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Preventing sleep deficit in adolescents: Long-term effects of a quasi-experimental school-based intervention study

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Abstract

Adolescents are at risk of sleep deficit, which has serious consequences for their daytime functioning. However, school-based interventions to improve sleep have shown limited success. This might be due to the content of the programmes (e.g., not targeting central factors such as daytime stress and technology use) or because changes have not been captured due to a lack of long-term follow-ups. Hence, the aim of this study was to evaluate the long-term effects of a school-based sleep education curriculum including time-management training. The study used a quasi-experimental design. Participants were 3,622 adolescents (mean age 13.7, 48% girls); 286 were in the intervention group and 3,336 were followed as a natural control group. Data were collected before the intervention and at a 1-year follow-up. We divided participants into three groups according to baseline sleep duration (calculated from self-reported bed- and wake times, minus sleep onset latency): insufficient (<7 hr), borderline (7–8 hr) and adequate (>8 hr). Adolescents in the intervention group were ~2 times less likely to report insufficient sleep at follow-up as compared to controls. Sleep knowledge improved significantly in the intervention group but there were no changes in emotional sleep hygiene (e.g., bedtime worry) and perceived stress. Surprisingly, technology use increased and behavioural sleep hygiene worsened in the intervention group. Although the mechanisms of change need further investigation, the results of this study point to potential long-term benefits of school-based sleep programmes.

KEYWORDS
information and communication technology, prevention, sleep health, youths

1 | INTRODUCTION

An increasing number of adolescents do not sleep enough. Insufficient sleep duration in early adolescence has been recently defined as <8 hr per night (Hirshkowitz et al., 2015) and 12%–31% of adolescents report sleeping less than that (Bauducco, Flink, Jansson-Fröjmark, & Linton, 2016; Chaput & Janssen, 2016; Maslowsky & Ozer, 2014). Sleep deficit in adolescence can be explained by biological and psychosocial changes occurring during this developmental period, including the tendency to shift to a later sleep phase (i.e., later bed- and wake times; Becker, Langberg, & Byars, 2015). Moreover, sleep competes with increasing school demands and the pervasive use of information and communication technology (ICT) (Hale & Guan, 2015). Conversely, protective factors, such as parent-set bedtimes and good sleep practices, decline as adolescents grow older (Bartel, Gradisar, & Williamson, 2015). Not getting

enough sleep has severe consequences, such as daytime sleepiness, behavioural and emotional problems, physical health issues, and poor school attendance and performance (Shochat, Cohen-Zion, & Tzischinsky, 2014). Action is needed to enhance sleep in adolescents.

Several school-based sleep programmes have been developed over the last decade to reach as many youths as possible and to promote better sleep health in this vulnerable age group. The aim of universal programmes (directed towards a whole group or population) is to gradually shift the trajectories of the adolescents who sleep too little and to maintain the trajectories of those sleeping enough. According to the "prevention paradox" (Rose, 2001), the majority of new cases sleeping poorly will come from the larger group of "good" sleepers. Therefore, paradoxically, the group that will benefit the most from universal interventions is the one not presenting problems at the time of the intervention. In fact, adolescents who do not experience sleep problems will not show changes in their sleep patterns right after the intervention but ideally they will be less likely to develop sleep problems over time, as compared to normal development.

Previous studies of school-based sleep programmes have not evaluated their preventive effect over time. No study has included a follow-up longer than 18 weeks (Rigney et al., 2015), which might be too short to detect long-term changes. If developmental sleep trajectories are truly affected, the results need to be studied over longer time periods (e.g., a year). Moreover, another methodological limitation is that some of the previous evaluation studies have used small samples (Blunden & Rigney, 2015), which precludes subgroup analyses. Looking at subgroups is especially important in order to understand for whom universal interventions may be most helpful. For example, one study found that a school-based motivational sleep intervention was most effective for adolescents with delayed sleep timing (Bonnar et al., 2015). This is not surprising because adolescents who experience sleep problems at the time of the intervention may be more motivated to change their sleep habits than adolescents who are satisfied with their sleep. However, to understand if universal interventions are also effective in preventing sleep problems in those who sleep well, it is necessary to investigate who benefits over time on a subgroup level. So, including longer follow-ups and observing subgroup changes is warranted.

There might also be a need to improve the content of sleep interventions in order to improve their effectiveness. Previous interventions have shown limited changes in observable behaviours (Cassoff, Knäuper, Michaelsen, & Gruber, 2013). More specifically, programmes focusing exclusively on sleep education have been effective in increasing adolescents' knowledge about sleep, but not in changing behaviours (Cassoff et al., 2013). Interventions aiming at changing sleep behaviours include, in addition to sleep education, behavioural techniques and motivational components (e.g., motivational interviewing [MI]) (Miller & Rollnick, 2012). Using an MI framework has shown benefits in increasing motivation, but not in improving sleep duration (Cain, Gradisar, & Moseley, 2011). A recent trial found some effects on sleep duration, independent of initial sleep, and the effects were maintained at a 6-week follow-up

(Bonnar et al., 2015). However, potential long-term benefits were not explored. So, the lack of clear evidence of the effectiveness of previous interventions might be due to a lack of long-term follow-ups but also to the content of the programmes.

Successful interventions rely on a number of key principles: (a) correct timing, (b) involving relevant contexts and (c) focus on practical skills (see Nation et al., 2003).

First, correct timing implies it might be more effective to target younger adolescents to prevent sleep deficit, as poor sleep habits at that age are not yet rigidly established (Wolfson, Harkins, Johnson, & Marco, 2015). In fact, a decline in sleep duration starts at the beginning of adolescence (roughly age 12) (Carskadon & Acebo, 2002; Gradisar, Gardner, & Dohnt, 2011). Also, parental involvement might be more easily accepted in this age group.

Second, using contexts may imply involving parents as well as peers in a successful intervention for young adolescents. A recent meta-analysis showed that parents' rules about bedtime were one of the most powerful protective factors for their children's sleep (Bartel et al., 2015). Although peers have not been explicitly involved in previous sleep programmes, targeting social influences has been successful in school-based programmes focusing on other health risk behaviours , such as early onset of sexual activity and alcohol drinking (Durlak, 1997). Thus, addressing parents' and peer's norms about sleep might be a powerful way to motivate change. Another important contextual aspect to consider is the impact of information and communication technology (ICT). ICT has been identified as a potential risk factor for poor sleep in children and adolescents (Hale & Guan, 2015) because it might elicit arousal at bedtime and displace time from sleep (Cain & Gradisar, 2010). Moreover, parents and peers have an important role in media usage. For example, children whose parents set limits regarding ICT use have earlier bedtimes (Pieters et al., 2014); so, targeting ICT through a combination of psychoeducation and involving parents and peers in discussions, might help adolescents achieve earlier bedtimes.

Third, targeting practical skills may imply a focus on abilities such as time management. Adolescents often report that they do not have time to sleep more, even though they want to, and they often prioritize other activities (e.g., ICT use and schoolwork) (Cassoff et al., 2013). Moreover, adolescents who perceive their everyday life as stressful also report poor sleep (Bauducco et al., 2016; Chung & Cheung, 2008; Lund, Reider, Whiting, & Prichard, 2010). Thus, time management may be one important strategy to help adolescents plan their activities, reduce stress and make up time for sleep.

To target these important factors, we developed a new school-based sleep programme, the Youth Enhanced Sleep (YES) Programme, aimed at young adolescents (age 12–14). In addition to sleep education, the programme focuses on time management of both daytime and evening activities, with particular attention given to providing strategies to regulate the persistent distraction provided by technological devices. The programme also involves parents and peers in supporting behavioural changes.

The aim of this study is to evaluate the effectiveness of this intervention in the long-term prevention of future sleep deprivation as

compared to a natural control group. We hypothesized that improvements in sleep duration would occur in the baseline risk group (i.e., adolescents reporting <7 hr/night), whereas baseline good sleepers (i.e., >8 hr/night) would maintain their sleep duration 1 year later to a larger extent as compared to a natural control group. Moreover, we hypothesized that adolescents in the intervention group would show an increase in sleep knowledge and sleep hygiene, and a decrease in perceived stress and ICT use.

2 | METHOD

2.1 | Study design

The study used a quasi-experimental design and was part of the Three Cities Study, a longitudinal study following a cohort of adolescents in the 7th and 8th grades in lower secondary school for five consecutive years (2014–2018; Boersma, 2019). The aim of the Three Cities Study was to study processes that buffer against mental health problems in youths. The present study used the longitudinal cohort as a natural control group, whereas the intervention group was recruited outside of the longitudinal cohort so as not to affect the original sample. The longitudinal cohort (i.e., natural control group) of 7th and 8th graders filled out questionnaires in the spring of 2014 and 2015 (end of January through to the beginning of June). The intervention group (also 7th and 8th grade) filled out questionnaires before, during (not reported here, except for the last session or "post-test") and 1 year after the intervention, during the spring of 2016 and 2017 (see Figure 1). The post-test was carried out at the end of May/beginning of June.

2.2 | Participants

Potential participants were 3,622 adolescents (mean age, 13.7; 48% girls). The control group included 3,336 adolescents in the lower secondary school grades 7 and 8 from all public schools in three Swedish towns (n = 18). Two of these schools were selected to participate in the sleep programme 2 years after the longitudinal study started. Thus, the intervention group included students (n = 286) in the same grades (7th and 8th) as the control group, but different cohorts (2016–17 versus 2014–15) (see Figure 1).

At follow-up, 1 year after the intervention, the retention rate was 80% in the intervention group and 89% in the control group. Participants with incomplete or unreliable data on the primary outcome variable sleep duration were excluded from the analyses,
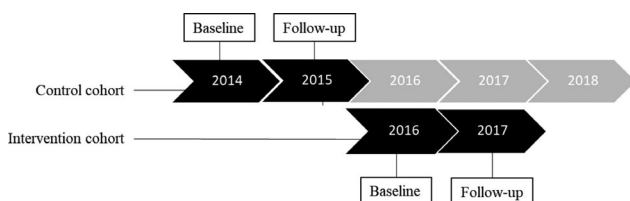
including adolescents sleeping >11 hr/night because the focus of the paper is on short sleep duration (baseline, 33% intervention/21% control; follow-up, 46% intervention/29% control), leaving a sample of 119 adolescents in the intervention group and 2,269 in the control group (see the flowchart in Figure 2). Participants who did not complete the follow-up measurement were less likely to be boys, both in the intervention group and control group ($OR_{Intervention}$ = 0.321, p = .05; $OR_{Control}$ = 0.734, p = .05); participants who dropped out of the control group were also more likely to report higher perceived stress (OR = 1.04, p < .001) and shorter sleep duration at baseline (OR = 0.997, p = .002). Participants in the intervention group and control group differed in terms of age, gender, living situation and sleep hygiene at baseline (see descriptive statistics in Table 1 separately for the intervention and control groups).

2.3 | Procedure

Before data collection, we received active informed consent from the students and passive consent from the parents (Pokorny, Jason, Schoeny, Townsend, & Curie, 2001; Shaw, Cross, Thomas, & Zubrick, 2015). Twenty-two parents declined to have their child in the sleep intervention study and 42 adolescents did not return the consent letter. In the control group, 122 parents declined participation and 447 adolescents did not return the active consent form. All parents received a letter informing them about the study and the consent form (to be signed and returned via mail if they did not want their child to participate). Parents of the adolescents in the intervention group also received a brochure with information about the content of the programme and tips on how to support their children's sleep health at home. At the first data collection, students were informed about confidentiality and that participation was voluntary. Students in the intervention group filled out the questionnaires at two baseline occasions, 1 and 2 weeks before the intervention started, and then at the beginning of each session. Adolescents in the intervention group completed questionnaires in the classroom via the app or by paper and pen, and each student used a personalized login/code so that no name would be linked to the questionnaire. Adolescents in the control group completed paper and pen questionnaires and names were removed afterwards and replaced by individual ID codes. In the intervention group, incentives for filling out the questionnaires consisted of a lottery (e.g., three movie tickets per class) after each data collection, whereas each class in the control group received 300 Swedish crowns each year. This study was approved by the Regional Ethical Board in Uppsala, Sweden (EPN, ref. n. 2016/021); the trial has not been registered.

2.4 | Youth Enhanced Sleep Programme

The intervention consisted of five sessions, 50–60 min, once per week for 6–7 weeks, and was scheduled as part of the school curriculum (e.g., health and physical activity classes). Parental involvement included a brochure with recommendations and information about teenagers' sleep. Moreover, the programme includes

FIGURE 1 Study design and timeline for intervention group and control group

two main components: (a) sleep education to teach about the importance of sleep and about good sleep practices and (b) time management strategies to reduce stress and better prioritize activities during the day and evening. In addition, the programme aims to help adolescents to take control of their technology use by discussing both negative and positive sides of it and the possibility to agree upon rules together with family and friends. The components are described in detail in Table 2. The sleep classes were held by six psychology students, one psychologist and one trained research assistant, two in each class with the assistance of the regular teacher. This choice was based on "the prevention programme research cycle" (Haggerty & Mrazek, 1994), where the first step is to test the programme under ideal conditions (e.g., with psychologists delivering the programme). Once the programme has proven effective, the next step will be to let the school deliver the programme and support its long-term sustainability.

2.5 | Measures

The primary outcome measure is self-reported sleep duration and secondary outcome measures are perceived stress, technology use and sleep hygiene. We controlled for sociodemographic factors.

2.5.1 | Sociodemographics

Sociodemographic items included age, gender, country of birth, family situation and caretakers' country of birth.

2.6 | Primary outcome

2.6.1 | Sleep duration

Weekday sleep duration was estimated by calculating the interval between students' self-reported bedtime ("What time do you usually go to bed on weekdays?") and wake time ("What time do you usually wake up on weekdays?"), subtracting sleep onset latency ("How long does it usually take for you to fall asleep?"). These items were taken from the School Sleep Habits Survey (SSHS) (Wolfson et al., 2003) and have shown good validity when compared to actigraphic measures (Short, Gradisar, Lack, Wright, & Carskadon, 2012). Cronbach's alpha was 0.83 for this study. The baseline measurement for the intervention group refers to the average between baselines 1 and 2 (1 week apart) due to how the question was asked: "When did you go to sleep last (weekday) night?" versus "When do you *usually* go to sleep on weekdays?". This is because the intervention group filled out weekly measures, whereas the control group filled out measures at one single point in time. The question was the same for control and intervention groups at 1-year follow-up.

2.7 | Secondary outcomes

2.7.1 | Perceived stress

Perceived stress was assessed through the Perceived Stress Scale, 14 items (PSS-14) (Cohen, Kamarck, & Mermelstein, 1983) (e.g., "How often
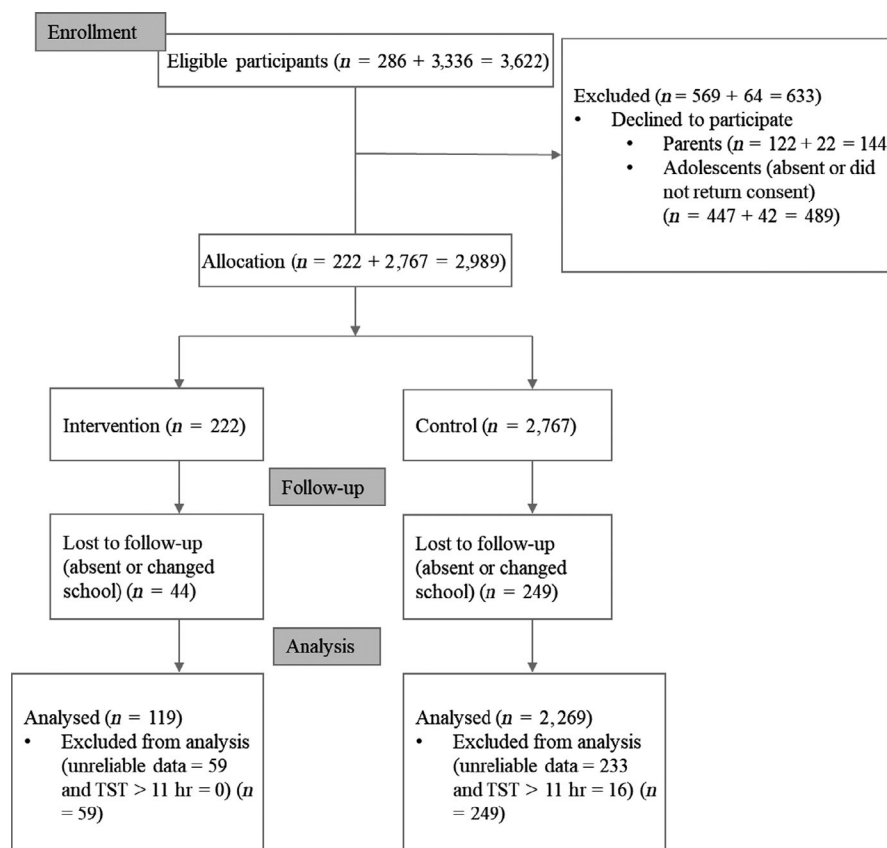

FIGURE 2 Flowchart of study participants

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TABLE 1 Baseline descriptive statistics for intervention group and control group separately

Characteristic	Control (*n* = 2,269)	YES (*n* = 119)	*P* value
Age (years)			
Mean, *SD*	13.6 (0.6)	13.9 (0.7)	.001*
Gender, % (*n*)			
Female	47.4 (1,076)	64.3 (72)	.001*
Male	52.6 (1,193)	35.7 (40)	
Born in Sweden, % (*n*)			
Yes	90.5 (2041)	88.3 (98)	.45
No	9.5 (215)	11.7 (13)	
Parents' country of birth, % (*n*)			
Both in Sweden	67.5 (1816)	62.8 (120)	.43
One in Sweden	10.5 (282)	11.0 (21)	
Both outside Sweden	22.1 (594)	26.2 (50)	
Living with both parents, % (*n*)			
Yes	73.2 (1633)	83.6 (92)	.02*
No	26.8 (597)	16.4 (18)	
Technology use, % (*n*)			
Never	22.6 (497)	23.7 (28)	.48
Sometimes	29.6 (651)	22.9 (27)	
Often	15.3 (337)	16.9 (20)	
Almost always	32.6 (718)	36.4 (43)	
Perceived stress score			
Mean (*SD*)	2.5 (0.6)	2.6 (0.6)	.10
Sleep hygiene (cognitive-emotional) at baseline			
Mean (*SD*)	3.3 (1.3)	2.8 (1.2)	.001*
Missing, % (*n*)	1.2 (27)	0.8 (1)	
Sleep hygiene (behaviour) at baseline			
Mean (*SD*)	4.6 (1)	4.4 (1)	.18
Missing, % (*n*)	2.6 (58)	0.8 (1)	
Sleep duration (hr)			
Mean (*SD*)	7:58 (1:09)	7:50 (1:15)	.19

during the last week have you felt that you had too much to do?"), with responses ranging from "never" to "very often"; Cronbach´s α = 0.79.

2.7.2 | Sleep hygiene

Sleep hygiene was measured through the Adolescent Sleep Hygiene Scale, ASHS (Storfer-Isser, Lebourgeois, Harsh, Tompsett, & Redline, 2013), including the cognitive/emotional factor (six items; e.g., "I go to bed and think about things I need to do") and the behavioural arousal factor (three items; e.g., "I go to bed and do things in my bed that keep me awake"). Responses ranged between "always" and "never" on a six-point scale, with higher scores indicating better sleep hygiene; cognitive/emotional factor Cronbach´s α = 0.83; behavioural arousal factor α = 0.63.

2.7.3 | Technology use after bedtime

One question assessed whether students used electronic media "after lights out", including a TV, computer, tablet or mobile phone after bedtime during the past week. Responses were on a four-point scale: "never", "sometimes", "often" and "almost always". This item was dichotomized for the final analysis into low versus high users (i.e., never–sometimes versus often–almost always) to facilitate the interpretation of the odds ratio.

2.8 | Intervention group only

2.8.1 | Sleep knowledge

Sleep knowledge was measured through a multiple choice quiz created for this study (see Appendix S1) and included 19 items that covered different topics discussed during the intervention (e.g., "How much sleep do adolescents need?"); correct answers were scored 1 and incorrect answers 0.

2.9 | Data analysis

We explored whether changes in sleep duration (primary outcome) were predicted by intervention condition (yes/no) using both linear regression and logistic regression analyses, and controlling for confounders that showed a significant association with baseline sleep duration (i.e., gender, age, caretaker's country of birth and family situation as well as baseline sleep duration). First, we used sleep duration as a continuous variable (linear regression) to investigate mean changes in sleep duration. Second, we divided adolescents into three subgroups (logistic regression) according to the National Sleep Foundation's sleep duration recommendations for teenagers (14–17 years) (Hirshkowitz et al., 2015), to more clearly illustrate the preventive effect of the intervention. More specifically, less than 7 hr/night at baseline was classified as "insufficient" sleep ($n_{intervention}$ = 28, 18.8%; $n_{control}$ = 377, 14.9%), 7 hr was classified as "borderline" ($n_{intervention}$ = 46, 30.9%; $n_{control}$ = 720, 28.4%) and between 8 and 10 hr was classified as "adequate" sleep ($n_{intervention}$ = 75, 50.3%; $n_{control}$ = 1,436, 56.7%). We also analyzed movements between groups from baseline to follow-up in the intervention and control groups using cross-tabulation analysis. We used listwise deletion for cases with incomplete data.

Finally, we analysed whether changes in sleep hygiene, perceived stress and technology use (secondary outcomes) were predicted by the intervention condition (yes/no) using three separate regression analyses (logistic regression for technology use, which is a dichotomous variable) and controlling for confounders. All analyses were conducted using SPSS (v. 23) and the alpha level was set at 0.05. We performed multilevel analysis using STATA to control for the effect of school, as participants are naturally nested in schools. However, these analyses are not reported because the effect of school level was negligible.

TABLE 2 Youth Enhanced Sleep Programme. Main components and sessions

Component	Description	Activity in class/home	Session
Sleep education	Social jetlag, bedtime routine, technology and sleep, caffeine, consequences on daytime functioning, etc.	*Information* and interactive *discussion* *Homework*: plan and evaluation of behavioural experiment (reduce social jetlag, quiet time). *Individualized feedback* (app) between sessions. *Problem-solving* anticipated difficulties and review homework following lesson	1–2, 5–summary
Time management	To-do list (both leisure and school activities), timing activities, setting reminders on the phone, etc.	*Visual diagram* of real versus ideal daytime scenario (app), interactive *discussion*. *Information* about time management *Homework*: plan a time-management strategy. *Individualized feedback* (app) between sessions. *Problem-solving* barriers/distractions and review homework	3 5–summary
Technology use	Effect of technology on sleep (bright light and arousal) and on time management (distraction)	*Information* Interactive *discussion* *Homework*: plan and evaluation of time management (e.g. mobile-free homework). *Individualized feedback* (app) between sessions. *Problem-solving* barriers/distractions and review homework	4 5–summary
Parent involvement	Written summary of the above topics and tips on how to support their adolescent´s sleep	Be ready to support adolescents with homework (i.e., social jetlag, quiet time, time management, including reducing technology use)	Before start

3 | RESULTS

3.1 | Effects of the Youth Enhanced Sleep Programme

3.1.1 | Primary outcome

The primary outcome was sleep duration (see Table 3). First, we analysed mean changes in sleep duration in the intervention and control groups and found that sleep duration increased for the intervention group (from 7:50 to 7:56 [1:13 hr;min], range 2:20–9:49) and decreased in the control group (from 7:58 to 7:49 [1:06], range 1:50–10:59) (see Figure 3), after controlling for baseline sleep duration and sociodemographic confounders. Then, we analysed whether adolescents who participated in the sleep programme were less likely to report borderline (7 hr) and inadequate (<7 hr) sleep duration after the intervention according to the NSF guidelines (Hirshkowitz et al., 2015). Adolescents in the intervention group were 1.7 times less likely to report borderline sleep duration and 2.4 times less likely to report insufficient sleep duration as compared to controls, after controlling for baseline sleep duration subgroup and sociodemographic confounders.

3.1.2 | Subgroup movements

As shown in Table 4, as compared to the intervention group, a larger proportion of adolescents in the control group showed chronicity of insufficient sleep (50.5% versus 38.1%) and a smaller proportion moved from insufficient to adequate sleep duration (15.6% versus 38.1%). Thus, intervention participants seem to both maintain and improve good sleep habits to a larger extent than the control group (see Figure 4).

3.1.3 | Secondary outcomes

Secondary outcomes included perceived stress, sleep hygiene (behavioural and emotional subscales), and technology use at bedtime (see Table 5).

3.1.4 | Perceived stress

There was no effect of the intervention on perceived stress ($M_{intervention}$ = 22.8 [10]; $M_{Control}$ = 22.8 [9.2]).

3.1.5 | Sleep hygiene

There was no effect of the intervention on cognitive-emotional sleep hygiene ($M_{Intervention}$ = 4.5 [0.9]; $M_{Control}$ = 4.5 [1.1]) but there was a small significant decline in behavioural sleep hygiene for the adolescents in the intervention group ($M_{Intervention}$ = 2.6 [1.2]; $M_{Control}$ = 3.0 [1.3]), even after controlling for baseline sleep hygiene score and sociodemographic confounders.

3.1.6 | Technology use after bedtime

Eleven percent of the adolescents in the YES Programme reported 'never' using technology after bedtime, 19% reported 'sometimes', 16% 'often' and 55% 'almost always'. In the control group, 18% reported 'never' using technology after bedtime, 26% reported 'sometimes', 18% 'often' and 37% 'almost always'. There was a significant effect of the intervention on technology use at bedtime, although in the opposite direction to that expected. That is, adolescents who participated in the sleep classes were 2.2 times more likely to report using technology use after bedtime as compared to

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TABLE 3 Primary outcome: multinominal logistic regression and linear regression for intervention condition predicting follow-up sleep group/duration

	Sleep duration in hours		Sleep duration in categories			
				OR (95% CI)		
	n = 2,388	Mean difference (95% CI)	n = 2,388	≥8 hr	7–8 hr	<7 hr
Model 1						
Intervention						
No	–	REF	2,269	REF	REF	REF
Yes	–	0.17 (0.00; 0.34)	119	REF	0.76 (0.49; 1.18)	0.52 (0.28; 0.98)
Baseline sleep		0.49 (0.46; 0.53)		REF	2.6 (2.3; 3.1)	6.1 (5.1; 7.3)
Model 2						
Intervention						
No	–	REF	2,215	REF	REF	REF
Yes	–	0.25 (0.07; 43)	109	REF	0.60 (0.38; 0.94)	0.41 (0.21; 0.78)
Baseline sleep		0.46 (0.43; 0.50)		REF	2.41 (2.07; 2.81)	5.44 (4.52; 6.54)
Gender (girl)		0.20 (0.13; 0.28)		REF	1.59 (1.31; 1.93)	1.80 (1.38; 2.33)
Age		−0.04 (−0.10; 0.02)		REF	1.27 (1.09; 1.47)	1.16 (0.95; 1.42)
Swedish ethnicity		0.01 (−0.03; 0.06)		REF	1.31 (1.02; 1.68)	0.94 (0.68; 1.28)
Living with both parents		−0.09 (−0.18; −0.01)		REF	0.90 (0.72; 1.13)	0.94 (0.68; 1.28)

Note: Model 1: adjusted for baseline sleep duration. Model 2: adjusted for baseline sleep duration and potential confounders (age, gender, parents' country of birth and family situation). Betas are derived from linear regression models and odds ratios are derived from multinominal logistic regression models with sleep duration > 8 hr as reference category.
Abbreviations: CI, confidence interval; OR, odds ratio.
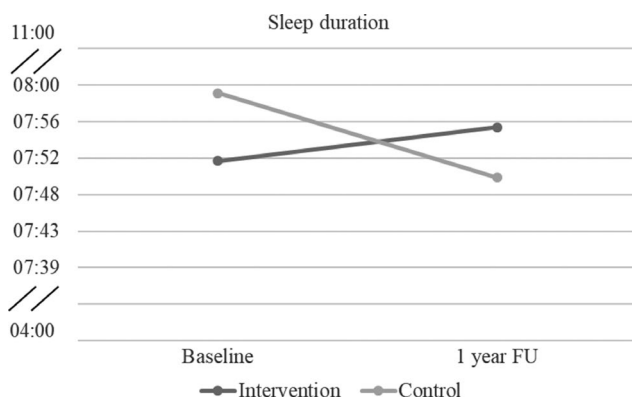
FIGURE 3 Average sleep duration (hr:min) for the intervention group versus the natural control group from baseline to 1-year follow-up (not controlling for confounders)

the control group, even after controlling for baseline technology use and sociodemographic confounders.

3.2 | Intervention group

3.2.1 | Sleep knowledge

Sleep knowledge increased significantly from pre- to post-test (F (1, 146) 67.81, $p < .001$, $\eta_p^2 = 0.428$) and was maintained at follow-up

(mean difference = 0.007 (0.18), confidence interval [CI] −0.427, 0.441, $p = 1.0$) (see Figure 5).

3.2.2 | Programme feedback

During the fifth and final session, adolescents in the intervention group answered some qualitative questions about the intervention, including whether the intervention was useful (31% 'yes', 43% 'partly', 18% 'maybe', 8% 'no') and interesting (11% 'no', 43% 'a little', 37% 'quite', 9% 'very') and if they had subsequently used any of the strategies (e.g., time management, mobile-free homework, etc.) (11.5% = 0, 43.1% = 1, 28.7% = 2, 8.6% = 3, 6.2% = 4, 1.9% = 5 strategies). In the risk group (<7 hr/night), 25% reported using more than two of the strategies they had learned, compared to 15.7% and 12.2% of adequate and borderline sleepers, respectively.

4 | DISCUSSION

This is the first study to our knowledge to evaluate the preventive effects of a school-based sleep intervention over 1 year using a large natural control group.

The results showed that sleep duration increased in the intervention group and decreased in the natural control group, controlling for baseline differences. This represents a potential

TABLE 4 Movements between groups in the Youth Enhanced Sleep (YES) intervention versus the natural control group from baseline to 1-year follow-up

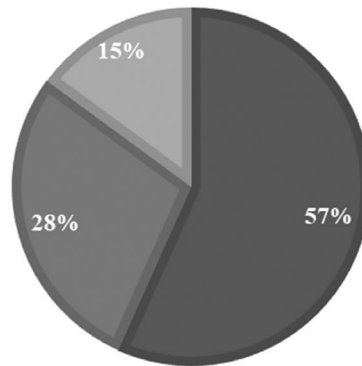|			Follow-up YES group			Follow-up control group		
			Adequate (8–10 hr)	Borderline (7–8 hr)	Insufficient (<7 hr)	Adequate (8–10 hr)	Borderline (7–8 hr)	Insufficient (<7 hr)
Baseline	Adequate (8–10 hr)	n	41	16	1	873	346	95
		%	70.7%	27.6%	1.7%	66.4%	26.3%	7.2%
	Borderline (7–8 hr)	n	16	17	7	208	293	139
		%	40.0%	42.5%	17.5%	32.5%	45.8%	21.7%
	Insufficient (<7 hr)	n	8	5	8	49	107	159
		%	38.1%	23.8%	38.1%	15.6%	34.0%	50.5%
Total		n	65	38	16	1,130	746	393
		%	54.6%	31.9%	13.4%	49.8%	32.9%	17.3%
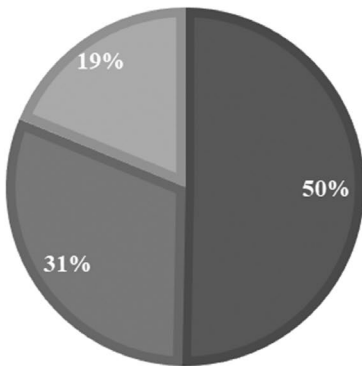
FIGURE 4 Sleep duration subgroups in the intervention group versus control group at baseline and 1-year follow-up (not controlling for confounders)
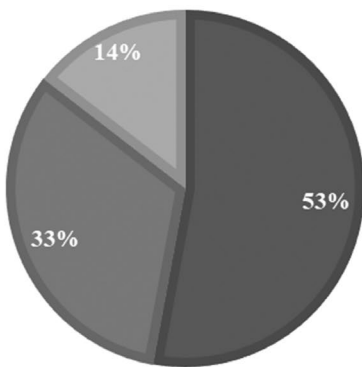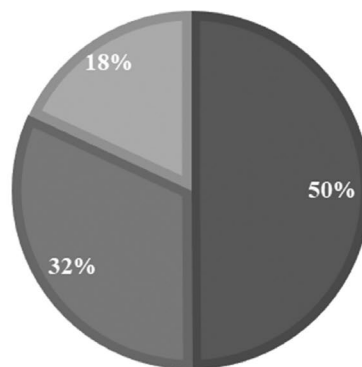
preventive effect of the intervention, showing that adolescents who participated in the sleep classes did not display the same negative trend in sleep duration as a large population of adolescents. A reduction in sleep duration over the course of adolescence has been shown in several studies as the natural pattern (Colrain & Baker, 2011). Furthermore, when looking at subgroups according to the recommended sleep duration (Hirshkowitz et al., 2015), adolescents who participated in the sleep programme were about two times less likely to be categorized as 'borderline' and 'insufficient' sleepers at follow-up. This suggests that the intervention prevents a significant proportion of adolescents from maintaining or developing a sleep deficit 1 year later.

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TABLE 5 Secondary outcomes: regression for intervention condition predicting follow-up stress, sleep hygiene and technology use after bedtime

	Stress score (per 1-unit increase)		Sleep hygiene (behavioural) (per 1-unit increase)		Sleep hygiene (cognitive-emotional) (per 1-unit increase)		High technology use after bedtime	
	n = 2,626	Mean difference (95% CI)	*n* = 2,654	Mean difference (95% CI)	*n* = 2,650	Mean difference (95% CI)	*n* = 2,573	OR (95% CI)
Model 1								
Intervention								
No	–	REF	–	REF	–	REF	–	REF
Yes	–	0.01 (−0.08; 0.09)	–	−0.19 (−0.36; −0.01)		0.05 (−0.08; 0.19)		2.15 (1.49; 3.12)
Model 2								
Intervention								
No	–	REF	–	REF	–	REF	–	REF
Yes	–	−0.01 (−0.10; 0.08)	–	−0.18 (−0.36; −0.00)	–	0.10 (0.03; −0.24)	–	2.20 (1.49; 3.25)

Note: Model 1: adjusted for baseline score. Model 2: adjusted for baseline score and potential confounders (age, gender, parents' country of birth and family situation). Betas are derived from linear regression models and odds ratios are derived from multinominal logistic regression models. Abbreviations: CI, confidence interval; OR, odds ratio.
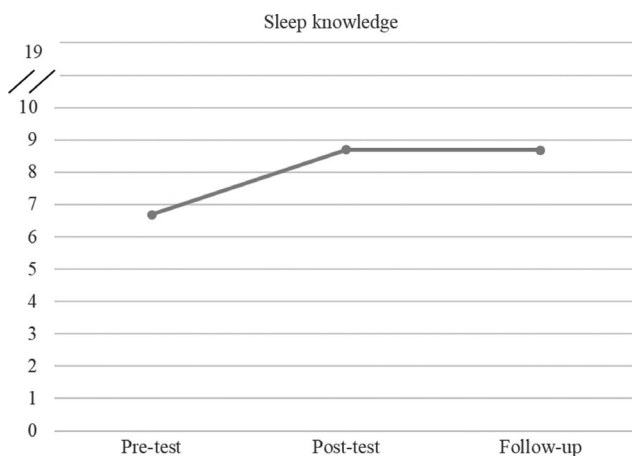
FIGURE 5 Changes in sleep knowledge from pre-test to follow-up in the intervention group

More specifically, we hypothesized that adolescents who reported sleeping 7 hr or less would improve their sleep duration after the intervention, whereas adolescents who reported sufficient sleep duration would maintain their sleep to a larger extent as compared to a natural control group. Looking at subgroup movements from baseline to follow-up, our data support this idea. However, according to the prevention paradox (Rose, 2001), universal interventions are most effective for the larger non-risk group because they prevent the development of problems over time. In this study, a larger proportion of at-risk adolescents in the intervention group (38%) moved from insufficient sleep duration to the recommended 8–10 hr of sleep. In contrast, in the natural control group only 16% of at-risk adolescents moved on to sufficient sleep and 50% maintained insufficient sleep duration after 1 year. These results are in line with previous studies showing that adolescents at risk (i.e., displaying a significantly delayed sleep–wake phase) benefit the most from school-based sleep programmes (Bonnar et al., 2015). This

raises the question of whether targeting risk groups would be more cost-effective than implementing universal interventions. Although healthy sleep appears to be stable for a large number of adolescents (Magee, Lee, & Vella, 2014), it might be difficult to identify who will develop sleep problems over time. Knowledge of risk and protective factors is not yet exhaustive (Bartel et al., 2015). Thus, further studies examining predictors of stability and change in adolescents' sleep disturbances and evaluating the long-term effects of preventive interventions are needed.

Only a few school-based sleep interventions have previously shown changes in adolescents' sleep duration (e.g., Bonnar et al., 2015), often not maintained at follow-up (e.g., Rigney et al., 2015). This is the first study to show positive long-term effects of a universal sleep programme. These different results might be due to the design of the study (i.e., including a 1-year follow-up), which allows observation of sleep patterns over an extended time period.

Nevertheless, the content of the YES Programme was different from that of earlier programmes (e.g., targeting ICT and teaching time-management skills), building on experiences from other studies. Because a package of techniques was used, the mechanisms through which the sleep intervention works are less clear. No improvements were observed for sleep hygiene, perceived stress and technology use. However, adolescents who participated in the intervention showed a significant increase in sleep knowledge, which has been positively affected by most sleep interventions but has not necessarily led to behavioural changes (see Cassoff et al., 2013). One interesting question is whether sleep knowledge itself would be enough to produce long-term benefits or whether a skills-teaching component is needed to impact adolescents' sleep trajectories. For example, one large-scale study found that adolescents who improved their sleep knowledge the most also showed a larger decrease in insomnia symptoms following the intervention (Wing et al., 2015). This is an important question as schools do not have unlimited time or resources and cost-effective programmes are needed.

The significant increase in ICT use at bedtime in the intervention group, as compared to the control group, was a change in the opposite direction to that expected. Some studies indicate that adolescents might use more ICT over time (Twenge, Martin, & Spitzberg, 2018). However, this increase was larger than in the control group. Perhaps talking about ICT use in the classroom leads to an increased use as a consequence of 'peer contagion' (Dishion & Dodge, 2005). This finding is in line with the decrease in behavioural sleep hygiene, indicating that adolescents reported engaging more in bedtime activities that made them feel awake after the intervention (although still in the expected range for this age group; see Storfer-Isser et al., 2013). These negative results make the improvement in sleep duration observed in the intervention group difficult to interpret. However, one possible explanation is that adolescents in the intervention group became more aware of their bedtime behaviours (e.g., technology use) after the programme and thus reported worse sleep hygiene, which was already lower than that of the controls at the start. One recent study (Bartel, Scheeren, & Gradisar, 2018) targeted specifically the reduction of phone use at bedtime and found that during the phone-restriction week, adolescents reported earlier lights-off times (with the intention to sleep) and 20 min longer sleep duration. However, the participation rate was low, indicating that adolescents are reluctant to modify their screen habits in the evening (Bartel et al., 2018). Therefore, the question is whether it is possible to achieve a mobile-free bedtime or whether it is better to teach adolescents sleep-friendly technology time. To conclude, further studies exploring sleep interventions' mechanisms of change are needed.

This study has both strengths and limitations. The main limitation is that participants were not randomized to the control or intervention condition, which should be taken into account when interpreting the results. That is, it is impossible to ascertain that the improvements in sleep are due to the intervention and not to characteristics specific to the two schools that were chosen for the programme. As noted in Table 1, YES participants were slightly older and more likely to be female, which have been found to be risk factors for shorter sleep duration (e.g., Maslowsky & Ozer, 2014). Moreover, these characteristics can be a proxy for later pubertal status, which has been linked to later sleep phase and shorter sleep duration (Carskadon & Acebo, 2002). Controlling for pubertal status would have strengthened the results of the study by excluding a possible explanatory variable for sleep changes over time. However, to counterbalance the risk of bias, a natural control group is likely to represent normal development and a similar sleep decline (4–16 min) has been shown in several studies observing the natural trends of adolescents' sleep duration over 1 year (Maslowsky & Ozer, 2014; Park et al., 2019; Patte, Qian, & Leatherdale, 2017). Another potential difference is that the intervention group data (post-test) were consistently collected at the end of the spring term, thus during longer days (i.e., more daylight) in Sweden, whereas the control group data were collected throughout the term, thus including more variation from short- to long-day months. Shorter day length has been found to be associated with slightly shorter sleep duration in adolescents in one study (Bartel et al., 2017) and with longer sleep in another (Figueiro

& Rea, 2010). Therefore, it is unclear whether and in what direction seasonal changes may have affected our results. Although it might seem counterintuitive that the intervention group's sleep duration did not increase as much as the control's at baseline, comparing the prevalence of sufficient sleep duration (ranging from 27% to 50%) reported in other studies suggests a potential preventive effect of the intervention (Gradisar et al., 2011; Keyes, Maslowsky, Hamilton, & Schulenberg, 2015; Park et al., 2019; Patte et al., 2017; Wheaton, Jones, Cooper, & Croft, 2018).

Another issue that should be taken into account is that it is difficult to control for response biases in the sleep measures because we solely relied upon self-report measures and not objective measures (e.g., actigraphy). One of the problems is to ascertain that adolescents report actual sleep onset latency rather than time spent, for instance, using technological devices (see Excelmans & Van den Bulck, 2017). Yet, adolescents' self-reports have been validated against objective sleep measures and found to be reliable (Short et al., 2012; Wolfson et al., 2003). Moreover, the sleep duration measure used is a composite score of several items (i.e., bedtime, sleep onset latency and wake time), which is likely to be more accurate than a single item (Wolfson et al., 2003). One potential reason for a difference in sleep estimation between the intervention group and control group might have been the framing of the questions at baseline (i.e., referring to a specific night versus average). This could explain why the intervention group showed shorter sleep at baseline (for example if a special event occurred during the first two weeks of data collection).

The main strength of the study is the large natural control because it allowed us to compare the intervention group to normal developmental trends in sleep duration, including enough variation to probably mirror that of a representative adolescent population. The other main strength of the study is the 1-year follow-up, which provided a unique insight into the long-term effects of a school-based sleep intervention. This allowed us to evaluate the preventive effect of the intervention and highlights the need for further research to look into the most cost-effective way of preventing sleep problems (e.g., Is sleep education enough?). Finally, another advantage with the present study is the large sample, making subgroup analyses possible. These observations shift the focus from 'mean changes' in sleep duration to the importance of both maintaining adequate sleep duration in the majority of adolescents and improving it in a smaller risk group. The present study is therefore redefining what outcomes are of importance when evaluating the preventive effects of school-based programmes, in line with the suggestions made by a recent review of sleep programmes (Blunden, 2017).

School-based interventions have shown small or no changes in adolescents' sleep in the short term (Blunden, 2017; Cassoff et al., 2013) but this study showed a potential preventive effect, which has not been investigated before. Although further studies are needed to confirm long-term effects of similar interventions and to understand the mechanisms of change, the positive trend in sleep duration in adolescents who participated in the intervention is promising. That is, an increase in sleep duration in the intervention group as compared

to a large representative population not receiving the intervention suggests that promoting sleep health in youths is indeed possible.

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CONFLICT OF INTEREST

None of the authors of this paper (SB, IF, KB and SJL) has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

AUTHOR CONTRIBUTIONS

SB, SJL and IF conceived the study and the intervention; IKF, SJL and KB supervised the study; SB analysed data; SB wrote the manuscript; KB, IF and SJL made manuscript revisions.

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