Efficacy of sleep extension therapy using a remote support system in university students with increased social jetlag: a parallel, single-blind, randomized controlled trial

Running title: Sleep extension to decrease social jetlag

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Abstract

Purpose: The efficacy of sleep extension therapy using a remote support system (SET-R) was investigated in university students with increased social jetlag (SJL).

Methods: For this two-arm parallel randomized controlled trial, we recruited Japanese university students with SJL ≥60 min. The SET-R provided an individualized sleep schedule for gradual sleep extension using email and sleep hygiene education, stimulus control therapy, and progressive muscle relaxation as web content. The control group was sent an email that encouraged them to record their sleep. The duration of the intervention program was two weeks. The primary outcome was the mean change in SJL two weeks later, assessed using the Munich ChronoType Questionnaire (MCTQ). The other outcomes included Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale (ESS), Insomnia Severity Index, Patient Health Questionnaire-9 (PHQ-9), and sleep quiz. A follow-up survey was conducted 6 months after the intervention.

Results: Of 54 students, 26 were assigned to an intervention group and 28 to a control group. The difference in the mean change in SJL between the two groups (n=26, n=27) at two weeks was statistically significant (27.7 minutes, *P*=0.048). The scores for the ESS, PHQ-9, and sleep quiz were improved in the intervention group relative to the control group. At the 6-month follow-up point, the difference in the mean change in SJL between the two groups (n=22, n=27) was not statistically significant, but scores for the PHQ-9, and sleep quiz remained significant.

Conclusions: This study demonstrated the efficacy of the SET-R among university students with increased SJL.

Trial Registration: The study was registered with the UMIN Clinical Trials Registry (UMIN000042634, 2021/02/01).

Keywords: sleep extension therapy; university students; social jetlag; randomized controlled trial

1. Introduction

Sleep has an important role in restoring physical and mental functions, and sleep deprivation is closely related to poor physical and mental health [1]. Sleep deprivation in adolescent students is often caused by a mismatch between social time, such as school, and the nature of the individual's biological clock. On weekdays, students wake up earlier than their normal waking time following social time, resulting in sleep deprivation. On weekends, they wake up later to relieve the sleep deficit accumulated on weekdays, resulting in long compensatory sleep. This discrepancy between weekday and weekend sleep is evaluated as the difference in mid-sleep time and is termed social jetlag (SJL) [2].

Recent studies have shown that increased SJL among adolescents is associated with altered mood, greater anxiety, daytime sleepiness, higher body mass index (BMI), more somatic and psychological symptomatology, more school absenteeism, poor academic performance, and compromised vocational aspirations [3-6]. SJL is therefore considered one of the most important issues impacting sleep health among university students [7, 8].

One therapeutic intervention strategy for SJL is to delay social time, such as the start of the school day. While it has been reported that delaying the start of the school day does improve students' sleep [9] and mental health in the short term [10], follow-up data have shown that whereas wake time becomes delayed, bedtime also becomes later, thus nullifying the effect of extending total sleep time [11]. Another strategy is to modify the individual's behavior through behavioral sleep medicine. In a study of high school students with sleep deprivation, which is considered to be one of the key factors responsible for increasing SJL [2], a two-week intervention trial involving gradual sleep extension via e-mail ameliorated sleep deprivation and depression, and improved subjective sleep quality [12]. SJL is also associated with poor sleep habits due to consumption of alcohol and caffeinated beverages, smoking, and smartphone and video game use [13], for which sleep hygiene education could offer a degree of intervention.

Although behavioral sleep medicine involving gradual sleep extension could be effective for

improving SJL, no randomized controlled trial (RCT) using SJL as the primary outcome has yet been conducted. Therefore, we developed a form of sleep extension therapy using a remote support system (SET-R), providing behavioral sleep medicine programs via e-mail and web content.

The present study, the Student of Kyoto University Sleep Health (SKUSH) Study, was conducted to evaluate the efficacy of the SET-R for university students with increased SJL. The study aims were to examine whether the SET-R helped to decrease SJL in university students.

2. Methods:

Design

The SKUSH study was designed as a two-arm (intervention using the SET-R versus a sleep monitoring control) parallel randomized controlled trial.

Setting and study participants

Participants were recruited at Kyoto University, Japan, between March 1st and May 31st, 2021, via a website and flyers.

Written informed consent was obtained through participation in online information sessions using a web conference system.

We included individuals who met all of the following criteria: (1) official students attending Japanese universities and graduate schools, (2) men and women aged between 18 and 40 years, (3) SJL of at least 60 minutes[4] as assessed by the Munich ChronoType Questionnaire (MCTQ), (4) possessing a smartphone or computer with internet access, (5) ability to access the internet, and (6) understanding the study content and providing written consent to participate.

We excluded individuals who met one or more of the following criteria: (1) shift workers, (2) those who might be subjected to significant time differences due to overseas travel during the study period, (3) those for whom the frequency of Q9 ("Thoughts that you would be better off

dead or of hurting yourself in some way") on the Patient Health Questionnaire-9 (PHQ-9) was "more than half the days," or “Nearly every day”, or for whom the total PHQ-9 score was 10 points or more, 4) those who were undergoing outpatient treatment involving psychosomatic medicine or psychiatry, and 5) those who were taking antidepressants. These criteria were confirmed during the online screening and online information session.

Randomization, allocation, and blinding

Students were randomly assigned at a 1:1 ratio to an intervention (SET-R) group or a control group. Randomization was performed using a block size of 4 and stratified according to sex (men, and women) and SJL scores obtained at the time of the baseline survey (<60 min, 60-120 min, and ≥120 min). Central randomization with computer-generated tables was used for allocation. The investigators (TS and YM) compiled the list, and a third investigator (KK) independently performed the allocation. Due to the nature of the intervention, the participants were not blinded to their allocation. The researchers, who included statisticians, outcome assessors, and data analysts, were all blinded to the participant group assignments.

Intervention

The SET-R provided an individualized sleep schedule for gradual sleep extension using email and sleep hygiene education, stimulus control therapy, and progressive muscle relaxation (PMR) as web content. Email messages were sent every day to the intervention group to encourage them to extend their sleeping hours on weekdays and to maintain the same rhythm on weekends as that on weekdays. The intervention program was conducted for two weeks in reference to the previous study [12]. **Fig. 1** illustrates the design of the study. Each study lasted 21 days, and we conducted three trials between April 2021 and July 2021. All follow-up was completed by January 2022.

1) Gradual sleep extension therapy

A sleep specialist (RF) formulated an individual sleep schedule. With regard to wake-up time, participants responded to a pre-test by answering a question about their wake-up time during the 2-week intervention period. This time was used as the target wake-up time during the intervention period. As for bedtime, participants answered the question about the average bedtime on weekdays at the pre-test. Using that time as a baseline, the schedule was designed to advance bedtime by 5 minutes on weekdays and to maintain the same bedtime and wake-up time on weekends as that on weekdays.

To communicate specific instructions to the subjects, the target bedtime, target wake-up time, and time in bed (TIB) were sent by e-mail every day during the intervention period.

2) Sleep hygiene education, stimulus control therapy, and PMR

For guidance on sleep hygiene and sleep knowledge [14, 15], we provided a list of sleep hygiene education points, sleep columns, and sleep quiz as web content. We provided information on the theoretical background of the stimulus control method, and behaviors recommended as a stimulus control therapy in the form of sleep columns and a sleep quiz. A video explaining the PMR was provided as web content.

On Day 8, a reminder email was sent to review a list of sleep hygiene education points. On Day 15, a reminder e-mail was sent to the participants to perform the exercises while watching a 6-minute PMR video. Other columns and sleep quizzes aimed at sleep education were sent as individual reminder e-mails during the intervention period to encourage viewing. All the web content was available for the intervention group to view at any time during the intervention period.

Measurements

The participants answered the online questionnaire: the pre-test at the baseline, the post-test after the intervention, and after the 6-month follow-up survey.

Both intervention and control group participants completed the sleep diary measures, sleep recording with the FS-770, during the 1-week baseline survey period, and after the 2-week intervention period.

Primary measure

The primary measure was the mean change in SJL assessed using the MCTQ from pre-test to post-test.

MCTQ

We employed the Japanese version of the MCTQ core module [16, 17], which asks 10 simple questions about sleep and wake behavior, carefully distinguishing between bedtimes and sleep times. These questions address i) bedtime, ii) time spent in bed awake before deciding to turn off the lights (preparation for sleep), iii) how long it takes to fall asleep (sleep latency), iv) waking up (sleep offset) time, and v) getting up time. This set of questions is asked separately for workdays and work-free days.

To assess SJL, the MCTQ uses the midpoint between sleep on- and offset on both free days (midsleep on free days, MSF) and workdays (midpoint of sleep-in workdays: MSW). Absolute SJL was calculated using the following formulae:

Absolute SJL = abs (MSF–MSW).

Secondary measures

Pittsburgh Sleep Quality Index (PSQI)

We employed the Japanese version of the PSQI [18]. This questionnaire comprises seven items: sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, sleep quality, use of sleeping medication, and daytime dysfunction, covering the previous 7 days. A score on a scale of 4 (0-3) is calculated for each component, and the scores for each component are summed.

Epworth Sleepiness Scale (ESS)

We also employed the Japanese version of the ESS [19]. This is an 8-item questionnaire with scores ranging from 0 (no daytime sleepiness) to 24 (severe daytime sleepiness).

Insomnia Severity Index (ISI)

The Japanese version of the Insomnia Severity Index (ISI) [20] was used as a reference; the ISI is a 7-item questionnaire ranging from 0 (no insomnia) to 28 (severe insomnia) points.

Patient Health Questionnaire-9 (PHQ-9)

We employed the Japanese version of the PHQ-9 to assess depressive symptoms [21]. On a scale of 0–3, respondents indicated the frequency with which they experienced the following symptoms: (1) anhedonia, (2) depressed mood, (3) sleep disturbance, (4) fatigue, (5) appetite change, (6) low self-esteem, (7) concentration problems, (8) psychomotor disturbances, and (9) suicidal ideation. Total scores range from 0 to 27, with scores of ≥10 representing clinically significant depressive symptoms.

Sleep quiz

A sleep quiz with nine "true or false" responses was used to assess the subjects' knowledge of sleep. The questions included topics such as electroencephalography, sleep stages, hormone secretion, caffeine intake, effects of bathing, effects of light, changes in body temperature during sleep, aging-related sleep changes, and stimulus control methods. The total score (range 0-9) was calculated by summing the item scores.

Sleep diary measures, and sleep recording

All participants were sent an email that encouraged them to record their online sleep diary every

day. The questions asked about: (1) the time of getting into bed; (2) the time at which the individual attempted to fall asleep; (3) sleep onset latency (SOL); (4) the number of awakenings; (5) duration of awakenings; (6) time of final awakening; (7) final rising time; (8) perceived sleep quality (rated using a Likert scale); and (9) additional space for open-ended comments from the respondent [22]. Based on the sleep diary measures, sleep parameters including total sleep time (TST), TIB, and sleep efficiency (SE) were calculated. To identify and exclude from analysis participants who had extremely irregular sleep-wake rhythms and for whom sleep and wake times could not be determined, all participants recorded activity during the night while the lights were off using the FS-770 (Estera Corporation, Saitama, Japan), which is worn at the waist [23].

Other measures

The online questionnaire asked for socio-demographic information (age, gender), height, weight, caffeinated beverage (coffee, tea, carbonated beverages) intake (yes or no), alcohol consumption (never, vs sometimes, daily), smoking habit (yes or no), living together with others, exercising (3 times per week or more, or less), and taking sleeping medication (more than once a week, or no). Body mass index (BMI) was calculated from height and weight. The subjects were divided into two groups: obese (BMI≥25) and normal.

Ethical approval

The study protocol was approved by the Ethics Committee of Kyoto University (C1504).

Sample size and statistical analysis

The mean change in SJL during two weeks in the intervention group was assumed to be 88 minutes [12], and the standard deviation (SD) was assumed to be 108 minutes. Since the study was to be conducted using two groups, the alpha level was set at 0.05, and the sample size was calculated to be 80% power, which means that 25 patients per group would be needed. We

estimated the target number of patients to be 60, with an expected dropout of 20%.

After completion of the follow-up, subjects who (1) did not respond to the questionnaire survey and (2) did not meet the selection criteria or were found to be in conflict with the exclusion criteria were excluded from the analysis.

Analysis of the baseline data for participant demographics was performed using descriptive statistical analysis. Chi-squared test was used for categorical variables and Student's independent samples t-test for continuous variables.

The differences between the intervention and the control group for the mean change in each scale variable on online questionnaires between the pre-test and post-test and between the pre-test and six-month follow-up, and the mean change in sleep parameters assessed using the sleep diary between weeks 1 and 3, were analyzed using independent samples t-test. Factors that differed significantly between the intervention and control groups in the baseline data were adjusted using generalized linear models (GLM), and the *P*-values were calculated.

The significance level used for statistical analysis with two-tailed testing was 5%. Data values were presented mainly as mean ± SD. All analyses were performed using SPSS 27.0 for Windows.

Results

The trial profile including recruitment, randomization, intervention, follow-up, and analysis is shown in **Fig. 2.** Of the 210 individuals who applied to participate, 71 met the inclusion criteria on screening, and 139 did not meet the inclusion criteria. Sixty-nine were eligible to participate in the trial briefing information session (excluding 2 who canceled their participation). Among these individuals, 54 were eligible for allocation (excluding 7 who could not attend the trial briefing session, 6 who declined to participate in the briefing session, and 2 who canceled the trial attendance before randomization). Of those remaining, 26 were assigned to the intervention group and 28 to the control group. One participant in the control group was excluded from the analysis

due to poor adherence. Thus, a total of 26 participants in the intervention group and 27 in the control group completed the trial. Finally, 22 participants in the intervention group and 27 in the control group completed the 6-month follow-up survey. No important harmful or unintended effects were observed in either group.

The participants' characteristics and sleep variables at the baseline are shown in **Table 1**. The percentage of obese (BMI≥25) individuals differed significantly between the two groups (χ^2=4.65, *P*=0.034), as did the percentage of individuals who consumed caffeine (χ^2=5.31, *P*=0.021).

Changes in outcomes from the pre-test to the post-test for each group are shown in **Table 2**. Regarding the primary outcome, the difference in the mean change in SJL during two weeks between the intervention group and the control group was statistically significant (-27.7 minutes, 95% confidence interval [95%CI] -54.6 to -0.86, *P*=0.043). GLM revealed significant differences after adjusting for obese and caffeine consumption (*P*=0.048).

The difference in the mean change in ESS over two weeks between the intervention group and the control group was -2.5 (95%CI -4.1 to -0.9, *P*=0.003). The GLM showed significant differences after adjusting for obese and caffeine consumption (*P*=0.009). The difference in the mean change in PHQ-9 during two weeks between the intervention group and the control group was -2.1 (95%CI -3.9 to -0.2, *P* =0.028). The GLM revealed significant differences after adjusting for obese and caffeine consumption (*P*=0.048). The difference in the mean change in sleep quiz score during two weeks between the intervention group and the control group was 1.2 (95%CI 0.2 to 2.1, *P*=0.015). The GLM revealed significant differences after adjusting for obese and caffeine consumption (*P*=0.002)

Changes in outcomes from the pre-test to the 6-month follow-up point for each group are shown in **Table 3**. The difference in the mean change in SJL from the pre-test to the 6-month follow-up point between the two groups was not statistically significant. The difference in the mean change in PHQ-9 during 6 months between the intervention group and the control group

was -1.4 (95%CI -3.3 to 0.4, *P*=0.126). The GLM showed significant differences after adjusting for obese and caffeine consumption (*P*=0.042). The difference in the mean change in sleep quiz score during two weeks between the intervention group and the control group was 1.0 (95%CI 0.1 to 1.9, *P*=0.025). The GLM revealed significant differences after adjusting for obese and caffeine consumption (*P*=0.004).

The sleep diary comparing sleep parameters between week 1 and week 3 revealed a significant advance in bedtime (*P*=0.028) and wake-up time (*P*=0.003) for the whole period in the intervention group relative to the control group (**Table 4**).

Discussion

This study is the first RCT to have shown that the SET-R, providing an individualized sleep schedule for gradual sleep extension, is effective for decreasing SJL in university students and has beneficial effects on not only SJL but also daytime sleepiness and depressive symptoms.

This study demonstrated that two weeks of the intervention decreased SJL by about 28 minutes relative to the control group. Previous data from a two-week study of gradual sleep extension in high school students (although SJL was not the primary measure) showed that SJL decreased in the intervention group [12], being consistent with the present results. Here, SJL was investigated 6 months after the intervention, and showed no significant difference from the control group. The change in SJL was shown to be reduced in the 6-month follow-up survey, suggesting difficulty in maintaining the efficacy of the SET-R. Therefore, to maintain efficacy over the long term, improvement of the intervention program, for example by sending regular follow-up e-mails, may be necessary.

There were few dropouts during this intervention period. In many previous studies using internet-based cognitive behavioral therapy for insomnia programs, about 20-40% of the participants dropped out [24, 25]. The shorter intervention period used in this study may have contributed to the lower dropout rate, as CBT-I usually involves a longer intervention period of 5

to 9 weeks [26]. This is considered a major strength when considering the social implementation of SET-R.

The results of the questionnaire-based survey revealed that the intervention group increased their weekday sleep duration by about 12 minutes. The effect of the SET-R on sleep duration was comparable to that in a previous study, which demonstrated a 13-minute increase in sleep duration from week 1 to week 3 by gradual sleep extension among high school students [12]. In the sleep diary, a comparison of the change in sleep parameters from week 1 to week 3 between the intervention group and the control group revealed a significant advance in bedtime and waking up time, respectively. An advance in bedtime due to the intervention was indicated, and the instruction to wake up at the same time on weekends as that on weekdays may have worked to advance the average weekly waking time. In a similar intervention study involving high school students, there was an advance in bedtime and sleep onset time [12], consistent with the present results.

The intervention group showed a significant decrease in ESS in the post-test and amelioration of daytime sleepiness. Several one-arm and non-randomized studies have found that sleep extension ameliorated daytime sleepiness [27, 28]. A two-group study involving high school students showed that a five-week sleep extension procedure reduced sleepiness in the intervention group [29]. Since sleep deprivation leads to increased daytime sleepiness, it is thought that sleep extension lessens daytime sleepiness when sleep deprivation improves.

The intervention group showed a significant decrease in PHQ-9 in the post-test and significant amelioration of depressive symptoms, this effect persisting in the follow-up survey after 6 months. It has been reported that sleep and depressive symptoms are bidirectionally related and that decreased sleep duration is associated with depressive symptoms [30]. Many intervention studies using sleep extension have reported amelioration of depressive symptoms. In an intervention study that extended TIB for 3 hours in healthy subjects, amelioration of depression was more pronounced after TIB extension [31]. Another study examining the effects of extended

sleep opportunity by 90 min per night in young women found a reduction of anhedonia and depressive symptoms [32]. As in the present study subjects with high depression scores were excluded, it will be necessary to investigate the efficacy of the intervention in subjects with severe depressive symptoms in the future.

The intervention group showed a significant improvement in sleep knowledge as assessed by the sleep quiz, and this effect persisted in the follow-up survey after 6 months. A study examining the effects of a sleep education program in schools found that it not only increased sleep knowledge but also reduced the discrepancy between school and weekend out-of-bed time [33]. These results suggested that appropriate sleep education would be effective for improving the sleep habits of study subjects. However, the number of questions in the sleep quiz may need to be increased, and more detailed assessments of changes in sleep knowledge should be considered.

There were several limitations to this study. First, the subjects wore a sleep monitor to prevent significant deviations from the research protocol and were aware that their sleep was being monitored. Therefore, their behavior may have altered through a placebo effect. Second, we were unable to confirm whether the subjects in the intervention group consciously followed the rules of the sleep hygiene education we gave them, or whether they implemented the PMR. Third, the study was conducted at a single university, albeit a large one, which may have biased the attributes of the participants. To increase generalizability, further multicenter studies will be required. Fourth, the use of self-report measures for sleep and mental health outcomes may be biased by memory recall and social desirability. Because of the difficulty of using measures other than self-report, self-report measures are often used to assess mental health outcomes, but future research may need to use additional measures (e.g., objective sleep measures or scoring by a blinded rater). Fifth, although the sample size was statistically estimated and the number of subjects reached the target number of cases during the 2-week intervention period, the sample size of this study was relatively small. The small sample size may have reduced external validity.

Future studies with larger sample sizes are needed to confirm the findings from the present study.

Conclusions

This RCT has demonstrated the efficacy of the SET-R among university students with increased SJL, suggesting that sleep extension is an effective method for acutely reducing SJL in this population. This intervention was also shown to have beneficial effects on daytime sleepiness and depressive symptoms.

Abbreviations

SJL: social jetlag

BMI: Body mass index

BDNF: brain-derived neurotrophic factor

RCT: randomized controlled trial

SET-R: sleep extension therapy using a remote support system

SKUSH: Student of Kyoto University Sleep Health

MCTQ: Munich ChronoType Questionnaire

PSQI: Pittsburgh Sleep Quality Index

ESS: Epworth Sleepiness Scale

ISI: Insomnia Severity Index

PHQ-9: Patient Health Questionnaire-9

PMR: progressive muscle relaxation

MSF: midsleep on free days

MSW: midpoint of sleep-in workdays

TIB: time in bed

TST: total sleep time

SOL: sleep onset latency

SD: standard deviation

GLM: generalized linear models

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Author Contributions

All authors contributed to and have approved the final manuscript. RF, TS, YM, SK, YT, SO, KK, and TI contributed to the study design, data collection, data interpretation, and preparation of the manuscript. KK independently performed the allocation. RF performed the statistical data analyses.

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Table 1. Characteristics of the participants and sleep variables at Pre-test.

Variables	Intervention (n=26)		Control (n=27)		*P*-value
Age (year), mean, SD	21.0	1.6	21.3	2.7	0.676
Female Sex, n, %	13	50.0%	12	44.4%	0.685
Living alone, n, %	21	80.8%	21	77.8%	0.788
Obese (BMI≥25), n, %	4	15.4%	0	0.0%	0.034
Exercising 3 times per week or more, n, %	14	53.8%	11	40.7%	0.339
Alcohol use (sometimes, daily vs never), n, %	13	50.0%	9	33.3%	0.218
Currently smoking (yes vs no), n, %	0	0.0%	1	3.7%	0.322
Caffeine consumption (yes vs no), n, %	22	84.6%	15	55.6%	0.021
Hypnotic medication use (more than once a week vs no), n, %	0	0.0%	0	0.0%	

Table 2. Change in outcome from pre-test to post-test in each group.

Variable	Group	Observed Value				Pre-test to Post-test						
		Pre-test		Post-test		Change in Outcome		The difference in the mean change between groups				
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	95%CI		*P*-value[a]	*P*-value[b]
MCTQ core module												
Social Jetlag, min	Intervention	80.8	41.4	53.1	37.4	-27.7	52.0	-27.7	-54.6	-0.9	0.043	0.048
	Control	84.6	49.1	84.6	44.7	0.0	45.4					
Sleep duration (average) on workdays, min	Intervention	421.0	56.9	433.1	49.9	12.1	66.8	9.6	-24.0	43.2	0.569	0.160
	Control	402.6	62.6	405.1	74.1	2.5	54.7					
Sleep duration (average) on free days, min	Intervention	454.0	74.3	450.9	57.4	-3.1	49.4	1.6	-30.0	33.1	0.922	0.882
	Control	450.0	84.7	445.4	70.5	-4.7	63.7					
Sleep duration (average) per week, min	Intervention	430.5	53.0	438.2	49.6	7.7	51.3	7.3	-20.2	34.8	0.596	0.205
	Control	416.2	57.5	416.6	65.9	0.4	48.4					
PSQI	Intervention	5.8	3.2	4.0	2.0	-1.7	3.3	-1.6	-3.1	-0.1	0.033	0.079
	Control	6.9	3.1	6.7	2.9	-0.1	2.0					
ESS	Intervention	9.3	3.8	7.1	3.9	-2.2	2.9	-2.5	-4.1	-0.9	0.003	0.009
	Control	10.6	3.5	10.9	4.0	0.3	2.9					

ISI	Intervention	6.2	4.3	4.5	3.4	-1.7	4.9	-1.6	-3.7	0.5	0.126	0.374
	Control	7.6	3.0	7.5	3.1	-0.1	1.8					
PHQ-9	Intervention	4.0	4.5	2.5	2.4	-1.4	3.5	-2.1	-3.9	-0.2	0.028	0.048
	Control	3.9	3.1	4.5	3.7	0.6	3.1					
Sleep quiz	Intervention	5.8	1.5	7.5	1.3	1.8	1.9	1.2	0.2	2.1	0.015	0.002
	Control	6.1	1.2	6.7	1.6	0.6	1.4					

MCTQ, Munich ChronoType Questionnaire; PSQI, Pittsburgh Sleep Quality Index (0-21points); ESS, Epworth Sleepiness Scale (0-24points); ISI, Insomnia Severity Index (0-28points); PHQ-9. Patient Health Questionnaire-9 (0-27points), sleep quiz (0-9points).

[a] Independent samples t-test

[b] Generalized linear models adjusted for obese, and caffeine consumption

Table 3. Changes in outcome from the pre-test to the 6-month follow-up point in each group.

Variable	Group	Observed Value				Pre-test to 6-Mo Follow-Up						
		Pre-test		6-month follow-up test		Change in Outcome		The difference of the mean change between groups				
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	95%CI		*P*-value[a]	*P*-value[b]
MCTQ core module												
Social Jetlag, min	Intervention	80.8	41.4	60.6	39.1	-18.0	52.2	-5.1	-35.2	25.0	0.736	0.624
	Control	84.6	49.1	71.7	57.9	-13.0	52.1					
Sleep duration (average) on workdays, min	Intervention	421.0	56.9	435.5	65.5	11.5	91.6	10.6	-34.8	55.9	0.641	0.274
	Control	402.6	62.6	403.6	56.3	0.9	66.0					
Sleep duration (average) on free days, min	Intervention	454.0	74.3	475.0	66.1	18.4	86.5	31.3	-20.5	83.1	0.230	0.182
	Control	450.0	84.7	437.1	69.6	-13.0	92.0					
Sleep duration (average) per week, min	Intervention	430.5	53.0	446.7	58.9	13.5	77.7	16.5	-24.8	57.8	0.425	0.177
	Control	416.2	57.5	413.1	53.1	-3.0	65.9					
PSQI	Intervention	5.8	3.2	4.9	2.8	-0.5	3.3	0.3	-1.6	2.1	0.764	0.604
	Control	6.9	3.1	6.1	3.2	-0.8	3.1					
ESS	Intervention	9.3	3.8	7.0	3.1	-2.6	3.3	-0.7	-3.2	1.8	0.597	0.895
	Control	10.6	3.5	8.7	4.2	-1.9	5.0					
ISI	Intervention	6.2	4.3	5.0	3.8	-0.6	4.5	0.0	-2.5	2.5	0.999	1.000
	Control	7.6	3.0	7.0	4.8	-0.6	4.3					
PHQ-9	Intervention	4.0	4.5	2.1	2.1	-1.4	3.5	-1.4	-3.3	0.4	0.126	0.042

	Control	3.9	3.1	3.9	3.2	0.0	3.0					
Sleep quiz	Intervention	5.8	1.5	7.3	1.2	1.5	1.7	1.0	0.1	1.9	0.025	0.004
	Control	6.1	1.2	6.5	1.3	0.4	1.4					

MCTQ, Munich ChronoType Questionnaire; PSQI, Pittsburgh Sleep Quality Index (0-21points); ESS, Epworth Sleepiness Scale (0-24points); ISI, Insomnia Severity Index (0-28points); PHQ-9. Patient Health Questionnaire-9 (0-27points), sleep quiz (0-9points).

[a] Independent samples t-test

[b] Generalized linear models adjusted for obese, and caffeine consumption

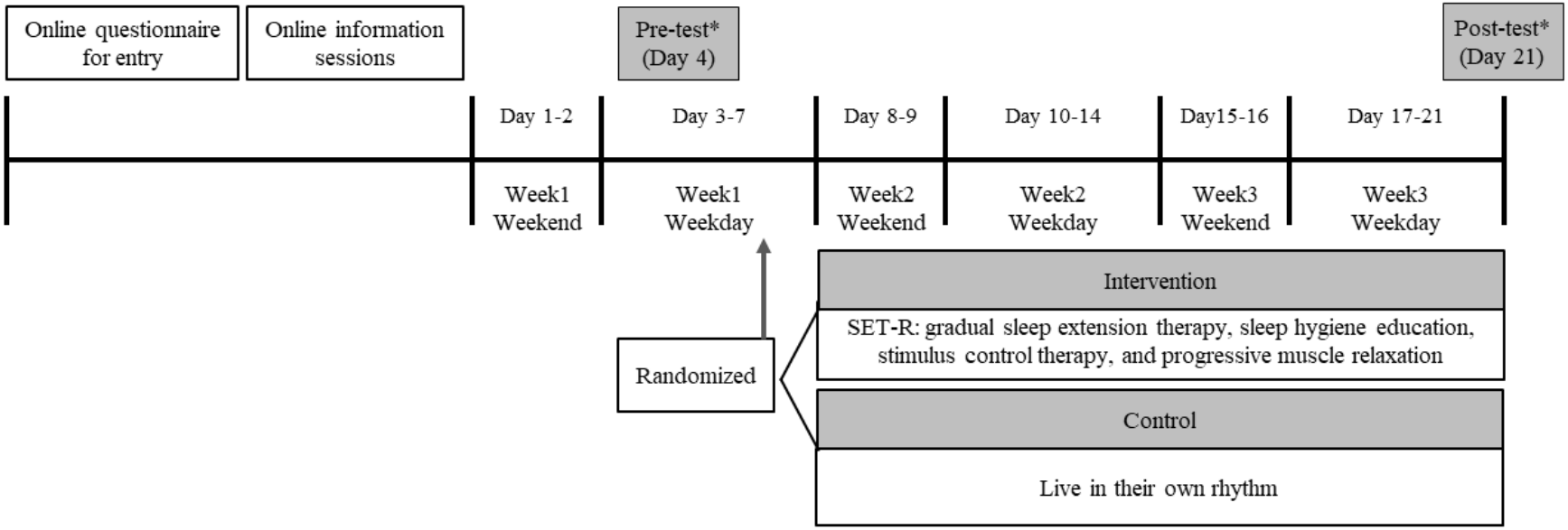
Table 4. Effect of sleep extension on sleep parameters in the sleep diary.

Variables	Group	Week 1						Week 3					
		Weekend		Weekday		Total		Weekend		Weekday		Total	
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Time in bed, min	Intervention	492.9	79.4	469.7	62.9	475.0	58.2	506.9	87.5	473.1	56.2	480.0	55.3
	Control	495.4	101.0	439.5	90.3	456.4	83.5	492.7	129.2	462.6	80.2	469.7	78.7
Total sleep time, min	Intervention	416.2	71.0	399.2	55.3	402.6	52.0	429.0	87.8	417.5	47.4	419.6	48.9
	Control	405.7	76.3	358.7	62.9	372.2	54.7	417.6	85.5	381.5	68.3	389.3	60.7
Sleep efficiency, %	Intervention	84.6	7.5	85.6	7.8	85.3	6.8	85.3	12.1	88.6	5.8	87.9	6.1
	Control	82.7	10.3	82.8	10.2	82.7	9.6	84.9	9.4	83.0	11.5	83.2	9.8
Sleep onset latency, min	Intervention	15.4	11.0	15.4	10.5	15.5	9.9	20.4	30.6	16.2	15.9	17.2	19.2
	Control	19.3	23.2	16.7	18.0	17.6	18.5	13.0	17.3	16.5	15.8	15.6	15.1
Waking time after sleep onset, min	Intervention	7.0	15.9	3.6	6.1	4.7	5.9	3.2	5.5	2.7	4.5	2.8	3.7
	Control	8.5	14.7	9.2	20.6	9.1	18.3	5.1	9.7	10.4	20.4	9.0	16.9
Terminal wakefulness, min	Intervention	33.0	31.5	24.7	17.8	27.0	18.7	31.8	67.0	17.1	12.0	19.8	17.1
	Control	39.7	31.0	28.0	26.8	32.0	24.2	26.2	21.6	24.2	21.3	25.5	18.6
Waking up time [a]	Intervention	9.4	1.7	8.6	1.1	8.8	1.1	9.0	2.1	8.4	1.2	8.5	1.2
	Control	9.5	1.9	8.3	1.0	8.6	1.1	9.3	1.8	8.8	1.3	8.9	1.2
Bedtime [a]	Intervention	25.2	1.7	24.8	1.4	24.9	1.4	24.5	1.6	24.5	1.2	24.5	1.2
	Control	25.2	1.8	24.9	1.5	25.0	1.4	25.0	1.5	25.1	1.2	25.1	1.2

a Significant difference from week 1 to week 3 in total (P<0.050)
Independent samples t-test for continuous variables.

Participants who did not record more than four times per week were excluded, and the records of 26 participants in the intervention group and 27 participants in the control group were included in the analyses.

Fig. 1. Timeline of the study.



*Pre-test, and Post-test included MCTQ core module, PSQI, ESS, ISI, PHQ-9, and a sleep quiz.

Fig. 2. Trial profile including recruitment, randomization, intervention, follow-up, and analysis.