

A School-Based Sleep Education Program for Adolescents: A Cluster Randomized Trial

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abstract

OBJECTIVES: To evaluate the effectiveness of a multilevel and multimodal school-based education program.

METHODS: A cluster randomized controlled trial with 14 secondary schools in Hong Kong and a total of 3713 students (intervention: 1545 vs control: 2168; 40.2% boys; mean age \pm SD: 14.72 \pm 1.53 years) were included in the final analysis. The intervention included a town hall seminar, small class workshops, a slogan competition, a brochure, and an educational Web site. Their parents and teachers were offered sleep education seminars. The control schools did not receive any sleep program. Data were collected before and 5 weeks after the intervention.

RESULTS: The students in the intervention group had significantly improved sleep knowledge compared with the control group (mean difference: 3.64 [95% confidence interval (CI): 3.21 to 4.07]; Cohen's d = 0.51) as measured by using a sleep knowledge questionnaire. Weekday sleep duration was reduced in both groups, and the significant difference in weekday sleep duration was lost in the intention-to-treat analysis (mean difference: 0:01 [95% CI: -0:00 to 0:04]). In addition, the intervention group had a lower incidence of consuming caffeine-containing energy drinks (adjusted odds ratio: 0.46 [95% CI: 0.22 to 0.99]) and had better behavioral (mean difference: -0.56 [95% CI: -1.02 to -0.10]; Cohen's d = 0.13) and mental health (mean difference: -0.30 [95% CI: -0.15 to -0.46]; Cohen's d = 0.11) outcomes.

CONCLUSIONS: A school-based sleep education program was effective in enhancing sleep knowledge and improving behavioral and mental health, but it had no significant impact on sleep duration or pattern among adolescents.



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WHAT'S KNOWN ON THIS SUBJECT: Sleep deprivation is a worldwide problem in adolescents. The effectiveness of sleep education in enhancing sleep knowledge with consequent modification of sleep habits remains uncertain, in view of small sample sizes and lack of control groups in previous studies.

WHAT THIS STUDY ADDS: This large-scale, cluster randomized controlled study found that a school-based sleep education program was effective in enhancing sleep knowledge and improving behavioral and mental health, but it had no significant impact on sleep duration or pattern among adolescents.

Although sleep deprivation has emerged as a worldwide problem in adolescents, controversy exists regarding the definition of optimal sleep and consensus on the recommended sleep for children and adolescents.^{1,2} Nonetheless, consistent data suggest a cross-cultural difference at which Asian adolescents obtained much less sleep (~1 hour) than their European and US counterparts.^{2,3} Compensation of sleep debt during weekends with >2 hours of discrepancy was often documented among young students.^{4,5} Sleep deprivation is associated with daytime sleepiness, attention impairment, and poor academic performance,⁶⁻⁹ and it is also empirically linked to heightened risk of mood disorders, obesity, hyperlipidemia, and high blood pressure in young students.¹⁰⁻¹⁴ An interactive network of internal and external factors contributes to insufficient sleep in adolescents. Although adolescents experience a marked change in circadian timing with a consequent delay of bedtime,¹⁵ school start time, academic work, extracurricular activities, media usage, and parental sleep pattern can all impede their sleep-wake schedule.¹⁶

Dissemination of relevant information on the importance of adequate sleep among schools, families, and society remains limited.^{17,18} Noland et al¹⁹ showed that nearly one-half of the students wrongly perceived watching television and exercising immediately before bedtime were beneficial sleep practices. Educators and caregivers were generally unaware of the debilitating effect of sleep deprivation on adolescents' health and learning.^{20,21}

Compared with other health-related behaviors, such as dietary intake and physical activity, relatively less emphasis and research are placed on sleep intervention, although sleep is one of the most essential biological needs. A recent review reported

that only 12 school-based sleep educational studies have been reported in the literature; among these studies, 4 were presented in an abstract format.²² In general, these programs were successful in improving sleep knowledge but less effective in improving sleep duration, with only 2 studies reporting specific improvements in sleep duration after the intervention.^{22,23} These previous studies were also limited by their small sample size, with low statistical power²³⁻²⁶ and a lack of a control group.^{23,26} Moreover, there were marked variations in the duration and intensity of these educational programs; they varied from using only an educational leaflet²⁷ to twelve 50-minute activities within 1 month.²³ Moreover, previous studies have also overlooked the important role of parents and teachers in shaping adolescents' sleep patterns and behaviors because none of these school-based sleep education programs involved significant others.²⁸

Thus, the goal of the present study was to rigorously evaluate the effects of a large-scale multilevel and multimodal school-based sleep educational program in adolescents. We hypothesized that adolescents in the intervention group would report greater improvement (compared with students in a control group) in the following: (1) sleep knowledge; (2) sleep-wake pattern (eg, sleep duration, regularity of bedtime and wakeup time); and (3) daytime functioning and behavior (eg, daytime sleepiness, mental health).

METHODS

Participants

The present study was part of our sleep education program (Healthy Sleep, Healthy School Life) that involved both primary and secondary school students. In light of the potential age effect on sleep, only data collected from secondary schools

are presented in this article. The study design and recruitment process of secondary schools are shown in Fig 1. In this study, all seventh- to 11th-grade students aged between 12 and 18 years were recruited. Originally, 15 schools were randomized (at a 1:1 ratio), but 1 school in the intervention arm withdrew consent after randomization. The randomization in the present study was based on a single sequence of random assignments to individual schools as a cluster. One of the authors (M.W.M.Y.) was responsible for the randomization process, including generating the random allocation sequence, enrolling the school, and assigning a school to the intervention group or the control group. Six schools were randomized into the active intervention group, and 8 schools were randomized into the control group. Ethical approval was granted by the Joint CUHK-NTEC Clinical Research Ethics Committee (CRE-2011.249-T), and the trial was registered with the Chinese Clinical Trial Registry.

Sample Size

Previous school-based trials showed that the effect size of improving sleep duration was between 0.03 and 0.10.^{29,30} Using the medium effect size (0.07) as the consideration for sample size estimation (with a type I error of 0.05 and a power of 0.90), the target sample size of the present study was 2586 (at least 1293 in each group). Assuming that 60% of the students would agree to enroll in the study and that 60% would complete the follow-up assessment, the planned sample size would be at least >7000 students.

Procedure

Invitation letters were sent to all secondary schools in Hong Kong. Principals were contacted individually to further explain the details of the sleep education program. Baseline questionnaires

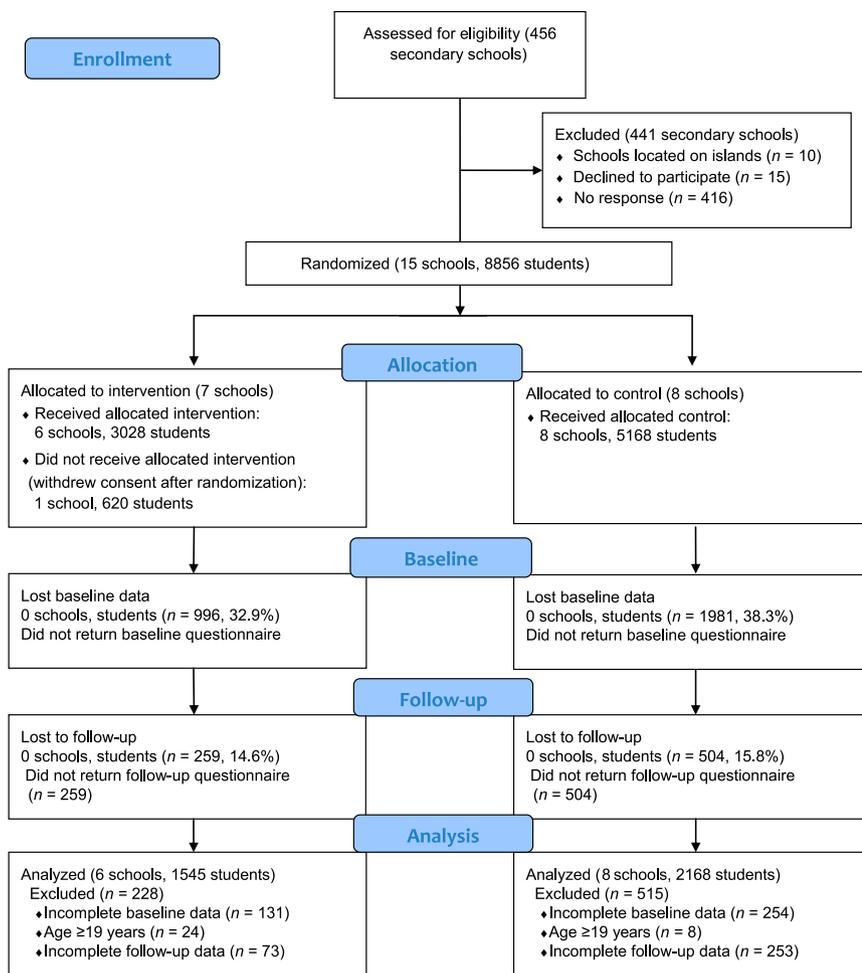


FIGURE 1
Flowchart of the school and subject recruitment process.

packed in coded envelopes were distributed to all eligible students. They were asked to return the questionnaires, together with the parental consent and individual assent, within 1 week.

Intervention

Schools in the intervention group attended a 1-hour town hall seminar provided by physicians experienced in sleep medicine (Y.K.W., A.M.L., S.P.L., and A.P.S.K.) and two 40-minute small class workshops (held once per month, 30–40 students per class) led by our trained research staff who had attended 2 training sessions and a practical mock session.

A set of structured educational materials (Table 1) was developed that covered the following: (1) the

importance of sleep; (2) the consequences of sleep deprivation; (3) factors contributing to insufficient sleep; and (4) good sleep practice. The town hall seminar involved didactic teaching and aimed to provide adolescents in the intervention group with a brief introduction of our program together with a general understanding of sleep medicine; it also provided them with tips for better sleep hygiene practices. The small class workshop was characterized by interactive small group discussions (4–5 students per group) and case studies. Students were asked to chart a 7-day sleep diary after the first workshop to review their individual sleep patterns. The program also included time and stress management skills; the goal was to equip students with effective

schedule arrangement and stress-coping skills so that they could prioritize the importance of sleep. Supplementary materials, including leaflets, brochures, and access to our self-developed sleep educational Web site (www.pae.cuhk.edu.hk/sleep/index.html), were also offered to all students, teachers, and parents (Supplemental Appendices 1 and 2) to enhance participants' accessibility to the sleep knowledge and information. A slogan design competition was also held during the intervention period. Participants were asked to create a slogan, with the goal of raising awareness regarding the importance of sleep and healthy sleep practices. A total of 2168 slogans from 3028 invited participants (71.6%) were collected. Parents and teachers were separately invited to attend a 1-hour sleep education seminar. All schools in the intervention group received the same package of sleep education except that 1 school omitted the town hall seminar and 1 school omitted the seminar for parents (attributed to their tight school schedule). The sleep education program was implemented from February to early May 2012. Baseline data were collected during late December 2011 to early February 2012, and the follow-up assessment was conducted 1 month after the end of the intervention.

Measurements

The package of questionnaires included several different tools. The General Sleep Questionnaire (HKCSQ) is a comprehensive and validated questionnaire used to measure various sleep issues such as insomnia symptoms and sleep-wake patterns during school days and weekends, with an adaptation to measure the sleep variables over the last month.^{31,32} The insomnia symptoms were measured according to frequency and were defined as abnormal if they occurred ≥ 3 times per week. Sleep duration was

TABLE 1 Educational Materials for the Intervention Group

Variable	Students	Parents	Teachers
Types of education			
Town hall seminar	✓	✓	✓
Small class (group discussion, case study)	✓		
Brochure/leaflets	✓	✓	✓
Sleep education Web site	✓	✓	✓
Slogan competition	✓		
Educational content			
Sleep facts	✓	✓	✓
Factors contributing to sleep loss	✓	✓	✓
Effects of chronic sleep deprivation	✓	✓	✓
Review of individual sleep patterns by using a sleep diary	✓		
Sleep assignment	✓		
Healthy sleep hygiene advice	✓	✓	✓
Time and stress managements skills (ie, prioritize daily activities by using an urgency and importance matrix, stress coping)	✓	✓	✓

calculated as the difference between wakeup time and bedtime for weekday and weekend, respectively. It has been shown that sleep duration as subjectively measured by using a questionnaire and objectively measured by using actigraphy was significantly correlated with an intraclass correlation coefficient of 0.72.¹¹ The HKCSQ was used to collect information on socioeconomic demography, caffeine beverage and energy drink intake consumption, and smoking and alcohol habits. It is defined as abnormal if adolescents consumed caffeinated drinks ≥ 3 times per week in the past one month. A single item with "Do you think you have enough sleep?" was added to measure students' perception whether they had "adequate sleep." The HKCSQ has satisfactory psychometric property for measuring sleep problems (Cronbach's $\alpha = 0.868$).³²

The Pediatric Daytime Sleepiness Scale was used to assess adolescents' daytime sleepiness.³³ The 12-item General Health Questionnaire (GHQ-12) was used to assess the current mental health status of the adolescents.³⁴

The Chinese version of the Sleep Knowledge Questionnaire is a 15-item, self-administered questionnaire measuring sleep knowledge; total scores range from -30 to 30.³⁵ The

Strengths and Difficulties Questionnaire is a local validated questionnaire assessing 5 aspects of adolescent life, including emotional problems, conduct problems, peer relationships, hyperactivity/inattention, and prosocial behaviors.³⁶

Statistical Analysis

To adjust for clustering effect, the present analysis was conducted mainly by using generalized estimating equations, with school as a subject variable and individual identification as a within-subject variable. Descriptive data are presented as mean \pm SE differences between follow-up and baseline for continuous variables and as percentages for discrete variables. Quantitative measures were analyzed by using linear regression, and dichotomous outcomes were analyzed by using logistic regression. For discrete data, subjects were first divided into 2 groups based on their baseline responses. Those without baseline symptoms were used to explore incidence rates; subjects with baseline symptoms were used to explore for persistence rate (persistence versus remission). Effect size was estimated by using Cohen's d and was interpreted as small ($d \leq 0.3$), medium ($d = 0.5$), and large ($d = 0.8$).³⁷ In addition, an intention-to-treat (ITT) analysis was

performed to take into account the number of dropouts.

The primary outcome of the study was sleep duration; secondary outcomes included sleep knowledge, daytime sleepiness, sleep quality (eg, sleep latency, insomnia symptoms), sleep hygiene practice (including nap habits), lifestyle practice in terms of caffeine consumption, mental health, and behavioral difficulties. Age and gender were used as covariates in the analyses. A P value of $<.05$ was considered statistically significant. SPSS Statistics 20.0 for Windows (SPSS Statistics, IBM Corporation, Armonk, NY) was used for all tests.

RESULTS

Sample Characteristics

Of a total of 8236 eligible students, 5219 (63.4% [2032 in the intervention group, 3187 in the control group]) returned the parental consent, student assent, and questionnaires. After the implementation of the program, 4456 participants (response rate: 85.4% [1773 intervention subjects, 2683 control subjects]; 43.5% boys; mean age: 14.72 ± 1.57 years) returned the follow-up questionnaires. The interval between baseline and follow-up assessment in the intervention group was similar to the control group (mean \pm SD: 4.3 ± 0.72 vs 3.8 ± 0.71 months; $P > .05$). The follow-up assessment of the intervention group was conducted at a mean \pm SD of 5 ± 2.6 weeks after the end of the intervention. Participants with incomplete baseline data ($n = 385$ [131 (6.4%) in the intervention group, 254 (8.0%) in the control group]) and follow-up data ($n = 326$ [73 (4.1%) in the intervention group, 253 (9.4%) in the control group]) regarding the main measurements were excluded from analysis. Participants aged ≥ 18 years ($n = 32$ [24 intervention subjects, 8 control subjects]) were also excluded. A total

of 3713 participants (1545 intervention subjects, 2168 control subjects; 40.2% boys; mean \pm SD age: 14.72 \pm 1.53 years) were thus included in the final analysis.

Students who dropped out were similar to the study sample with regard to gender, age, and sociodemographic status. They had comparable weekday and weekend sleep duration, but they adopted a later weekend bedtime (mean \pm SE: 24:18 \pm 0:35 vs 24:09 \pm 0:33; $P = .04$) and wakeup time (10:21 \pm 0:46 vs 10:07 \pm 0:44; $P = .03$) than those who completed the study. There were no differences in age, gender, or sociodemographic data between the intervention and control groups (Table 2). The 2 groups had similar baseline sleep-wake patterns except that the intervention group woke up earlier during weekdays than the control group (mean \pm SE: 6:40 \pm 0:12 vs 6:50 \pm 0:12; $P = .04$).

Weekday and weekend sleep duration of the whole sample was 7 hours 27 minutes and 9 hours 59 minutes, respectively. Nearly two-thirds (64.5%) of students reported having <8 hours of sleep during weekdays. A large proportion of students (66%) had a weekday/weekend sleep time difference >2 hours. More than one-half (58.4%) of the subjects reported having inadequate sleep, as noted by

their subjective perception of sleep sufficiency.

Effects of the Intervention on Sleep, Health, and Behavioral Aspects

The means, mean differences, and SEs in sleep, sleep knowledge, daytime sleepiness, and mental and behavioral functioning for the control and intervention groups are summarized in Table 3. The intervention group demonstrated a marked enhancement in their sleep knowledge compared with subjects in the control group (mean change, intervention versus control: 5.27 \pm 2.36 vs 1.63 \pm 2.28; Cohen's $d = 0.51$, $P < .001$). Both groups of students had a later bedtime at follow-up, but the intervention group had less delay than the control group (0:05 \pm 0:15 vs 0:07 \pm 0:15; Cohen's $d = 0.06$, $P = .02$). The overall sleep duration of both groups was shortened, but the decrement was less in the intervention group (mean change: -0:05 \pm 0:17 vs -0:08 \pm 0:17; Cohen's $d = 0.06$, $P = .03$). We also used an ITT analysis by treating baseline data before dropout as the observation of follow-up assessment. The significant difference in sleep knowledge was retained in the ITT analysis, but the difference in weekday bedtime (intervention versus control: 0:05 \pm 0:11 vs 0:06 \pm 0:11; mean difference: -0:00 [95% confidence interval (CI): -0:02 to

0:00]) and sleep duration (intervention versus control: -0:04 \pm 0:12 vs -0:06 \pm 0:12; mean difference: 0:01 [95% CI: -0:00 to 0:04]) was lost. In addition, there was no significant effect on weekend practices. The regularity of the sleep pattern, sleep latency, insomnia symptoms, nap habits, and daytime sleepiness between the 2 groups yielded no significant differences.

Students in the intervention group had improved scores on several behavioral domains, including conduct (mean change: intervention versus control, -0.13 \pm 0.70 vs 0.00 \pm 0.69; Cohen's $d = 0.09$, $P = .03$), hyperactivity (-0.14 \pm 0.30 vs 0.07 \pm 0.03; Cohen's $d = 0.11$, $P = .003$) and total difficulty (-0.17 \pm 1.39 vs 0.39 \pm 1.48; Cohen's $d = 0.13$, $P = .02$). In addition, mental health status (as shown by using the GHQ-12) was also better in the intervention group (mean change: 0.01 \pm 0.84 vs 0.31 \pm 0.82; Cohen's $d = 0.11$, $P < .001$).

We also measured students' lifestyle practices in terms of the consumption of caffeinated drinks (Table 4). The incidence rate of energy drink consumption for the intervention and control groups was 0.9% and 2.1% (adjusted odds ratio: 0.46 [95% CI: 0.22 to 0.99]), respectively. Similar incidence rates, however, were found in the intake of other caffeinated products (all $P > .05$). The improvement in behavioral, mental health, and reduced incidence rate of energy drink consumption remained significant after ITT analysis (all $P < .05$).

The majority of students (70% and 60%) reported that the program was effective in increasing their sleep knowledge and raised their awareness toward sleep deprivation, respectively. However, only 32% of the students believed that the program would change their sleep habits.

Subgroup Analysis

To explore the relationship between sleep knowledge acquisition and

TABLE 2 Sociodemographic Characteristics of Subjects in the Intervention and Control Groups

Characteristic	Intervention	Control	<i>P</i>
Age, y (<i>n</i> = 3713)	14.86 \pm 0.11	14.62 \pm 0.18	.26
Male gender (<i>n</i> = 3713)	30	48	.34
Paternal education (<i>n</i> = 2576)			
Tertiary or above	20.2	25.4	.86
Secondary	68	64.7	
Primary or below	11.8	9.9	
Paternal employment	92.6	91.7	.42
Maternal education (<i>n</i> = 2914)			
Tertiary or above	16.4	15.2	.53
Secondary	73.4	77	
Primary or below	10.2	7.8	
Maternal employment	64.9	63.9	.66
Family income (HK\$ \geq 15 000) (<i>n</i> = 2765)	76.0	81.3	.54
Interval between baseline and follow-up assessment, mo	4.3 \pm 0.72	3.8 \pm 0.71	.24
Interval between last intervention and follow-up assessment, wk	5 \pm 2.6	-	NA

Data are presented as mean \pm SD or %. NA, not available.

TABLE 3 Adolescent Sleep–Wake Pattern, Daytime Sleepiness, and Psychological and Behavioral Profiles at Baseline and During Follow-up

Variable	Baseline		Follow-up		Preintervention and Postintervention Differences		Difference in Mean Change (95% CI)	P
	Control	Intervention	Control	Intervention	Control	Intervention		
Weekdays (n = 3713)								
Bedtime	23:19 ± 0:16	23:18 ± 0:16	23:26 ± 0:27	23:23 ± 0:26	0:07 ± 0:15	0:05 ± 0:15	−0:02 (−0:03 to 0:00)	.02*
Wakeup time	6:50 ± 0:12	6:40 ± 0:12 ^a	6:49 ± 0:13	6:41 ± 0:13	−0:01 ± 0:04	0:00 ± 0:04	0:01 (−0:00 to 0:03)	.12
Sleep duration	7:31 ± 0:18	7:22 ± 0:19	7:23 ± 0:25	7:17 ± 0:27	−0:08 ± 0:17	−0:05 ± 0:17	0:03 (0:06 to 0:00)	.03*
Weekends (n = 3713)								
Bedtime	24:09 ± 0:34	24:06 ± 0:35	24:13 ± 0:30	24:09 ± 0:30	0:03 ± 0:18	0:02 ± 0:19	−0:01 (−0:06 to 0:05)	.82
Wakeup time	10:05 ± 0:40	10:10 ± 0:41	9:50 ± 0:40	9:54 ± 0:42	−0:15 ± 0:27	−0:15 ± 0:25	0:00 (0:07 to −0:07)	.99
Sleep duration	9:56 ± 0:16	10:03 ± 0:18	9:36 ± 0:25	9:44 ± 0:25	−0:19 ± 0:21	−0:18 ± 0:19	0:01 (−0:05 to 0:07)	.85
Sleep knowledge (n = 3713)								
PDSS (n = 3596)	6.84 ± 2.24	7.06 ± 2.71	8.47 ± 2.62	12.33 ± 3.15	1.63 ± 2.28	5.27 ± 2.36	3.64 (3.21 to 4.07)	.00**
GHQ-12 (n = 3708)	1.47 ± 0.74	1.75 ± 0.74 ^a	1.78 ± 0.83	1.76 ± 0.83	0.31 ± 0.82	0.01 ± 0.84	−0.30 (−0.46 to −0.15)	.00**
Strengths and difficulties								
Total difficulty (n = 3694)	11.8 ± 2.87	12.57 ± 2.80 ^a	12.20 ± 1.74	12.40 ± 1.78	0.39 ± 1.48	−0.17 ± 1.39	−0.56 (−1.02 to −0.10)	.02*
Peer (n = 3693)	2.67 ± 0.55	2.75 ± 0.48	2.82 ± 0.42	2.82 ± 0.41	0.15 ± 0.35	0.08 ± 0.32	−0.07 (−0.21 to 0.07)	.30
Emotion (n = 3694)	3.21 ± 0.71	3.45 ± 0.79	3.37 ± 0.62	3.47 ± 0.61	0.16 ± 0.49	0.02 ± 0.44	−0.14 (−0.36 to 0.07)	.20
Conduct (n = 3693)	2.24 ± 0.93	2.4 ± 0.91	2.25 ± 0.39	2.28 ± 0.40	0.00 ± 0.69	−0.13 ± 0.70	−0.13 (−0.24 to −0.02)	.03*
Hyperactive (n = 3694)	3.67 ± 0.94	3.96 ± 0.97 ^a	3.75 ± 0.84	3.83 ± 0.86	0.07 ± 0.03	−0.14 ± 0.30	−0.21 (−0.35 to −0.07)	.003*
Prosocial (n = 3684)	7.16 ± 0.91	6.95 ± 0.83	6.96 ± 0.86	6.83 ± 0.78	−0.20 ± 0.73	−0.11 ± 0.75	0.09 (−0.04 to 0.21)	.16

Discrepancies in total values are due to missing responses. Significant differences in weekday bedtime and sleep duration were lost in the ITT analysis, whereas significant improvements in sleep knowledge and GHQ-12 and Strengths and Difficulties Questionnaire subscale scores remained. Weekday and weekend sleep data are presented as mean ± SE (hh:mm). PDSS, Pediatric Daytime Sleepiness Scale.

^a Significant difference between groups at baseline.

behavioral change, subjects were further divided into 2 groups on the basis of the sleep knowledge difference by using the upper quartile as a cutoff within the intervention group (Supplemental Tables 5 and 6). The comparison between these subgroups indicated that improvement in sleep knowledge was associated with a significant lowering of the persistence rate of insomnia

(difficulty initiating sleep) (intervention versus control: 19% vs 35.2%; adjusted odds ratio: 0.39 [95% CI: 0.18 to 0.85]) but not other sleep practices ($P > .05$).

DISCUSSION

To our knowledge, this study is the first large-scale, cluster randomized controlled trial to evaluate the efficacy of a sleep education program in promoting good sleep

practices among adolescents. Our study further confirmed the high prevalence of sleep deprivation and irregular sleep patterns among adolescents in Hong Kong, especially compared with white adolescents.^{2,3,11}

In agreement with previous studies,^{23–27,29,30} there was a prominent enhancement of sleep knowledge among adolescents in the intervention group, with a medium

TABLE 4 Incidence and Persistence Rate for Insomnia Symptoms and Caffeine Consumption Practices

Variable	Incidence				Persistence			
	N (%)	Control (%)	Intervention (%)	OR (95% CI)	N (%)	Control (%)	Intervention (%)	OR (95% CI)
Insomnia symptoms								
DIS (≥3times/wk)	72 (2.1)	1.8	2.5	1.53 (0.90 to 2.60)	80 (34.3)	35.5	33.0	0.89 (0.63 to 1.26)
DMS (≥3times/wk)	66 (1.8)	1.8	1.9	0.99 (0.52 to 1.90)	24 (24.5)	22.6	26.7	1.17 (0.60 to 2.25)
EMA (≥3times/wk)	68 (1.9)	1.9	1.9	1.05 (0.77 to 1.44)	19 (26.8)	28.6	24.1	0.64 (0.36 to 2.46)
Any insomnia symptoms (≥3times/wk)	118 (3.6)	3.3	4.1	1.29 (0.84 to 1.99)	109 (35.3)	36.2	34.2	0.90 (0.63 to 1.29)
Caffeine consumption								
Tea (≥3times/wk)	142 (4.3)	4.3	4.4	0.99 (0.59 to 1.67)	151 (39.2)	39.1	39.4	0.99 (0.70 to 1.41)
Coffee (≥3times/wk)	77 (2.2)	2.2	2.1	1.45 (0.97 to 2.91)	38 (30.6)	35.1	24.0	0.95 (0.24 to 1.65)
Energy drink (≥3times/wk)	56 (1.6)	2.1	0.9	0.46 (0.22 to 0.99)*	9 (17.6)	22.6	10.0	1.24 (0.14 to 11.13)
Alcohol (≥3times/wk)	4 (0.1)	0.1	0.1	0.37 (0.02 to 6.23)	1 (9.1)	0	16.7 ^a	—
Beverage (≥3times/wk)	214 (6.5)	7.3	5.5	0.75 (0.50 to 1.14)	174 (43.7)	46.5	38.9	0.87 (0.61 to 1.24)
Cigarette (≥3times/wk)	7 (0.2)	0.3	0.1	0.22 (0.02 to 2.49)	3 (25)	28.6	20.0	1.38 (0.06 to 33.18)

Three or more times per week was defined as abnormal. DIS = difficulty initiating sleep; DMS = difficulty maintaining sleep; EMA = early morning awakening; OR, odds ratio.

^a Fisher's exact test was used because 3 cells had an expected count <5.

effect size. The marked increase in sleep knowledge, however, did not translate into a change in sleep behavior. In fact, weekday sleep duration was reduced in both groups. The decline in sleep duration across the academic term was mainly due to later bedtime, indicating that students' sleep quantity was worse as the academic quarter progressed³⁸ and/or possibly associated with advancing age.³ Although students in the intervention group had a lesser degree of reduction in sleep duration compared with the control group during the initial analysis, this apparent effect was lost when the ITT analysis was used. The lack of concomitant improvement in daytime sleepiness and the fact that the average sleep duration was far below the recommended sleep time suggest that the current educational program was not able to improve adolescents' sleep duration and pattern.

Nonetheless, the incidence rate of regular energy drink consumption was significantly lower in the intervention group, which supports the notion that acquiring adequate sleep knowledge might potentially improve some specific sleep hygiene practices among students.²⁴ Furthermore, in the subgroup analysis, the persistent rate of insomnia symptoms among those students who achieved better sleep knowledge was lower. Because chronic insomnia is a common problem among children and adolescents (with a moderate persistent rate),³⁹ our finding suggests that sleep knowledge provisions may be beneficial to certain subgroups of students who have mastered sleep knowledge.

There was a significant enhancement in students' behavioral and mental health, as reflected by their improvement in scores on the Strengths and Difficulties Questionnaire and the GHQ-12,

respectively. Because there was no significant improvement in sleep duration or pattern, the exact reasons for the observed improvements in these 2 profiles are unclear. The possibility remains of some generalized nonspecific or placebo effects (ie, receiving attention or encouragement from sleep educators) in the intervention group.^{22,40} However, the improvements could also be related to other educational components of our program, such as time and stress management skills. Moreover, the current program also involved significant others (parents and teachers) in addition to written and electronic information. Although we did not assess the degree of parental and teacher engagement in the current study, numerous data suggest that these key stakeholders have profound effects on shaping adolescents' development and well-being.⁴¹⁻⁴³

Implications

The findings of the present study add to the increasing literature that enhanced knowledge by itself is insufficient in changing adolescents' sleep behaviors. Compared with other health practices, advising adolescents to sleep more was more challenging due to its perceived low priority.¹⁷ Even when they realized the importance of sleep, the subjects' propensity to change was low given the highly packed daily life schedule among this age group.^{16,18} Thus, simply educating students to sleep better may not be adequate to change their sleep behavior, although we already had a multilevel and multimodal education program. Future studies may need to emphasize ways of motivating students to change and incorporate a self-efficacy element, which aims to enhance one's perceived control to change and confidence in making changes by providing continuous feedback and modification of the positive sleep

habits throughout the intervention.^{22,30,44} In addition, instead of targeting the entire school population, it may be more cost-effective to specifically target high-risk adolescents (eg, those who suffer from severe sleep deprivation). Finally, schools and education authorities should consider incorporating a sleep education component into their regular school curriculum to equip teachers and students with essential sleep knowledge.

Strengths and Limitations

The main strength of the present study was our use of the clustered randomized control design, with a good retention rate and a large sample size, to ensure a comprehensive evaluation with adequate statistical power. The study had limitations, however. First, all data were gathered by using self-administered instruments without objective sleep measurements. Nonetheless, self-reported measures have been shown to offer sufficient validity in studying sleep habits in adolescents in large-scale population studies.^{31,39,45} In fact, our previous study found considerable correlations between sleep questionnaire and actigraphy findings in sleep pattern and duration.¹¹ Second, we only measured students' sleep and behavioral change at a 5-week follow-up due to limited resources. Future intervention programs should consider a longer follow-up to evaluate any delayed intervention effect. Third, although we used a multimodal intervention, we did not measure the effect and the amount of exposure of each educational component separately but considered it as a whole intervention. This design limited our ability to differentiate the specific effect of each individual educational element on adolescents' sleep duration and pattern.

CONCLUSIONS

The present study demonstrated that this multilevel and multimodal school-based sleep education program was effective in improving sleep knowledge among students, with positive effects on their mental health, lifestyle practice, and behavioral

aspects, but with no significant improvement in sleep duration. Further studies (with a longer follow-up period) are needed to identify the gap between sleep knowledge and behavioral change by introducing strategies to promote motivation and self-efficacy among adolescents.

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