SLEEPJ, 2018, 1–8

doi: 10.1093/sleep/zsy052
Advance Access Publication Date: 10 April 2018
Original Article

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Sustained benefits of delaying school start time on adolescent sleep and well-being

June C. Lo, Su Mei Lee, Xuan Kai Lee, Karen Sasmita, Nicholas I.Y.N. Chee, Jesisca Tandi, Wei Shan Cher, Joshua J. Gooley and Michael W.L. Chee*

Centre for Cognitive Neuroscience, Neuroscience and Behavioral Disorders Program, Duke-NUS Medical School, Singapore

*Corresponding author. Michael W.L. Chee, Center for Cognitive Neuroscience, Duke-NUS Medical School, 8 College Road, Singapore 169857. Email: michael.chee@duke-nus.edu.sg.

Abstract

Study Objectives: To investigate the short- and longer-term impact of a 45-min delay in school start time on sleep and well-being of adolescents.

Methods: The sample consisted of 375 students in grades 7–10 (mean age ± SD: 14.6 ± 1.15 years) from an all-girls' secondary school in Singapore that delayed its start time from 07:30 to 08:15. Self-reports of sleep timing, sleepiness, and well-being (depressive symptoms and mood) were obtained at baseline prior to the delay, and at approximately 1 and 9 months after the delay. Total sleep time (TST) was evaluated via actigraphy.

Results: After 1 month, bedtimes on school nights were delayed by 9.0 min, while rise times were delayed by 31.6 min, resulting in an increase in time in bed (TIB) of 23.2 min. After 9 months, the increase in TIB was sustained, and TST increased by 10.0 min relative to baseline. Participants also reported lower levels of subjective sleepiness and improvement in well-being at both follow-ups. Notably, greater increase in sleep duration on school nights was associated with greater improvement in alertness and well-being.

Conclusions: Delaying school start time can result in sustained benefits on sleep duration, daytime alertness, and mental well-being even within a culture where trading sleep for academic success is widespread.

Statement of Significance

Delaying school start times to improve adolescent sleep and well-being has been shown to be beneficial in Western cultures, but its usefulness in East Asian countries where students are driven to trade sleep for academic success is less clear. The sustainability of sleep habit improvement is also not well characterized. In this study, students in a Singapore school demonstrated improvements in sleep and well-being at 1 month after a 45-min delay in school start time, and these positive changes were maintained at 9 months. Moreover, the majority of students, teachers, and parents were supportive of the schedule change. Thus, in a culture where academic achievement outweighs the importance of sleep, starting school later is feasible and can lead to sustainable benefits.

Key words: adolescents; delayed school start time; sleep duration; sleep timing; sleepiness; well-being

Submitted: 23 November, 2017; **Revised:** 29 January, 2018

Introduction

East Asian students live in a culture where the importance of academic success is deeply ingrained [1]. This relentless drive for academic achievement leads to high attainment in international academic assessments [2], but has contributed to the curtailment of nocturnal sleep on school nights to well below the recommended [3, 4] 8–10 hours [5–7], putting students at risk of adverse cognitive and psychological outcomes [8–12]. In addition, the maturational delay in circadian timing and slower accumulation of sleep pressure [13], as well as technology use before bedtime [14], all lead to delays in bedtime. However, most students wake up before their natural biological rise time because their schools start early. Since students in schools that start later are found to have longer sleep duration [15, 16], delaying school start times is one of the principled solutions to improving sleep duration in adolescents [17–19].

Most studies on later school start times have been conducted in Western countries [20]. These studies have consistently found increased sleep duration on school nights with later start times [21–26]. Accompanying benefits include less daytime sleepiness and fewer depressive symptoms [21, 24, 25, 27, 28]. Such desirable outcomes may fail to be sustained if students gradually delay their bedtime. For example, one study found that the sleep gained 2 months after a 45-min delay in start time was no longer observed another 7 months later due to a delay in the sleep period [29]. Delaying bedtimes, partly as a result of mounting academic workload, is a pressing reality in most East Asian households. Compounding this erosion of sleep time in East Asian societies is the resistance to changing the already packed school schedules [30]. For example, recently, a secondary school in Hong Kong agreed to delay its start time, but only by 15 min. Nevertheless, a 4-min increase in time-in-bed on weekdays was found, together with gains in mental health, prosocial behavior and better attentiveness in class and peer relationships [30]. When the start time of a primary school in China could be delayed by 60 min, there was a gain in sleep duration by 23 min, and daytime sleepiness was reduced [31].

Singapore is a typical hard driving East Asian society that leads the world in the Programme for International Student Assessment (PISA) rankings [2], which measures scholastic performance in students aged 15 years. In Singapore, school typically starts around 07:30, which is 1 hour earlier than the 08:30 or later start time recommended by the American Academy of Pediatrics [17], the American Medical Association [18], and the American Academy of Sleep Medicine [19]. Short sleep among Singaporean adolescents is rampant, and the average time in bed (TIB) on school nights is 6.5 hours or less [9, 10]. In July 2016, an all-girls' secondary school in Singapore delayed its start time from 07:30 to 08:15 by restructuring its timetable in a manner that did not delay school end time. We investigated the impact of starting school later on students' sleep and well-being 1 month and 9 months after the institution of the start time delay. In addition, parents' and teachers' views on the benefits of this change for their child/students were surveyed, as they are important stakeholders in initiatives to delay school start time.

Methods

Participants

Participants were recruited through invitation emails sent to all students and parents in an all-girls' secondary school, which is a leading school in Singapore that receives partial government funding but has more freedom, relative to other public schools, in its operation. All the ~1600 students were eligible to participate. A total of 375 students (~23 per cent) from grades 7–10 (mean age ± SD = 14.6 ± 1.15 years) participated at baseline. The sample size decreased to 352 at the 1-month follow-up, and further to 150 at the 9-month follow-up partly because the grade 10 students (n = 111) had graduated. Sample size also varied across different measurements (i.e. actigraphy, questionnaire, and mood and sleepiness ratings; see below for further details; Table S1) since participants varied in their willingness to undergo different tests.

Design and procedure

This study consisted of three phases. Baseline data were collected in April 2016 prior to the change in start time. In July 2016, school start time was delayed from 07:30 to 08:15. Students who participated at the baseline phase were invited to take part in the first follow-up, which was conducted approximately 1 month after the change in start time (August 2016) in order to capture the immediate impact of the manipulation. The 9-month follow-up was conducted in April 2017 to assess the sustainability of any positive change in outcomes and only those who participated in the previous two phases were invited to take part. The timing of the 9-month follow-up was chosen to occur on a time scale similar to previous work [29], and it took place over a period that was determined as feasible and most convenient for the partnering school.

At each phase, participants wore a wrist actigraph for 1 week and attended an after-school session during which they rated their current mood and levels of sleepiness. They filled in an online questionnaire for the assessment of their sleep patterns and well-being. Due to restrictions in the number of wrist actigraphs and in students' availability, data were collected over a period of 1 month per phase. All procedures took place during the school term. Participants were financially compensated for their participation.

At the 1-month follow-up, parents and teachers were surveyed for their opinion about the change in school start time through an online questionnaire. Parents and teachers were recruited via email. A total of 124 parents and 37 teachers responded.

This study was approved by the National University of Singapore Institutional Review Board. All the adolescent participants and their legal guardians provided written informed consent. Parents and teachers also provided written informed consent for their survey.

Measures

Sleep timing and duration

Participants reported their usual bedtime and rise time on school days and non-school days (referred to as weekdays and weekends from here) via an online questionnaire. TIB was defined as the period between bedtime and rise time. Additionally, weekend extension of TIB, that is the difference between weekend and weekday TIB, was also derived since it may reflect the magnitude of sleep loss on weekdays.

To measure total sleep time (TST) objectively, participants wore a wrist actigraph (Actiwatch 2, Philips Respironics, Inc., Pittsburgh, PA) on their non-dominant hand for 1 week during term time. Weekend extension of TST was also computed. Activity was recorded in 2-min epochs. A low wake-sensitivity threshold (i.e. 80 counts per epoch) was used for analysis as previous research has found this setting to be most comparable to polysomnographically assessed TST in adolescents [32]. Sleep diaries were collected only in the 9-month follow-up. Therefore, sleep scoring intervals were determined using a combination of factors: reported sleep and wake times from the diaries if available, event markers on the actograms, and changes in light and activity levels. Only participants who had at least three weekday nights and one weekend night of usable data were included in the analyses.

Sleepiness

Levels of subjective sleepiness were assessed during an after-school session with the Karolinska Sleepiness Scale (KSS; 1 = extremely alert; 9 = very sleepy, great effort to keep awake, fighting sleep) [33]. We also used an online questionnaire to assess how difficult participants found staying awake during the day ("During your daytime activities, how much of a problem do you have trying to stay awake (e.g., feeling sleepy, struggling to stay awake)?" [0 = no problem at all; 4 = a very big problem]), as well as how refreshed they felt after waking ("During the first half hour after having woken in the morning, how tired do you feel on school days?" [0 = very tired; 3 = very refreshed]).

Well-being

Mood was assessed during the after-school session with the Positive And Negative Affect Schedule (PANAS) [34], which consists of 10 items for positive mood and 10 items for negative mood. Each item was rated on a 5-point Likert scale (1 = very slight or not at all; 5 = extremely), and the total scores for the positive and negative mood subscales were analyzed. Furthermore, depressive symptoms were measured with the 11-item Kutcher Adolescent Depression Scale [35] in an online questionnaire. The scale assessed how participants felt on average over the past week with regard to depressive symptoms such as sadness, worthlessness, and thoughts of self-harm. Each item was rated on a 4-point scale (0 = hardly ever; 3 = all of the time) and the total score for the 11 items was analyzed.

Acceptance of change in start time by students, parents, and teachers

At the 1-month follow-up, students were asked about their views on the later start time with the question, "Do you prefer this semester's school start time or last semester's school start time?" with "This semester," "Last semester," and "No difference" as options.

Parents' and teachers' views of the later start time were also assessed at this time point with the question, "Is the later school start time better or worse for your child / students and her / their schedule?" with "No difference," "Better," "Worse," and "Both better and worse" as response options.

Statistical analyses

Data were analyzed using SPSS version 24. To assess the immediate impact of the later start time on sleep, sleepiness, and well-being, the changes in these measures from baseline to the first follow-up were tested against 0 in one-sample *t*-tests. We also assessed if these changes were maintained 9 months after the delay by testing the changes from baseline and from the first follow-up against 0. Standard error of the mean was reported unless otherwise specified. Cohen's *d* was computed to determine the effect sizes associated with these changes [36]. Note that here, we did not use repeated-measures ANOVAs because this would dramatically reduce the sample size (n = 77–139 depending on the measurement in question) and the statistical power. Furthermore, mixed effect models were not appropriate since in this study, data were missing systematically from students who graduated in December 2016 and did not participate in the 9-month follow-up.

To investigate if changes in sleepiness and well-being 1 and 9 months after the delay (relative to baseline) were associated with changes in sleep on weekdays, Pearson's correlations were used. Extreme outliers, that is, data points greater than 3 times the interquartile range below the first and above the third quartiles, were removed before analysis.

Results

The impact of a delayed school start time at 1 month

Sleep timing and duration

Compared with baseline, at the first follow-up, there was a small delay in bedtime by 8.98 ± 2.27 min on weekdays (t = 3.96, $p < 0.001$, d = 0.32; Table 1; Figure 1A), but rise times were considerably delayed by 31.61 ± 1.96 min (t = 16.10, $p < 0.001$, d = 1.33; Figure 1B), resulting in a mean increase in TIB by 23.18 ± 3.22 min (t = 7.21, $p < 0.001$, d = 0.60; Figure 1C). Also, the percentage of participants whose TIB on weekdays was at least 8 hours (the minimum sleep duration recommended for this age group [3, 4]) increased from 6.9 to 16.1 per cent. No significant change in TST was observed (t = 0.94, p = 0.35; Figure 1D).

On weekends, bedtime was slightly delayed by 15.77 ± 3.99 min (t = 3.95, $p < 0.001$, d = 0.33; Figure 1A). However, no statistically significant changes were found for rise time, TIB, or TST ($t < 1.71$, $p > 0.09$; Table 1; Figure 1B–D).

Weekend extension of TIB was reduced by 29.19 ± 6.03 min (t = 4.84, $p < 0.001$, d = 0.41; Figure 1E). No significant change in weekend extension of TST was observed (t = 0.76, p = 0.45; Figure 1F).

Sleepiness and well-being

In general, participants' sleepiness and well-being improved after the delay in start time. They reported fewer depressive symptoms, lower levels of subjective sleepiness, fewer problems staying awake during the day, feeling more refreshed after waking on school days, and less negative mood compared with baseline ($t > 2.46$, $p < 0.02$, $d > 0.16$; Table 2; Figure 2). However, positive mood did not significantly change from the baseline level (t = 0.83, p = 0.41).

Relationships of sleep changes with sleepiness and well-being

Increase in TIB on weekdays was significantly associated with lower levels of subjective sleepiness, fewer problems staying awake during the day, and feeling more refreshed after waking in the morning on school days (r = –0.17 to 0.29, $p < 0.05$; Table 3).

Table 1. Changes in Sleep Timing and Duration from Baseline to the Follow-ups

	Baseline to 1 month			1–9 months			Baseline to 9 months		
	Mean ± SEM	p	d	Mean ± SEM	p	d	Mean ± SEM	p	d
Weekday									
Bedtime (min)	8.98 ± 2.27	**<0.001**	0.32	3.44 ± 3.46	0.32	0.10	9.68 ± 3.65	**0.01**	0.28
Rise time (min)	31.61 ± 1.96	**<0.001**	1.33	3.68 ± 1.95	0.06	0.19	30.25 ± 2.39	**<0.001**	1.36
Time in bed (min)	23.18 ± 3.22	**<0.001**	0.60	1.36 ± 3.86	0.73	0.03	21.52 ± 4.16	**<0.001**	0.55
Total sleep time (min)	2.06 ± 2.20	0.35	0.05	5.80 ± 3.91	0.14	0.13	9.95 ± 3.63	**0.01**	0.24
Weekend									
Bedtime	15.77 ± 3.99	**<0.001**	0.33	6.15 ± 5.16	0.24	0.11	20.52 ± 5.24	**<0.001**	0.41
Rise time	7.21 ± 4.21	0.09	0.14	−6.49 ± 5.22	0.22	0.12	−1.81 ± 7.45	.81	0.03
Time in bed	−7.65 ± 4.90	0.12	0.13	−13.02 ± 6.69	**0.05**	0.19	−24.70 ± 8.06	**0.003**	0.33
Total sleep time	−1.16 ± 4.83	0.81	0.01	−26.24 ± 7.22	**<0.001**	0.32	−28.81 ± 7.46	**<0.001**	0.34
Weekend extension									
Time in bed	−29.19 ± 6.03	**<0.001**	0.41	−14.46 ± 7.35	**0.05**	0.20	−45.31 ± 9.34	**<0.001**	0.53
Total sleep time	−3.85 ± 5.06	0.45	0.04	−32.03 ± 7.88	**<0.001**	0.36	−41.34 ± 7.88	**<0.001**	0.47

d, Cohen's *d*.
Bedtime, rise time, and time in bed were derived from an online questionnaire, while total sleep time was measured with actigraphy. Significant findings are indicated in bold.

Increase in TIB on weekdays was also related to decrease in depressive symptoms and increase in positive mood ($r = -0.18$ and .21, respectively, $p < 0.04$; Table 3). No significant association was found for change in negative mood ($r = -0.06$, $p = 0.45$).

Increase in weekday TST was significantly associated with decrease in subjective sleepiness level ($r = -0.13$, $p = 0.03$; Table 3). No significant associations were observed for other well-being measures ($r < 0.12$, $p > 0.19$).

Acceptance of change in start time by students, parents, and teachers

Of 248 student respondents, 89.1 per cent indicated that they preferred the later start time, 4.9 per cent indicated that they preferred the earlier start time, and 8.5 per cent indicated that there was no difference.

Of 123 parent respondents, 75.6 per cent reported that the change in start time was better for students, 4.9 per cent reported that it was worse, 6.5 per cent reported that it was both better and worse, and 13.0 per cent reported that it made no difference.

Of 37 teacher respondents, 67.6 per cent said that the change in start time was better for students, 2.7 per cent said that it was worse, 8.1 per cent said that it was both better and worse, and 21.6 per cent said that it made no difference.

The impact of a delayed school start time at 9 months

Sleep timing and duration

On weekdays, bedtime was not delayed further from the first follow-up ($t = 0.99$, $p = 0.32$; Table 1) and remained modestly later relative to baseline by 9.68 ± 3.65 min ($t = 2.65$, $p = 0.01$, $d = 0.28$; Figure 1A). For rise time, there was a trend toward a further delay from the first follow-up ($t = 1.90$, $p = 0.06$, $d = 0.19$), and it remained considerably later than baseline by 30.25 ± 2.39 min ($t = 12.67$, $p < 0.001$, $d = 1.36$; Figure 1B). Importantly, TIB was similar to that observed during the 1-month follow-up ($t = 0.35$, $p = 0.73$) and remained lengthened moderately by 21.52 ± 4.16 min compared with baseline ($t = 5.17$, $p < 0.001$, $d = 0.55$; Figure 1C). Also, TST increased modestly by 9.95 ± 3.63 min from baseline ($t = 2.74$, $p = 0.007$, $d = 0.24$; Figure 1D). Furthermore, 14.1 per cent of the students still had at least 8 hours of TIB, which was similar to the 16.1 per cent observed for the 1-month follow-up.

On weekends, bedtime remained moderately later by 20.52 ± 5.24 min compared with baseline ($t = 3.92$, $p < 0.001$, $d = 0.41$), but was not delayed further from the 1-month follow-up ($t = 1.19$, $p = 0.24$; Figure 1A). Rise time was similar to the previous two phases ($t < 1.24$, $p > 0.22$; Figure 1B). TIB was modestly shorter than baseline by 24.70 ± 8.06 min ($t = 3.06$, $p = 0.003$, $d = 0.33$) and the 1-month follow-up by 13.02 ± 6.69 ($t = 1.95$, $p = 0.05$, $d = 0.19$; Figure 1C). Weekend TST was also moderately shorter than baseline by 28.81 ± 7.46 min ($t = 3.86$, $p < 0.001$, $d = 0.34$) and the 1-month follow-up by 26.24 ± 7.22 min ($t = 3.63$, $p < 0.001$, $d = 0.32$; Figure 1D).

There was a further, albeit small, 14.46 ± 7.35 min decrease in weekend extension of TIB from the 1-month follow-up ($t = 1.97$, $p = 0.05$, $d = 0.20$; Table 1). Thus, relative to baseline, weekend extension of TIB was considerably shorter by 45.31 ± 9.34 min ($t = 4.85$, $p < 0.001$, $d = 0.53$; Figure 1E). Weekend extension of TST also showed a moderate decrease from 1-month follow-up by 32.03 ± 7.88 min ($t = 4.07$, $p < 0.001$, $d = 0.36$), such that when compared with baseline, there was a moderate decrease by 41.34 ± 7.88 min ($t = 5.25$, $p < 0.001$, $d = 0.47$; Figure 1F).

Sleepiness and well-being

None of the sleepiness and well-being measures changed significantly from the first follow-up ($t < 1.75$, $p > 0.08$; Table 2). Hence, at the 9-month follow-up, participants still reported lower levels of subjective sleepiness, fewer problems staying awake during the day, feeling more refreshed after waking in the morning on school days, fewer depressive symptoms, and reduced negative mood relative to baseline ($t > 1.96$, $p < 0.05$).

Relationships of sleep changes with sleepiness and well-being

From baseline to the 9-month follow-up, the increase in TIB on weekdays remained significantly associated with the decrease in depressive symptoms ($r = -0.27$, $p = 0.02$; Table 3). The increase in weekday TST also remained significantly associated with the decrease in subjective sleepiness level ($r = -0.24$, $p = 0.006$).

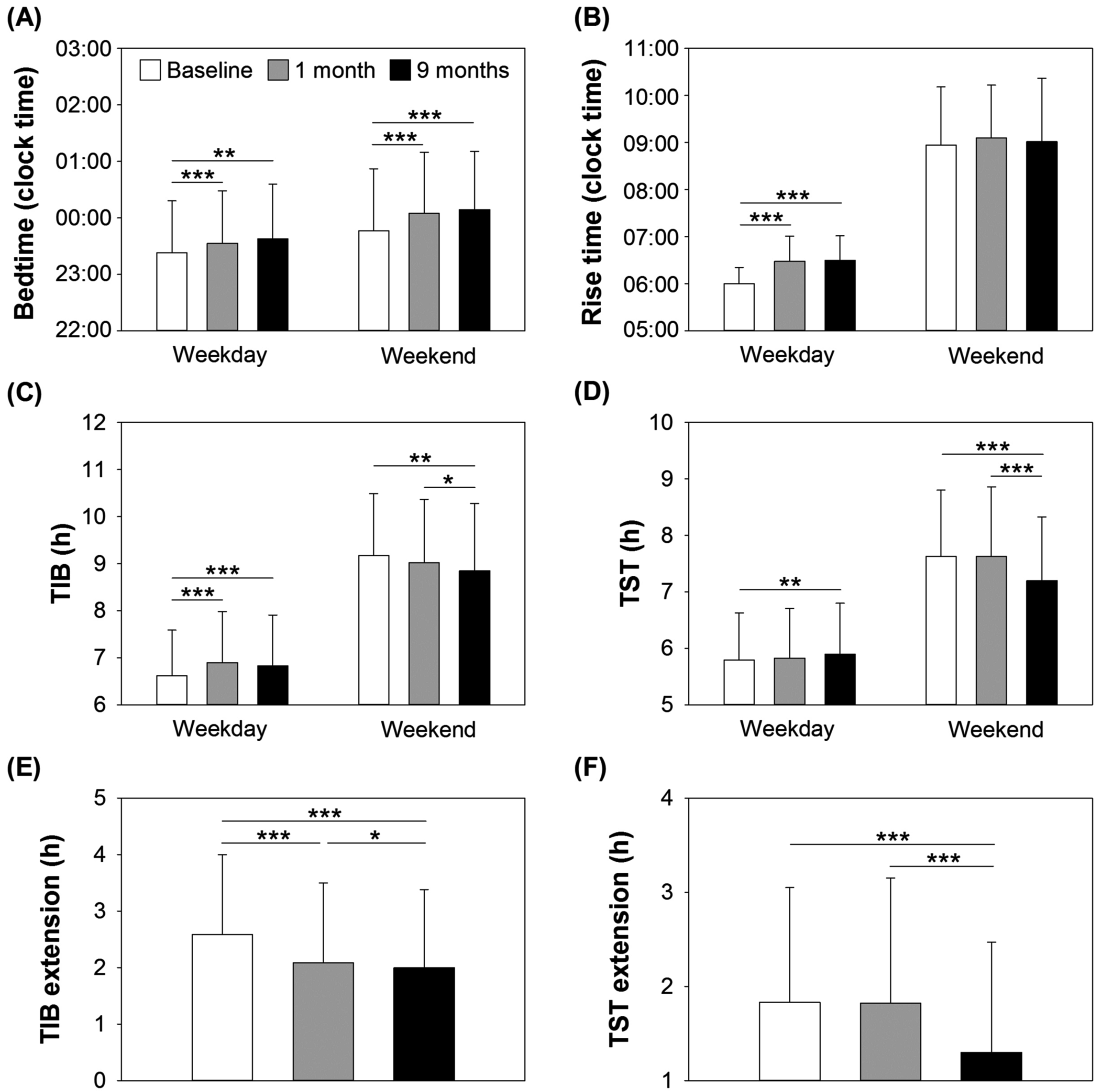

Figure 1. Sleep on weekdays and weekends from baseline to follow-ups. (A) Bedtime, (B) rise time, (C) time in bed (TIB), (D) total sleep time (TST), as well as (E) extension in TIB and (F) extension in TST on weekends relative to weekdays at baseline prior to the delay in school start time are shown in white, at the 1-month follow-up in gray, and at the 9-month follow-up in black. Error bars represent standard deviations. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ for the comparisons of sleep changes against 0 in one-sample *t*-tests.

Discussion

Many adolescents in East Asia chronically curtail their sleep [5–7] for academic achievement [2], but have poor life satisfaction and high levels of anxiety [1, 37]. Here, we studied the effects of delaying school start time by 45 min in a secondary school in Singapore and found that 1 month after the delay, participants' TIB increased by 23 min with ensuing benefits to subjective alertness and well-being. These positive changes were maintained at the 9-month mark.

The increase in TIB realized in this study is comparable to the ~20-min [21, 23] increase in sleep duration reported in recent meta-analyses of studies in which school start time was delayed by 20–65 min. Critically, with a later school start time, there was a twofold increase in the number of students obtaining a minimum of 8 hours of TIB on school nights—an amount deemed appropriate for adolescents [3, 4]. Although actigraphically assessed TST did not significantly change at the 1-month follow-up, it increased by about 10 min at the 9-month follow-up, indicating that it may take time for the benefit of a policy change to be realized. Notably, this 10-min increase in TST seemed numerically smaller than the 22-min increase in self-reported TIB over the corresponding period, suggesting that participants might over-estimate their sleep change, and that school start time needs to be delayed by more than 45 min in order to achieve greater gains in objective (actual) sleep duration. Extension of

Table 2. Changes in Sleepiness and Well-Being from Baseline to Follow-ups

	Baseline to 1 month			1–9 months			Baseline to 9 months		
	Mean ± SEM	p	d	Mean ± SEM	p	d	Mean ± SEM	p	d
Sleepiness									
KSS score	−0.39 ± 0.11	**<0.001**	0.20	0.13 ± 0.14	0.39	0.07	−0.45 ± 0.16	**0.01**	0.23
Problems staying awake	−0.19 ± 0.07	**0.01**	0.22	−0.04 ± 0.08	0.64	0.05	−0.27 ± 0.09	**0.002**	0.33
Refreshed after waking	0.20 ± 0.06	**0.001**	0.26	0.14 ± 0.08	0.08	0.17	0.26 ± 0.10	**0.01**	0.28
Well-being									
Depression score	−0.97 ± 0.39	**0.02**	0.20	−0.28 ± 0.39	0.47	0.07	−1.22 ± 0.48	**0.01**	0.27
Positive mood	0.30 ± 0.37	0.41	0.04	0.29 ± 0.53	0.59	0.05	1.07 ± 0.56	0.06	0.16
Negative mood	−1.01 ± 0.34	**0.004**	0.16	0.06 ± 0.51	0.91	0.01	−0.98 ± 0.50	**0.05**	0.16

d, Cohen's *d*. Significant findings are indicated in bold.

TIB and TST on weekends was reduced by as much as 45 min after school start time was delayed, bolstering the notion that the revised school start time attenuated the sleep debt accumulated on school days.

Although the gain in sleep duration was modest, the ancillary benefits to self-rated alertness and well-being should not be discounted in view of the high levels of anxiety and low levels of life satisfaction expressed by East Asian students [1, 37]. The associations between even seemingly trivial increases in sleep duration and lowered depression scores as well as increased daytime alertness, speak to a scaling of benefit that might be larger if even later start times could be implemented although this is difficult to achieve in East Asia on account of strong resistance to changing the status quo on study hours.

Our finding of increased sleep 1 month after the delay is similar to that of Thacher et al. [29], where sleep duration increased by 20 min when assessed 2 months after a 45-min delay in school start time. Additionally, while Thacher et al. found that sleep duration returned to the baseline level at the 9-month follow-up, we found a sustained increase in TIB. There are several reasons for this difference in findings. Firstly, at baseline, while Thacher et al. reported a sleep duration of 7 hours 20 min, our sample had an average TIB of 6 hours 37 min and average actigraphically assessed TST of 5 hours 48 min on weekdays. Thus, our sample might be more chronically sleep-deprived and were better positioned to experience marginal gains from even the modest increase in sleep opportunity. Secondly, sleep was actively promoted to participants in our study. Participants

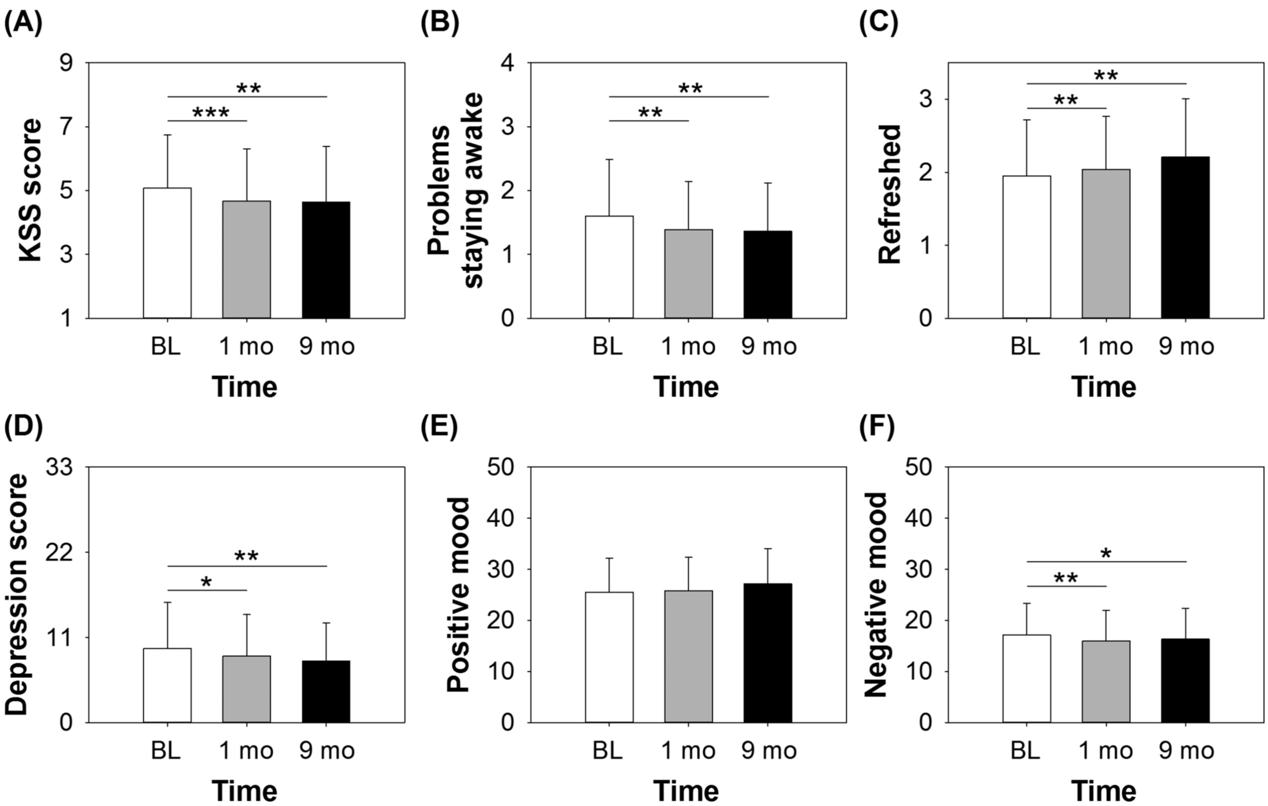

Figure 2. Sleepiness and well-being from baseline to follow-ups. (A) Score on the Karolinska Sleepiness Scale (KSS), (B) problems staying awake during the day, (C) feeling refreshed after waking, (D) depression score (E) positive mood, and (F) negative mood at baseline (BL) prior to the delay in school start time are shown in white, at the 1-month follow-up in gray, and at the 9-month follow-up in black. Error bars represent standard deviations. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ for the comparisons of sleepiness and well-being changes against 0 in one-sample *t*-tests.

Table 3. Correlations of Changes in Sleep on Weekdays with Changes in Sleepiness and Well-Being from Baseline

	Baseline to 1 month		Baseline to 9 months	
	r	p	r	p
Change in time in bed				
KSS score	**−0.27**	**0.001**	−0.05	0.67
Problems staying awake	**−0.17**	**0.05**	−0.05	0.65
Refreshed after waking	**0.29**	**<0.001**	0.12	0.29
Depression score	**−0.18**	**0.04**	**−0.27**	**0.02**
Positive mood	**0.21**	**0.01**	0.07	0.55
Negative mood	−0.06	0.45	−0.08	0.49
Change in total sleep time				
KSS score	**−0.13**	**0.03**	**−0.24**	**0.01**
Problems staying awake	0.12	0.19	−0.13	0.26
Refreshed after waking	0.00	0.97	0.03	0.76
Depression score	−0.02	0.86	−0.15	0.19
Positive mood	−0.02	0.74	−0.02	0.81
Negative mood	0.05	0.45	−0.16	.08

Bedtime, rise time, time in bed, and measures of sleepiness and well-being were derived from questionnaires, while total sleep time was measured with actigraphy. Significant findings are indicated in bold.

were aware of the purpose for the delay in start time. The school and research staff were also active in encouraging students to use the opportunity from the later start time to get more sleep. Indeed, proponents of later start times have acknowledged that delaying start times may not be sufficient to solve the problem of sleep loss in adolescents. Rather, later start times should be accompanied by educational programs to help students practice and maintain healthy sleep behaviors [38]. In this study, although the promotion of sleep could have led to demand characteristics in the self-reports, the increase in actigraphically assessed TST observed at the 9-month follow-up provides evidence for an objective increase in sleep duration.

Our study replicated findings showing improved outcomes, such as lower levels of subjective sleepiness and fewer depressive symptoms, after school start time was delayed [21, 24, 27, 28, 30, 31]. We also found that these improvements were sustained at the 9-month follow-up. Importantly, we found significant associations between improvements in alertness and well-being with the increase in sleep obtained on school nights. Hence, sleep changes associated with delaying school start time may contribute to positive changes in alertness and well-being during this study.

Finally, students, their parents, and teachers are joint stakeholders in any initiative to start school later, as school start times inevitably affect all three groups. After the delay in school start time, all three groups agreed that the change was better. This positive response is vital for the success and continuity of the initiative especially in a culture that has very traditional notions about changing practices to improve productivity and well-being.

Limitations

Like many previous studies [20], one limitation of this study is the lack of a control group with no change in the school schedule, without which the changes in sleep or well-being may be attributed to factors other than the change in start time. Although we found associations between improved well-being and increased sleep, comparisons with a control group would have provided more direct evidence that the benefits observed were the result of the later start time.

A second limitation of the study is that all participants were female, and therefore, the results might not be generalized to male adolescents. However, it is worth pointing out that previous studies have not found any gender difference in the impact of later start times on sleep duration [27–29, 39].

Finally, nap duration was not assessed in this study. Napping is common among adolescents [40]. With a delay in school start time and an increase in nocturnal sleep duration, shortening of daytime naps might be observed. As a result, total sleep duration over a 24-hour period might remain unchanged. Relatedly, we have previously shown that in adolescents, daytime napping cannot replace adequate sleep at night for optimal performance [9]. Redistribution of sleep time from daytime naps to nocturnal sleep could be beneficial but this remains to be studied empirically.

Conclusions

Benefits to sleep and well-being in adolescent students were observed after the school delayed its start time by 45 min without delaying school end time or compromising curriculum time. These benefits remained 9 months after the change. These findings suggest that even in East Asia, where many students curtail sleep in the pursuit of academic achievement [2, 5] and where students' life satisfaction is the lowest in the world [37], delaying school start times is feasible and can lead to sustained improvement in students' sleep and well-being.

Supplementary Material

Supplementary material is available at *SLEEP* online.

Acknowledgments

We thank Madam Boey Hong Heng, Mrs Choon Juen Ho-Sam, and Mr Benny Chin Seah Koh from the participating school for their partnership in this research. We also thank the students, parents, and teachers who participated in this research for their contribution to the field. We further thank all research assistants who assisted in data collection and analyses.

Funding

This work was supported by the National Medical Research Council, Singapore (NMRC/StaR/015/2013) and the Far East Organization.

Notes

Conflict of interest statement. All authors declare no conflicts of interest. This work was approved by the Institutional Review Board of the National University of Singapore. All adolescent participants and their legal guardian provided written, informed consent.

References

1. Stankov L. Unforgiving Confucian culture: a breeding ground for high academic achievement, test anxiety and self-doubt? *Learn Individ Differ*. 2010;**20**:555–563.
2. Organisation for Economic Co-operation and Development. *PISA 2015 Results* (volume i). Paris: OECD Publishing, 2016.
3. Hirshkowitz M, *et al*. National Sleep Foundation's updated sleep duration recommendations: final report. *Sleep Health*. 2015;**1**(4):233–243.
4. Paruthi S, *et al*. Recommended amount of sleep for pediatric populations: a consensus statement of the American Academy of Sleep Medicine. *J Clin Sleep Med*. 2016;**12**(6):785–786.
5. Chen T, *et al*. Sleep duration in Chinese adolescents: biological, environmental, and behavioral predictors. *Sleep Med*. 2014;**15**(11):1345–1353.
6. Gradisar M, *et al*. Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep. *Sleep Med*. 2011;**12**(2):110–118.
7. Olds T, *et al*. The relationships between sex, age, geography and time in bed in adolescents: a meta-analysis of data from 23 countries. *Sleep Med Rev*. 2010;**14**(6):371–378.
8. Baum KT, *et al*. Sleep restriction worsens mood and emotion regulation in adolescents. *J Child Psychol Psychiatry*. 2014;**55**(2):180–190.
9. Lo JC, *et al*. Neurobehavioral impact of successive cycles of sleep restriction with and without naps in adolescents. *Sleep*. 2017;**40**. zsw042
10. Lo JC, *et al*. Cognitive performance, sleepiness, and mood in partially sleep deprived adolescents: the need for sleep study. *Sleep*. 2016;**39**(3):687–698.
11. Lowe CJ, *et al*. The neurocognitive consequences of sleep restriction: a meta-analytic review. *Neurosci Biobehav Rev*. 2017;**80**:586–604.
12. Wolfson AR, *et al*. Sleep schedules and daytime functioning in adolescents. *Child Dev*. 1998;**69**(4):875–887.
13. Hagenauer MH, *et al*. Adolescent changes in the homeostatic and circadian regulation of sleep. *Dev Neurosci*. 2009;**31**(4):276–284.
14. Bartel KA, *et al*. Protective and risk factors for adolescent sleep: a meta-analytic review. *Sleep Med Rev*. 2015;**21**:72–85.
15. Nahmod NG, *et al*. High school start times after 8:30 am are associated with later wake times and longer time in bed among teens in a national urban cohort study. *Sleep Health*. 2017;**3**(6):444–450.
16. Patte KA, *et al*. Youth sleep durations and school start times: a cross-sectional analysis of the COMPASS study. *Sleep Health*. 2017;**3**(6):432–436.
17. Adolescent Sleep Working Group, Committee on Adolescence, Council on School Health. School start times for adolescents. *Pediatrics*. 2014;**134**:642–649.
18. The American Medical Association. AMA supports delayed school start times to improve adolescent wellness. 2016. https://www.ama-assn.org/ama-supports-delayed-school-start-times-improve-adolescent-wellness. Accessed 28 January 2018.
19. Watson NF, *et al*.; American Academy of Sleep Medicine Board of Directors. Delaying middle school and high school start times promotes student health and performance: an American Academy of Sleep Medicine Position Statement. *J Clin Sleep Med*. 2017;**13**(4):623–625.
20. Wahlstrom KL, *et al*. School start time effects on adolescent learning and academic performance, emotional health and behaviour. *Curr Opin Psychiatry*. 2017;**30**(6):485–490.
21. Bowers JM, *et al*. Effects of school start time on students' sleep duration, daytime sleepiness, and attendance: a meta-analysis. *Sleep Health*. 2017;**3**(6) 421–431.
22. Minges KE, *et al*. Delayed school start times and adolescent sleep: a systematic review of the experimental evidence. *Sleep Med Rev*. 2016;**28**:86–95.
23. Morgenthaler TI, *et al*. High school start times and the impact on high school students: what we know, and what we hope to learn. *J Clin Sleep Med*. 2016;**12**(12):1681–1689.
24. Owens JA, *et al*. A quasi-experimental study of the impact of school start time changes on adolescent sleep. *Sleep Health*. 2017;**3**(6):437–443.
25. Wahistrom K. Changing times: findings from the first longitudinal study of later high school start times. *NASSP Bull*. 2002;**86**:3–21.
26. Wahlstrom KL, *et al*. *Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-site Study*. St Paul, MN: University of Minnesota; 2014. Retrieved from https://conservancy.umn.edu/handle/11299/162769.
27. Boergers J, *et al*. Later school start time is associated with improved sleep and daytime functioning in adolescents. *J Dev Behav Pediatr*. 2014;**35**(1):11–17.
28. Owens JA, *et al*. Impact of delaying school start time on adolescent sleep, mood, and behavior. *Arch Pediatr Adolesc Med*. 2010;**164**(7):608–614.
29. Thacher PV, *et al*. Longitudinal Outcomes of Start Time Delay on Sleep, Behavior, and Achievement in High School. *Sleep*. 2016;**39**(2):271–281.
30. Chan NY, *et al*. Impact of a modest delay in school start time in Hong Kong school adolescents. *Sleep Med*. 2017;**30**:164–170.
31. Li S, *et al*. Sleep, school performance, and a school-based intervention among school-aged children: a sleep series study in China. *PLoS One*. 2013;**8**(7):e67928.
32. Meltzer LJ, *et al*. Direct comparison of two new actigraphs and polysomnography in children and adolescents. *Sleep*. 2012;**35**(1):159–166.
33. Akerstedt T, *et al*. Subjective and objective sleepiness in the active individual. *Int J Neurosci*. 1990;**52**(1–2):29–37.
34. Watson D, *et al*. Development and validation of brief measures of positive and negative affect: the PANAS scales. *J Pers Soc Psychol*. 1988;**54**(6):1063–1070.
35. LeBlanc JC, *et al*. Screening for adolescent depression: comparison of the Kutcher Adolescent Depression Scale with the Beck depression inventory. *J Child Adolesc Psychopharmacol*. 2002;**12**(2):113–126.
36. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
37. Organisation for Economic Co-operation and Development. *PISA 2015 Results* (volume iii). Paris: OECD Publishing; 2016.
38. Millman RP, *et al*. Healthy school start times: can we do a better job in reaching our goals? *Sleep*. 2016;**39**(2):267–268.
39. Carskadon MA, *et al*. Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. *Sleep*. 1998;**21**(8):871–881.
40. Gradisar M, *et al*. Adolescent napping behavior: comparisons of school week versus weekend sleep patterns. *Sleep Biol Rhythms*. 2008;**6**:183–186.