counterbalancing, since we carried out a new round of testing on a small number of students from the intervention school to equalize the number of subjects exposed to the two test orders.

Conclusions and future direction

We conclude that a one-hour delay in school start time on Mondays in junior high schools in Norway both lengthens the students' total sleep time and makes them more vigilant in early morning classes on Mondays. It is, however, not clear whether this intervention leads to positive effects on students' sleep and alertness throughout the whole week. A further exploration of the effects of delayed start times at the beginning of the week contra the whole week would be interesting. Still, as interventions like this have a considerable impact on the community, we encourage further exploration of alternative options such as sleep hygiene educational programs. Large-scale long-term experimental studies evaluating the impact of both delayed school start times and sleep hygiene educational programs on a wide range of parameters (sleep, mood, alertness, school performance, behavior and family life) should be conducted before firm recommendations on how to deal with sleep loss in adolescents are warranted. As also emphasized by others (e.g. Curcio et al., 2006; Wolfson & Carskadon, 2003), future studies should preferably adopt a multi-measure approach when assessing the effects of sleep loss on students functioning (e.g. neurobehavioral and standardized tests, grade point average, and self-reports from students, parents, and teachers).

References

- Allen, R. (1992). Social factors associated with the amount of school week sleep lag for seniors in an early starting suburban high school. *Journal of Sleep Research*, 21, 114.
- Banks, S., & Dinges, D.F. (2007). Behavioral and physiological consequences of sleep restriction. *Journal of Clinical Sleep Medicine*, 3, 519–528.
- Beebe, D.W., Rose, D., & Amin, R. (2010). Attention, Learning, and Arousal of Experimentally Sleep-restricted Adolescents in a Simulated Classroom. *Journal of Adolescent Health*, 47, 523–525.
- Bjorvatn, B., & Pallesen, S. (2009). A practical approach to circadian rhythm sleep disorders. *Sleep Medicine Reviews*, 13, 47–60.
- Brown, F.C., Buboltz, W.C.J., & Soper, B. (2006). Development and evaluation of the Sleep Treatment and Education Program for Students (STEPS). *Journal of American College Health*, 54, 231–237.
- Calamaro, C.J., Mason, T.B.A., & Ratcliffe, S.J. (2009). Adolescents Living the 24/7 Lifestyle: Effects of Caffeine and Technology on Sleep Duration and Daytime Functioning. *Pediatrics*, 123, 1005–1010.
- Carskadon, M.A. (1982). The second decade. In C. Guilleminault (Ed.), *Sleeping and waking disorders: Indications and techniques* (pp. 871–881). Menlo Park, CA: Addison Wesley.
- Carskadon, M.A. (1990a). Adolescent sleepiness: increased risk in a highrisk population. *Alcohol Drugs Driving*, 5/6, pp. 317–328.
- Carskadon, M.A. (1990b). Patterns of sleep and sleepiness in adolescents. *Pediatrician*, 17, 5–12.
- Carskadon, M.A. (2002). Factors influencing sleep patterns of adolescents. *Adolescent sleep patterns. Biological, social, and psychological influences* (pp. 4–26). Cambridge: Cambridge University Press.
- Carskadon, M.A., Acebo, C., Richardson, G.S., Tate, B.A., & Seifer, R. (1997). An approach to studying circadian rhythms of adolescent humans. *Journal of Biological Rhythms*, 12, 278–289.
- Carskadon, M.A., Harvey, K., Duke, P., Anders, T.F., Litt, I.F., & Dement, W.C. (1980). Pubertal changes in daytime sleepiness. *Sleep*, 2(4), 453–460.

- Carskadon, M.A., Harvey, K., Duke, P., Anders, T.F., Litt, I.F., & Dement, W.C. (2002). Pubertal changes in daytime sleepiness. *Sleep: Journal of Sleep and Sleep Disorders Research*, *25*, 525–605.
- Carskadon, M.A., Mancuso, J., & Rosekind, M.R. (1989). Impact of part-time employment on adolescent sleep patterns. *Sleep Research*, *18*, 114.
- Carskadon, M.A., Vieira, C., & Acebo, C. (1993). Association between puberty and delayed phase preference. *Journal of Sleep Research & Sleep Medicine*, *16*, 258–262.
- Carskadon, M.A., Wolfson, A.R., Acebo, C., Tzischinsky, O., & Seifer, R. (1998). Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. *Sleep*, *21*, 871–881.
- Choi, K., Son, H., Park, M., Han, J., Kim, K., Lee, B., & Gwak, H. (2009). Internet overuse and excessive daytime sleepiness in adolescents. *Psychiatry and Clinical Neurosciences*, *63*, 455–462.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.
- Cortesi, F., Giannotti, F., Sebastiani, T., Bruni, O., & Ottaviano, S. (2004). Knowledge of sleep in Italian high school students: pilot-test of a school-based sleep educational program. *Journal of Adolescent Health*, *34*, 344–351.
- Curcio, G., Ferrara, M., & De Gennaro, L. (2006). Sleep loss, learning capacity and academic performance. *Sleep Medicine Reviews*, *10*, 323–337.
- Czeisler, C.A., Duffy, J.F., Shanahan, T.L., Brown, E.N., Mitchell, J.F., Rimmer, D.W., et al. (1999). Stability, precision, and near-24-hour period of the human circadian pacemaker. *Science*, *284*(5423), 2177–2181.
- Czeisler, C.A., Kronauer, R.E., Allan, J.S., Duffy, J.F., Jewett, M.E., Brown, E.N., et al. (1989). Bright light induction of strong (type 0) resetting of the human circadian pacemaker. *Science*, *244*, 1328–1333.
- Dahl, R.E., & Lewin, D.S. (2002). Pathways to Adolescent Health: Sleep Regulation and Behavior. *Journal of Adolescent Health*, *31*, 175–184.
- Danner, F., & Phillips, B. (2008). Adolescent sleep, school start times, and teen motor vehicle crashes. *Journal of Clinical Sleep Medicine*, *15*, 533–535.
- Dewald, J.F., Meijer, A.M., Oort, F.J., Kerkhof, G.A., & Bögels, S.M. (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep Medicine Reviews*, *14*, 179–189.
- Dexter, D., Bijwadia, J., Schilling, D., & Applebauqh, G. (2003). Sleep, sleepiness and school start time: a preliminary study. *Wisconsin Medical Journal*, *102*, 44–46.
- Epstein, R., Chillag, N., & Lavie, P. (1998). Starting time of school: effects on daytime functioning of fifth-grade children in Israel. *Sleep*, *21*, 250–256.
- Fallone, G., Owens, J.A., & Deane, J. (2002). Sleepiness in children and adolescents: clinical implications. *Sleep Medicine Reviews*, *6*, 287–306.
- Franzen, P.L., Siegle, G.J., & Buysse, D.J. (2008). Relationships between affect, vigilance, and sleepiness following sleep deprivation. *Journal of Sleep Research*, *17*, 34–41.
- Hagenauer, M.H., Perryman, J.I., Lee, T.M., & Carskadon, M.A. (2009). Adolescent changes in the homeostatic and circadian regulation of sleep. *Developmental Neuroscience*, *31*, 276–284.
- Hansen, M., Janssen, I., Schiff, A., Zee, P.C., & Dubocovich, M.L. (2005). The impact of school daily schedule on adolescent sleep. *Pediatrics*, *115*, 1555–1561.
- Haslam, D.R. (1983). The incentive effect and sleep deprivation. *Sleep*, *6*, 362–368.
- Hill, P. (1994). Sleep disturbances in depression and anxiety: Issues in childhood and adolescence. *Journal of Psychosomatic Research*, *38*, 61–67.
- Hofstra, W.A., & de Weerd, A.W. (2008). How to assess circadian rhythm in humans: A review of literature. *Epilepsy & Behavior*, *13*, 438–444.
- Jenni, O.G., Achermann, P., & Carskadon, M.A. (2005). Homeostatic sleep regulation in adolescents. *Sleep*, *28*, 1446–1454.

- Kelly, W.E., Kelly, K.E., & Clanton, R.C. (2001). The relationship between sleep length and grade-point average among college students. *College Student Journal*, 35, 84–86.
- Lamond, N., Dawson, D., & Roach, G.D. (2005). Fatigue assessment in the field: Validation of a hand-held electronic psychomotor vigilance task. *Aviation, Space, and Environmental Medicine*, 76, 486–489.
- Lee, B., Bardwell, W.A., Ancoli-Israel, S., & Dimsdale, J.E. (2010). Number of lapses during the psychomotor vigilance task as an objective measure of fatigue. *Journal of Clinical Sleep Medicine*, 6, 163–168.
- Linck, S.C., & Ancoli-Israel, S. (1995). Sleep and the teenager. *Sleep Research*, 24, 184.
- Liu, X. (2004). Sleep and adolescent suicidal behavior. *Sleep*, 27, 1351–1358.
- Lowden, A., Kecklund, G., Axelsson, J., & Åkerstedt, T. (1998). Changes from an 8-hour shift to a 12-hour shift, attitudes, sleep, sleepiness and performance. *Scandinavian Journal of Work, Environment & Health*, 24 suppl 3 (pp. 69–75).
- Manber, R., Pardee, R.E., Bootzin, R.R., Kuo, T., Rider, A.M., Rider, S.P., et al. (1995). Changing sleep patterns in adolescents. *Sleep Research*, 24, 106.
- Meijer, A.M., Habekothé, H.T., & Van Den Wittenboer, G.L.H. (2000). Time in bed, quality of sleep and school functioning of children. *Journal of Sleep Research*, 9, 145–153.
- Moore, M., & Meltzer, L.J. (2008). The sleepy adolescent: Causes and consequences of sleepiness in teens. *Paediatric Respiratory Reviews*, 9, 114–121.
- Moseley, L., & Gradisar, M. (2009). Evaluation of a school-based intervention for adolescent sleep problems. *Sleep*, 32, 334–341.
- Ohida, T., Osaki, Y., Doi, Y., Tanihata, T., Minowa, M., Suzuki, K., et al. (2004). An epidemiologic study of self-reported sleep problems among Japanese adolescents. *Sleep*, 27(5), 978–985.
- Owens, J.A., Belon, K., & Moss, P. (2010). Impact of Delaying School Start Time on Adolescent Sleep, Mood, and Behavior. *Archives of Pediatrics & Adolescent Medicine*, 164, 608–614.
- Pallesen, S., Nordhus, I.H., Havik, O.E., & Nielsen, G.H. (2001). Clinical assessment and treatment of insomnia. *Professional Psychology: Research and Practice*, 32, 115–124.
- Peters, J., Biggs, S.H., Bauer, K.M.M., Lushington, K., Kennedy, D., Martin, J., & Dorrian, J. (2009). The sensitivity of a PDA-based psychomotor vigilance task to sleep restriction in 10-year-old girls. *Journal of Sleep Research*, 18, 173–177.
- Pilcher, J.J., & Huffcutt, A.J. (1996). Effects of sleep deprivation on performance: A meta-analysis. *Sleep*, 19, 318–326.
- Shochat, T., Flint-Bretler, O., & Tzischinsky, O. (2010). Sleep patterns, electronic media exposure and daytime sleep-related behaviours among Israeli adolescents. *Acta Paediatrica* (pp. 1–5).
- Van den Bulck, J. (2004). Television viewing, computer game playing, and internet use and self-reported time to bed and time out of bed in secondary-school children. *Sleep*, 27, 101–104.
- Van den Bulck, J. (2007). Adolescent use of mobile phones for calling and for sending text messages after lights out: results from a prospective cohort study with a one-year follow-up. *Sleep*, 30, 1220–1223.
- Van Dongen, H.P.A., & Dinges, D.F. (2000). Circadian Rhythms in Fatigue, Alertness and Performance. In M.H. Kryger, T. Roth, & W.C. Dement (Eds.), *Principles and Practice of Sleep Medicine* (3rd ed.,) (pp. 391–399). Philadelphia: W. B. Saunders Company.
- Wahlstrom, K. (2001). School start time study, technical report, volume II: analysis of student survey data. Retrieved 27 October 2009 from <http://education.umn.edu/carei/Reports/default.html>.
- Wahlstrom, K. (2002). Changing times: Findings from the first longitudinal study of later high school start times. *Sleep*, 86, 3–21.
- Watson, D., Clark, L.A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scale. *Journal of Personality and Social Psychology*, 54, 1063–1070.
- Wolfson, A.R., & Carskadon, M.A. (1998). Sleep schedules and daytime functioning in adolescents. *Child Development*, 69, 875–887.

Wolfson, A.R., & Carskadon, M.A. (2003). Understanding adolescents' sleep patterns and school performance: A critical appraisal. *Sleep Medicine Reviews*, 7, 491–506.

Åkerstedt, T., & Gillberg, M. (1990). Subjective and objective sleepiness in the active individual. *International Journal of Neuroscience*, 52, 29–37.