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ORIGINAL ARTICLE

Effects of school start times and technology use on teenagers' sleep: 1999–2008

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Abstract

This study compared sleep patterns of high school students in 1999 and 2008. In 2006, school start times were delayed for senior students (years 12–13) from 09:00 to 10:30. For junior students (years 9–11), start time remained unchanged at 09:00. Questionnaires were completed at school by 212 year 9 and 12 students in 1999, and 455 year 9, 11 and 12 students in 2008. Year 12 students in 2008 were less likely to report sleep loss on school nights (OR = 0.06, 95% CI = 0.01–0.11) and were less sleepy (OR = 0.58, 95% CI = 0.34–0.98) than Year 12 in 1999 or than Year 11 in 2008, after controlling for gender (sleep loss, OR = 0.31, 95%CI = 0.19–0.53; sleepiness, OR = 0.46, 95% CI = 0.28–0.75). There were no comparable changes for Year 9 students. From 1999–2008, students having technologies in the bedroom rose from 80.7% to 96.4% ($P(\chi^2) < 0.001$). In 2008, having more technologies was associated with less sleep on school nights (Spearman's rho $P = 0.005$). In 2008, Year 9 students with more technologies were more likely to report daytime sleepiness (OR = 4.06, 95% CI = 1.44–11.41) and being evening type (OR = 3.38, 95% CI = 1.27–9.01), after controlling for gender. In 2008 all year groups went to bed earlier than in 1999, possibly due to increased sleep awareness, but only Year 12 students sleep later on school mornings. We conclude that delaying school start time had beneficial effects for Year 12 students, reducing sleep loss on school nights and daytime sleepiness. However, increased presence of technologies is associated with later sleep times and daytime sleepiness among Year 9 students.

Key words: school start time, technology, teenage sleep

INTRODUCTION

Teenagers typically sleep less than younger children, although laboratory studies suggest that they need at least the same amount of sleep to remain alert during the day.[1,2] Previous studies have identified common trends in sleep timing and duration across adolescence.[3–6] These include progressively later bedtimes and increasing evening tendency,[7] declining total sleep time on week nights,[8] and increasing discrepancy between the amount and timing of sleep on week nights versus weekend nights, with later onset and longer sleep on weekends.[4,9,10] These patterns have been reported consistently from studies around the world.[11–13] A New Zealand study reported a mean total sleep time of 9567 teens (range 13–17 years) of 8 hours 40 minutes on week nights compared to 9 hours 23 minutes on weekends.[14] School start times are one of a range of factors affecting decisions about sleep and wake times in teens.[15,16]

Sleep loss in teens is related to lower academic performance;[17–19] lower self-esteem and higher incidence of depressive symptoms;[20,21] increased substance use;[22,23] and an association with being overweight.[24] Fatigue has been identified as a risk factor for physical

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injury among adolescents,[25] including fatigue-related road traffic crashes.[26] In contrast, adequate sleep has been positively related to self-reported good health status and healthy behaviours among adolescents.[27] Despite this evidence, the problems associated with adolescent sleepiness tend to go unrecognised because they are so common that they are considered normal.[4]

In 1999, we piloted a questionnaire in a large urban high school (Wellington High) to examine sleep issues among New Zealand teenagers. In 2006 the school decided independently to delay the start time for the two most senior year groups (Years 12 and 13) from 09:30 to 10:30, by introducing a study period at the start of the day. Anecdotal feedback from teachers, students and school administrators, suggested that students become more responsive, more alert and better engaged, particularly in the first classes of the day. This paper describes an evaluation of the effects of the delay in school start time on sleep restriction during the school week, daytime sleepiness, and morning/evening tendency, comparing the 1999 survey with a second survey conducted in 2008.

A potential confounding factor is the major increase from 1999 to 2008 in the range of entertainment and communication technologies available to teenagers. Items such as stereos, televisions, digital audio players, gaming consoles, mobile phones for text and talking, and computers, have been shown to have a negative effect on total sleep time and daytime functioning.[28–31] To address this, both surveys asked questions about the technologies that students had in their bedrooms.

METHOD

The 1999 survey received ethical approval from the Wellington Ethics Committee. The 2008 survey received ethical approval from Massey University Human Ethics Committee Southern A (Application 08/01).

Questionnaire

The survey questionnaire was based on the Bradley Hospital/Brown University School Sleep Habits Survey (1994) used by researchers in a range of countries with varying school systems and schedules.[7,8,18,32] The survey was modified to reflect the New Zealand vernacular and education system. Prior to both surveys, small focus groups with students from the target classes checked that the questionnaire was understandable and could be completed in a 1-hr class.

In 1999, the technology question asked whether students had a TV, stereo, or computer in the bedroom. The 2008 question asked whether students had a TV, stereo or similar (like an iPod), a phone (NOT a cell phone), a cell phone, a computer, or a Playstation/Xbox/Wii or a DS/PSP, reflecting the technologies developed since 1999. The comparison of the two surveys was limited to whether or not students had any of the listed technologies in their bedroom. For the 2008 survey, analyses also examined the impact of the number of technologies in the bedroom, with students separated into three categories (tertiles) according to the number of technologies they reported.

When asked about their usual bedtime and wake time, students typically responded in whole hours or half hours. Their responses were therefore categorized in 30-min or 1-hr bins and used to calculate total sleep time (TST) for sleep episodes prior to school days (Sunday to Thursday nights) and on non-school nights (Friday and Saturday). To calculate sleep discrepancy, TST on school nights was subtracted from TST on non-school nights. Students were also asked how much sleep they felt they need to do their best every day, as a measure of their perceived sleep need. To calculate sleep loss, sleep need was subtracted from TST on school nights.

Validated scales were used to measure daytime sleepiness (Epworth Sleepiness Score (ESS)), morningness/eveningness preference, and frequency of sleep or fatigue problems.[33] When students did not complete all questions in a scale, they were excluded from analyses for that scale. Copies of the questionnaires are available from the corresponding author.

Recruitment and consent

New Zealand high schools cater for students between 13 years of age (Year 9) and 17–18 yrs of age (Year 13). School attendance is compulsory until age 16 yrs. The school day normally begins between 08:30-09:00 and concludes around 15:00, with a 1-hr lunch break. Students in the last two years of high school (Years 12 and 13) usually have study periods included in the school day. Wellington High School is an inner city state-run high school with a wide catchment and diverse student population, and it follows the typical scheduling for state-run schools except for the delayed start time of its senior students.

The 1999 survey targeted all Wellington High students in Year 9 and Year 12. At that time, all classes began at 09:00. The 2008 survey targeted all students in

Table 1 Participants by survey year, school class, and gender

1999 Survey				2008 Survey			
# Male	# Female	# Unknown	Age (yrs) (mean, s.d.)	# Male	# Female	# Unknown	Age (yrs) (mean, s.d.)
Year 9							
52	19	0	13.0 (0.43)	93	43	1	13.08 (0.39)
Year 11							
–	–	–	–	71	60	2	15.02 (0.59)
Year 12							
78	61	2	16.0 (0.46)	102	82	1	16.13 (0.67)

Note: Year 11 students were not included in the 1999 survey.

Year 9 (school start time 09:00) and Year 12 (school start time 10:30). In 2008, Year 11 students were also surveyed (school start time 09:00) to provide a comparison group close in age, but with the earlier school start time. In 2008, 12.8% of Year 12 students took an extra subject and therefore started school at 09:00 rather than 10:30. For study purposes, they were included with the Year other 12 students. This would have tended to reduce differences between the 2008 Year 12 students and other groups.

Participants were recruited through school newsletters and fliers to the target year groups. Following the school's "opting out" policy for parental consent, parents of students under 16 years were asked to inform the school if they did *not* consent to their child being involved in focus groups or the questionnaire. No students were excluded from either survey on this basis. Students over the age of 16 years are legally entitled to decide whether or not to participate. Completing the questionnaire was taken as consent.

During a designated class, participating students were provided with a paper copy of the questionnaire and an instruction sheet. A member of the research team provided a verbal introduction to the study, the questionnaire, and the instructions.

Data management and analysis

Questionnaire data were entered into a Windows Access database. All the 1999 questionnaires and 10% of the 2008 questionnaires were double-entered. Statistical analyses were conducted using SPSS 13.0 and 16.0 for Windows (SPSS, Inc., Chicago, IL, USA). As TST and sleep discrepancy between school nights and non-school nights were not normally distributed, Mann–Whitney U-tests were used to compare the 1999 and 2008 samples, and between year groups in 2008. Logistic multiple regression analyses examined whether changes between 1999 and 2008, and difference between Year 11 and Year 12 students in 2008, were significant after controlling for gender.

RESULTS

All students present on the day of the 1999 survey participated, while in 2008 two opted out. Table 1 summarises the sample demographics.

Sleep timing

Table 2 summarises the sleep timing variables in 30-min or 1-hr blocks, total sleep time (TST), wake times, and students' perceived sleep need. The distribution of wake times on school days for Year 12 (1999 vs 2008) and Year 11 (2008) are shown in Figure 1.

Between 1999 and 2008, TST increased significantly for Year 12 students. Bedtimes on weeknights and weekends were significantly earlier for both Year 9 and Year 12 students in 2008, but the reasons for this are not clear.

For Year 9 students, sleep discrepancy (TST on non-school nights vs school nights) did not change significantly between 1999 and 2008. However for Year 12 students, median sleep discrepancy *decreased* between 1999 and 2008 (median 1999 = 2 hours, median 2008 = 1 hour; Mann–Whitney $U = 8081.5$ $P \leq 0.001$). In 2008, Year 12 students also had a significantly smaller median sleep discrepancy than Year 11 students (Mann–Whitney $U = 9484.5$, $P = 0.005$).

Sleep, sleepiness and eveningness tendency: comparing 1999 and 2008

Table 3 summarises the findings from logistic multiple regression models that compared Years 9 and 12, from the 1999 and 2008 samples, controlling for gender.

Table 2 Median sleep timing variables comparing 1999 and 2008 (Mann–Whitney *U*-test)

	1999	2008
TST on school nights(hrs)		
Year 9	9.0–9.9	9.0–9.9
Year 12	7.0–7.9	9.0–9.9***
Year 11 vs Year 12, 2008		
Year 11	–	8.0–8.9**
TST on weekends (hrs)		
Year 9	9.0–9.9	10.0–10.9*
Year 12	9.0–9.9	9.0–9.9
Year 11 vs Year 12, 2008		
Year 11	–	10.0–10.9
Bed time on school nights		
Year 9	22:00–22:59	21:00–21:59**
Year 12	23:00–23:59	22:00–22:59**
Year 11 vs Year 12, 2008		
Year 11	–	22:00–22:59**
Wake time on school days		
Year 9	07:00–07:29	07:00–07:29
Year 12	07:00–07:29	08:00–08:29***
Year 11 vs Year 12, 2008		
Year 11	–	07:00–07:29***
Bed time on weekends		
Year 9	23:00–23:59	22:00–22:59***
Year 12	01:00–01:59	00:00–00:59**
Year 11 vs Year 12, 2008		
Year 11	–	00:00–00:59
Wake time on weekends		
Year 9	09:00–09:59	09:00–09:59
Year 12	10:00–10:59	09:00–09:59*
Year 11 vs Year 12, 2008		
Year 11	–	09:00–10:00
Perceived sleep need (hrs)		
Year 9	≥10.0	8.0–8.9***
Year 12	9.0–9.9	8.0–8.9***
Year 11 vs Year 12, 2008		
Year 11	–	8.0–8.9

$^*P \leq 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

Epworth Sleepiness Scores (ESS) were split at the median (ESS ≤ 4 versus ESS > 4). Evening types were defined as having an MEQ (Morning–Evening Questionnaire) score <30.

Year 9 girls were more likely than boys to report losing sleep on school nights and to score above the median on the ESS. Year 12 girls were also more likely to score above the median on the ESS than Year 12 boys.

After controlling for gender, Year 9 students were *less* likely to report losing sleep on school nights in 2008 than in 1999. A contributing factor was that Year 9 students in 2008 reported a lower median sleep need than those in 1999 (8–9 h versus 9–10 h; Mann–Whitney $U = 4355$, $P = 0.042$), This reported reduction in sleep need was not accompanied by an overall reduction in sleepiness in 2008 (Table 2).

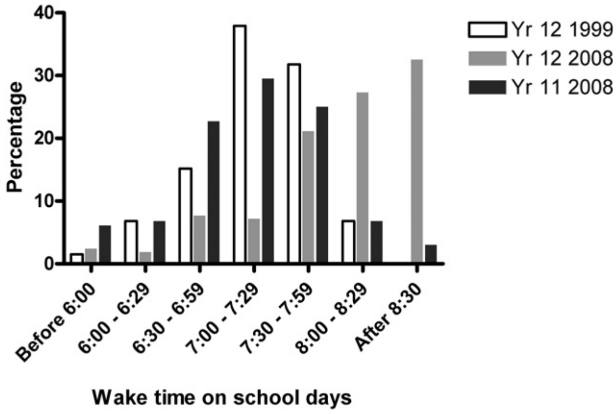

Figure 1 Histogram showing the percentage of students waking at different time on school days, split by year group.

Comparing 1999 and 2008, Year 12 students in 2008 were less likely to report losing sleep on school nights, less likely to be above the median for sleepiness, and more likely to score as evening-type on the MEQ, after controlling for gender.

Effects of delaying school start time: comparing year 11 and year 12 in 2008

Table 4 summarises the results of logistic multiple regression analyses comparing Year 11 (start time 09:00) and Year 12 students (start time 10:30) in the 2008 survey.

Year 11 students were more likely to report sleep loss on school nights, score above the median on the Epworth sleepiness scale, and score as evening type on the MEQ. Analysis of the individual questions in the MEQ score showed that compared to Year 11, Year 12 students were more likely to report that it is easy for them to get up in the morning ($\chi^2 = 25.6$, $P < 0.001$), feel "OK" or "fine" on waking ($\chi^2 = 10.8$; $P \leq 0.005$); and took less time to feel "with it" on waking ($\chi^2 = 15.26$; $P \leq 0.05$). Year 12 students were significantly more likely to report waking after 07:00 on weekdays ($\chi^2 = 68.79$; $P \leq 0.0001$), suggesting that they used the delayed school start to sleep later.

Technologies in the bedroom

In 1999, 80.7% of students had at least one entertainment or communications technology in their bedroom.

Table 3 Sleep loss on school days, sleepiness, and evening tendency: 1999 versus 2008

	1999		2008		OR (95% CI) gender	OR (95% CI) survey year
	Male	Female	Male	Female		
Year 9						
% losing sleep on school nights	58	80	21	36	2.32 (1.18–4.53)**	0.17 (0.09–0.33)***
% ESS ≥ 4	41	67	54	74	2.64 (1.32–5.29)**	1.63 (0.85–3.11)
% MEQ < 30 (evening type)	50	47	55	78	1.71 (0.92–3.21)	1.92 (0.99–3.70)
Year 12						
% losing sleep on school nights	72	82	19	13	1.06 (0.60–1.89)	0.06 (0.03–0.11)***
% ESS ≥ 4	60	82	45	74	3.32 (1.94–5.65)***	0.58 (0.34–0.98)**
% MEQ < 30 (evening type)	62	49	74	74	0.81 (0.48–1.35)	2.22 (1.33–3.70)***

*$P \leq 0.05$; **$P < 0.01$; ***$P < 0.001$. Reference groups: males, 1999 survey.

Table 4 Sleep loss on school days, sleepiness, and eveningness tendency, comparing year 11 and year 12 (2008 sample)

	Year 11		Year 12		OR (95% CI) gender	OR (95% CI) year group
	Male	Female	Male	Female		
% losing sleep on school nights	33	45	19	13	0.92 (0.54–1.56)	0.31 (0.19–0.53)***
% ESS ≥ 5†	53	76	31	64	3.40 (2.08–5.57)***	0.46 (0.28–0.75)**
% MEQ < 30 (evening type)	77	93	74	74	1.56 (0.87–2.79)	0.52 (0.29–0.96)*

*$P < 0.05$; **$P \leq 0.001$; ***$P < 0.001$. †Median ESS for Year 11 students = 5. Reference groups: males, 1999 survey.

Table 5 Breakdown of technology categories for logistic regression analyses, 2008

Technology group	Year 9 Low	Year 9 Medium	Year 9 High	Year 11 Low	Year 11 Medium	Year 11 High	Years 12 Low	Years 12 Medium	Years 12 High
	0–1	2–3	4–6	0–2	3	4–6	0–2	3	4–6
% Girls	14.0	53.5	32.8	28.8	32.2	39.0	45.1	26.8	28.0
% Boys	25.8	36.6	37.8	33.3	26.1	40.6	39.0	15.0	28.0

By 2008, this had risen to 96.4% ($\chi^2 = 45.21$, $P < 0.001$). The increase was significant for Year 9 students ($\chi^2 = 6.815$, $P < 0.05$) and Year 12 students ($\chi^2 = 27.756$ $P < 0.001$). In the 2008 sample there was a significant inverse relationship between the number of technologies in the bedroom and TST on school nights (Spearman's rho = −0.134, P (2-tailed) = 0.005).

Students in each year group were sorted into approximate tertiles according to the frequency distribution of the number of technological items in the bedroom (Table 5). The median number of technologies for boys and for girls in each group was 3.0.

For each year group, three logistic regression models were run to evaluate whether gender and the number of technologies in the bedroom (grouped as in Table 5) were independent risk factors for the following dependent variables: sleep loss on school nights (yes/no); being above the median ESS for the year group; and being evening type (MEQ < 30). These analyses are summarised in Table 6.

Among Year 9 students, the risk of daytime sleepiness was strongly associated with more technologies in the bedroom. Evening tendency was associated with being female, and with medium or high number of technologies. The findings were similar for Year 11 students. The only significant finding among Year 12 students was a greater evening tendency for girls. There were no significant associations between technologies and either morning/evening tendency or daytime sleepiness.

Table 6 Effects of having technology in the bedroom, 2008 survey

	Gender OR (95% CI)	# Technologies Low vs Medium OR (95% CI)	# Technologies Low vs High OR (95% CI)
Year 9			
% ESS ≥ 4	2.74 (1.13–6.60)*	1.21 (0.47–3.13)	4.06 (1.44–11.41)**
MEQ < 30 (evening type)	2.65 (1.10–6.37*	2.82 (1.07–7.38)*	3.38 (1.27–9.01)*
Year 11			
% ESS ≥ 5†	2.76 (1.28–5.93)**	1.52 (0.57–3.99)	1.16 (0.49–2.76)
MEQ < 30 (evening type)	4.07 (1.24–13.33)*	1.08 (0.33–3.55)	2.67 (0.74–9.71)
Years 12			
% ESS ≥ 4	3.55 (1.81–6.94)***	1.19 (0.49–2.90)	1.21 (0.59–2.46)

*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$. †Median ESS for Year 11 students = 5. Reference group: males.

DISCUSSION

This study confirms that early school start times and having entertainment and communication technologies in the bedroom are associated with restricted sleep and increased sleepiness among teenagers.

In 1999, the commonly reported pattern of change across the teenage years was observed, with older students (Year 12, average age 16 years) more likely to report insufficient sleep on school nights, having a larger discrepancy between their weekday and weekend sleep patterns, and being sleepier and more evening type, than younger students (Year 9, average age 13 years). As reported by others, girls were also more likely to report insufficient sleep on school nights, and to be sleepier and more evening-type than boys.[34] However not all studies have report this gender difference.[35]

As expected by 2008, two major changes had affected the students' sleep: the delay in school start time for Year 12 and the increased presence and diversity of entertainment and communications technologies in students' bedrooms.

Change in school start time

In 2008, Year 12 students (start time 10:30) reported a *smaller* discrepancy between TST on school nights and non-school nights than Year 12 students in 1999 (start time 09:00). After controlling for gender, students in 2008 were also 16.7 times *less* likely to report sleep loss on school nights and 1.7 times *less* likely to score above the combined group median on the ESS.

On the other hand, they were 2.2 times *more* likely to score as evening type on the MEQ. Among teenagers, being more evening-type has been reported to be associated with lower TST, poorer sleep efficiency and greater daytime fatigue.,[36,36–38] as well as being a risk factor for emotional, behavioural and physical health problems..[38–42] In the present study, we would argue that the intervention did not make Year 12 students more evening-type. Rather, it facilitated the expression of eveningness, by allowing them to sleep later on school mornings, thereby reducing sleep loss and sleepiness.

Despite being a year older than the Year 11 students (school start time 09:00), Year 12 students in 2008 were 3.2 times *less* likely to report sleep loss on school nights, 2.2 times *less* likely to score above the median on the ESS, and 1.9 *less* likely to score as evening type on the MEQ. Together, these findings strongly support the anecdotal observations of teachers, students, and school administrators that the delay in school start time has been beneficial for the Year 12 students.

A possible negative outcome of delaying school start times is that students might delay their sleep start times on school nights, because of decreased exposure to phase advancing morning light and/or because they count on being able to sleep later in the morning. However, in this study the introduction of the delayed school start time did not delay the median sleep start time on school nights of Year 12 students. Indeed, sleep start times were earlier in 2008 for Year 12 students (median = 22:00–22:59 compared to 23:00–23:59 in 1999). There is no clear explanation for this, however the Year 9 students also showed an advance in sleep start times in 2008 (median = 21:00–21:59 compared to 22:00–22:59 in 1999). In addition, in 2008 the Year 11 students had the same median sleep start time on school nights as the Year 12 students. These findings suggest that the earlier median sleep start time on school nights of Year 12 s in 2008 compare to 1999 was not related to the change in school start times. General public awareness about the importance of sleep is increasing in New Zealand, and it is possible that the feedback to the school community of findings from the 1999 survey heightened awareness amongst teachers, school administrators, and parents.

Comparing the sleep patterns of Year 9 students between 1999 and 2008 (both started school at 09:00), there was no change in sleep discrepancy between school nights and non-school nights, and no change in the proportion of students scoring above the combined group median on ESS, or in the proportion of students who scored as evening-type, after controlling for gender. However, Year 9 students in 2008 were less likely to report losing sleep on school nights than their counterparts in 1999, after controlling for gender. This anomalous finding was largely attributable to Year 9 students in 2008 reporting a lower perceived sleep need. It is not clear why students in 2008 think they need less sleep, and this warrants further research because it is inconsistent with the lack of change in other measures of sleep and sleepiness.

Technologies in the bedroom

Between 1999 and 2008, the proportion of students who had at least one personal entertainment or communications technology in their bedroom increased by 15.7%, to 96.4%. In the 2008 sample, after controlling for gender, Year 9 students who had 4–6 technologies in the bedroom were 4.06 times more likely to score above the median for sleepiness (ESS $\geq$ 4), than students with $\leq$1 technology in the bedroom. After controlling for gender, more technologies in the bedroom also increased the likelihood that students scored as evening type. These findings are consistent with other studies that have reported negative effects of personal entertainment and communications technologies on total sleep time and daytime functioning.[37,43–46]

Among older students, there were no significant relationships between the number of technologies in the bedroom and any of the dependent variables, after controlling for gender. This may reflect the lower number of technologies in the bedroom reported by Year 12 students (Table 5). An important caveat is that these analyses address only the number of technologies present, not the amount of time that students spend using them.

Study limitations

All the data in this study are subjective and retrospective. Biases could be introduced in some variables if students attach kudos to particular answers, for example getting very little sleep. However, students did not see each other's responses which may have limited the tendency to exaggerate. Not measuring the amount of technology use, and changes in the technology question between 1999 and 2008, limited the analysis of the effects of the introduction of new personal technologies.

The participating school has students from a wide range of ethnicities and socioeconomic backgrounds, but cannot be considered representative of New Zealand high schools. The start time of 10:30 is significantly later than high schools in American school districts where start times have been delayed,[47] limiting the ability to make comparisons on the interactions between school start time and other environmental and biological factors.

The study did not capture teenagers who are working or not in school for other reasons. Other studies have indicated that fatigue and sleepiness pose health and injury risks to young people in the workforce,[48] and it is reasonable to expect that adolescents not in school would experience similar biological and psychosocial issues to those in school. This study did not capture daily exposure to potential time cues (such as time spent outdoors or social activities) and lifestyle regularity. Poorer social regulation and irregular exposure to time cues have been related to sleep disruption among teenagers.[49,50]

Evening-type students may be challenged when they move into the workforce or tertiary study and have to cope with earlier starts. However, a delay in their high school start time can give them several years of better sleep, with improved academic performance and mental and physical health.

CONCLUSIONS

The intervention attracted ill-informed criticism from a number of sources outside the school. However, this study supports anecdotal observations of its beneficial effects. Students with the later start time were less likely to report sleep loss on school nights and were less sleepy than their counterparts nine years earlier, despite lower perceived sleep need and an increase in the number of technologies in their bedrooms. The data suggest that high levels of technology use may be a particular problem for the younger Year 9 students who do not have the benefit of the delayed school start time.

Delayed school start times are not a magic bullet for sleep loss and sleepiness among teenagers, which have multiple interacting causes. Good quality sleep education can be beneficial for parents, teachers and students, and further research evaluating the effectiveness of interventions is essential.

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