


# Effect Evaluation of a School-Based Intervention Promoting Sleep in Adolescents: A Cluster-Randomized Controlled Trial

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## ABSTRACT

**BACKGROUND:** This study evaluated the effect of the school-based intervention Charge Your Brainzzz on adolescents' social-cognitive determinants, sleep hygiene and sleep duration and quality.

**METHODS:** A cluster-randomized controlled trial was conducted with 972 students from 10 Dutch high schools. Schools were randomly allocated to the intervention (N = 5) or control condition (N = 5). Outcomes were measured with the digital Consensus Sleep Diary and via a digital questionnaire, based on valid measures. Data were collected at baseline (T<sub>0</sub>), ±1.5 weeks post-intervention (T<sub>1</sub>) and ±3 months post-intervention (T<sub>2</sub>). Mixed model analyses were performed to estimate the effects on social-cognitive determinants, sleep hygiene, and sleep outcomes.

**RESULTS:** The intervention increased sleep knowledge post-intervention ( $b = 1.91$ ; 95%CI: 1.22-2.60) and at follow up ( $b = 1.40$ ; 95%CI: 0.70-2.10). The intervention was also effective in changing adolescents' attitudes ( $b = 0.10$ ; 95%CI: 0.01-0.19) and perceived behavioral control ( $b = 0.11$ ; 95%CI: 0.01-0.22) post-intervention. No positive changes were found regarding subjective norms, behavioral intentions, sleep hygiene, or sleep outcomes.

**CONCLUSIONS:** The intervention improved adolescents' sleep knowledge, attitude, and perceived behavioral control. To significantly impact sleep health, theoretically sound and systematically developed interventions are needed which take into account the interplay between sleep, sleep-related behaviors, and adolescents' social and physical environment.

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**Keywords:** sleep; school-based intervention; adolescents; health behavior; randomized controlled trial.

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Healthy sleep is defined as sleeping sufficiently, having a good sleep quality and the absence of daytime sleepiness.<sup>1</sup> In addition, it comprises sleep efficiency (ie, the ease of falling asleep and returning to sleep) and appropriate sleep timing (ie, regularity of bed times). Good sleep health is vital for adolescents' learning abilities and school performance,<sup>2</sup> their

mental and physical health, and a lack thereof increases their chances to develop depression and obesity.<sup>3</sup> Thus, healthy sleep habits play a crucial role in adolescent development, with lifelong impact on various health and social outcomes.<sup>1,4</sup> Unfortunately, many studies report a decrease in adolescents' sleep duration and quality, with many adolescents not

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obtaining their recommended 8-10 hours (ie, for 14-17 year olds) or 9-11 hours of sleep per night (ie, for 6-13 year olds).<sup>5-7</sup> In the Netherlands, more than half of adolescents sleep almost an hour less than recommended.<sup>5,8</sup> Also, 44% of adolescents report not waking up fully rested and experience more sleepiness compared to any other age group.<sup>5,8</sup> Given these developments and the detrimental consequences of unhealthy sleep, promoting sleep health is increasingly seen as a serious public health priority.<sup>7,9</sup>

The decline in sleep quantity and quality during adolescence is a complex, multifactorial process that can partly be explained by biological changes<sup>10,11</sup> as a shift in circadian rhythm results in a preference for late morning and late day activities and later bedtimes.<sup>11</sup> Further adding to their sleep deprivation are psychosocial factors such as academic pressure, and decreased parental supervision regarding bedtime and screen time.<sup>4,11,12</sup> Factors which aid upholding healthy sleep habits, yet which undergo changes during adolescence, are called sleep hygiene practices (eg, having a regular sleep schedule, a supporting environment, sufficient daylight during the day and limited use of electronic screens before bedtime).<sup>9,10</sup>

Given the importance of many such changeable determinants, taking preventive action to stimulate adolescents' healthy sleep habits seems promising. Schools might be an appropriate setting for such actions, since school-based interventions have been shown to be beneficial in aiding to promote other health-related behaviors, such as physical activity and dietary behaviors.<sup>13</sup> Despite the potential outreach to youth to positively contribute to adolescents' sleep habits, current school health curricula in the Netherlands devote no structural attention to the subject of sleep.<sup>5</sup> Existing school-based programs on sleep vary widely in their quality, aims, design, and implementation success.<sup>14-16</sup> They demonstrate mixed effects in terms of outcomes on sleep health, sleep knowledge, and sleep-related outcomes.<sup>14,15</sup> Several programs effectively improved sleep knowledge, but improvement of sleep outcomes is limited.<sup>17,18</sup> As indications of the limited effects, reviews identified methodological shortcomings such as small sample sizes, lack of follow-up measures, and a lack of theoretical underpinnings of the intervention.<sup>16,17</sup>

Using theory when developing and evaluating sleep interventions is not yet self-evident, despite its importance.<sup>17,19-21</sup> Theoretical development of sleep interventions is often lacking which complicates adequate intervention evaluation and identification of working mechanisms. Also, evaluation studies often only report on the sleep outcome(s) of interest whereas analyzing effects on social-cognitive determinants will provide an understanding of what works for a specific behavior and population.<sup>17</sup> A theory that is widely used in other health behavior interventions for

evaluating social-cognitive determinants is the Theory of Planned Behavior (TPB).<sup>22</sup> It presumes that health behavior is predicted by the intention to perform a certain behavior and consecutively determined by the social-cognitive determinants including attitude, subjective norm, perceived behavioral control.<sup>22</sup> To alter most of these determinants, knowledge is an essential, although not sufficient, prerequisite.<sup>19</sup> Consequently, these social-cognitive determinants should be targeted in interventions and the evaluation of interventions aiming at behavioral change.

In the Netherlands no school-based intervention currently exists that focuses on adolescent sleep health.<sup>5</sup> Given the potential of school-based interventions in general and the lack of evidence-based programs regarding the topic of sleep, the Dutch Brain Foundation Netherlands and Chrono@Work developed the educational intervention "Charge Your Brainzzz" (CYB) to stimulate adolescents' healthy sleep habits. The current study aims to evaluate the intervention which includes effects of CYB on adolescents' social-cognitive determinants, sleep hygiene and sleep duration, and quality.

## METHODS

A cluster-randomized controlled trial was conducted to evaluate the effects of the Charge Your Brainzzz intervention (Box 1).

### Box 1. Description of the Intervention

#### Charge Your Brainzzz

Charge Your Brainzzz (CYB) ([www.chargeyourbrainzzz.nl](http://www.chargeyourbrainzzz.nl)) is comprised of three 45-minute classroom-based education sessions with interactive assignments and a supporting educational website. Accompanying homework includes a serious game and an assignment for students and their parents. CYB is delivered by high school teachers and fits the Dutch high school biology curriculum (year 2/3, age 13-15). The program contains exercises of varying difficulty levels as it was tailored to fit different educational levels. The content and the learning objectives were similar for both versions of the intervention. CYB informs students on the importance of good sleep health, the biological clock, and sleep-wake rhythms. It also teaches students how to evaluate their own sleep habits and—if needed—improve upon their sleep hygiene. CYB targets students' knowledge, awareness, attitudes, subjective norms, and perceived behavioral control to stimulate healthy sleep, of which most are determinants of the Theory of Planned Behavior.

The theoretical foundation of the intervention, including determinants and theoretical methods, is based on the taxonomy of behavior change methods, following the Intervention Mapping Framework.<sup>19,33</sup> This framework is a protocol for developing theory-based and evidence-based health promotion programs. The applied theoretical methods and practical strategies can be found in [Appendix 1](#).

### Recruitment and Participants

Given the content of CYB, second- and third-grade students from all regular Dutch educational levels were eligible to participate. High schools were recruited by using several recruitment strategies. First, schools were asked to participate when they subscribed to the intervention on the online portal of CYB. Second, Municipal Health Services ( $N = 4$ ) actively promoted the study among their network of schools, in part via their Healthy School Advisors. Furthermore, the study was promoted among biology teachers via an online platform and a magazine for professionals. Schools that agreed on participation invited their second- and third-grade students (generally between 13 and 15 years old) for the study, by providing students and their parents or caretakers an information letter about the study. Active written consent from students and their parents or caretakers was requested prior to their enrollment in the study. The CONSORT flow diagram including the procedure of the study, the enrollment and follow-up of schools and students, is shown in [Figure 1](#).

### Allocation

Eligible schools were allocated at random to the intervention or control group based on educational level and the number of participating classes within a school to increase the similarity of the intervention and control group. The randomization was performed by an independent statistician at the Vrije Universiteit Amsterdam. Twelve schools were randomized into the intervention or control group. After allocation 2 schools withdrew from the study, resulting in 10 participating schools. The intervention group (5 schools; 32 classes) implemented CYB during the school year 2018-2019, and the control group (5 schools; 27 classes) could implement it after the research period (ie, wait-list control).

### Procedure

CYB was implemented at the intervention schools from September to November 2018. Teachers who participated with their class were either biology teachers or mentors of that class. Well before the start of the study teachers in the intervention group

received the CYB package, which consisted of the program, materials, and a teacher manual. By design, no formal teacher training was required. However, teachers could contact the principal researcher (MI) to offer clarification of the CYB program if they wished. Both intervention and control schools conducted 3 surveys in the period September 2018 to January 2019: baseline, post-intervention ( $\pm 1.5$  week post-intervention; direct effect) and follow-up ( $\pm 3$  months post-intervention; sustained effect). The moment of implementing the intervention and conducting the 3 surveys varied between the intervention schools due to scheduling differences. For all 3 measurements, students received a web link via their school. They completed a questionnaire and recorded the first day of a 7-day sleep diary on an electronic device. The 6 remaining days of the online sleep diary were recorded at school where possible or at home. One lesson (approximately 45 min) was used to complete each measurement. Classes could win an excursion by participating in the study. In addition to measurement of intervention outcomes, the implementation of the intervention was measured by interviewing the participating teachers and by a short questionnaire for the intervention group based on theoretical frameworks on implementation. The results of the implementation study will be described elsewhere.

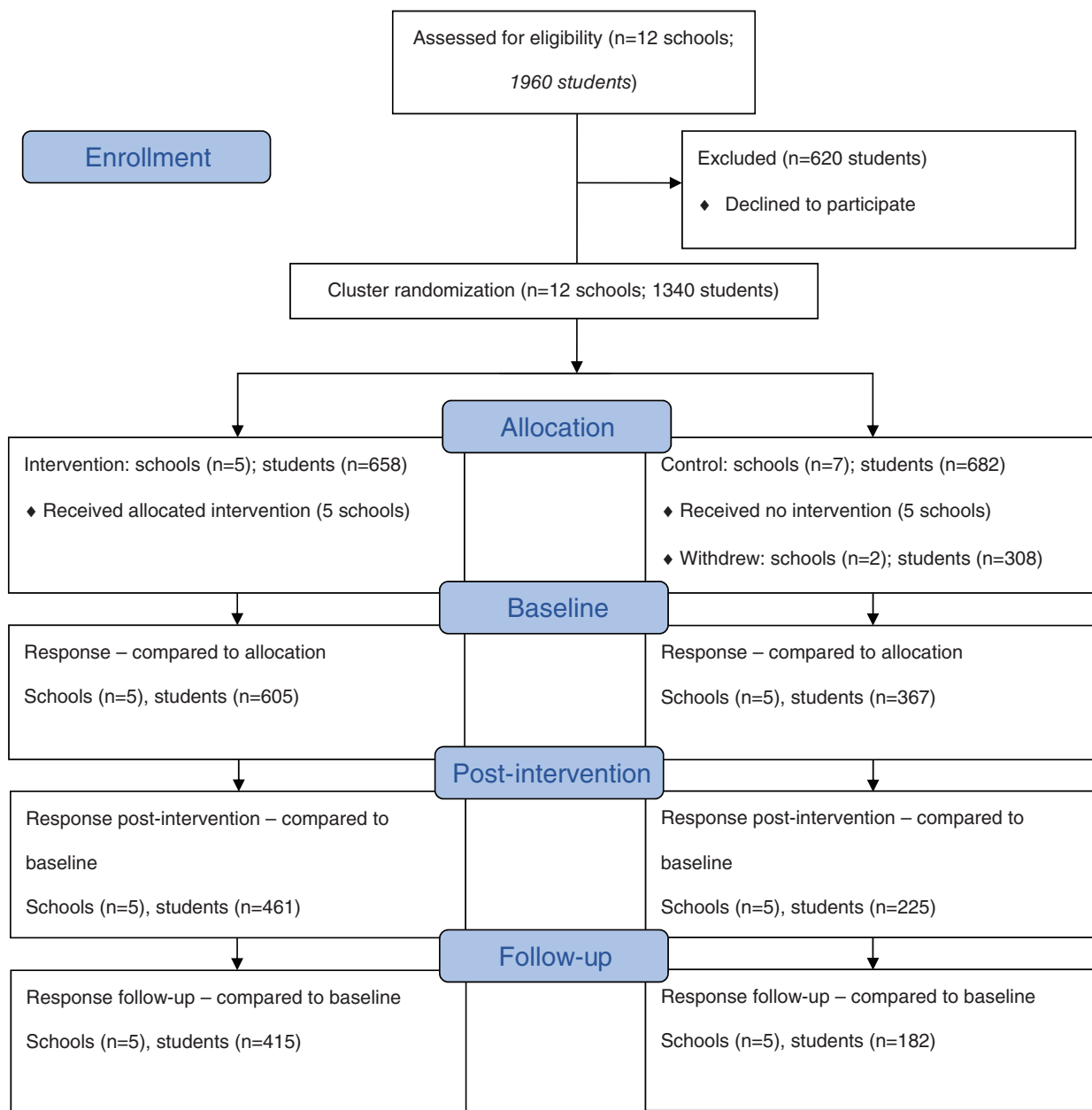
### Sample Size

A power analysis determined a sample size of 750 was needed based on an effect size of 0.25 in order to determine a minimal improvement of 10 minutes of sleep per night as an intervention effect, a SD of 0.66, an intra-cluster correlation coefficient (ICC) of 0.10 and a significance level ( $\alpha$ ) of 0.05. Taking into account a potential drop-out rate of 50%, 1500 students should participate at baseline to have a sufficiently large study population.

### Instruments

**Demographics.** The questionnaire contained questions on age, gender, perceived cultural group, educational level, and grade. To indicate their perceived cultural group, participants could give multiple answers. Based on the definition of Statistics Netherlands,<sup>23</sup> perceived cultural group was divided into 3 groups for the analyses: Native Dutch, Non-native/Western, and Non-native/Non-Western. In the case of multiple answers, participants were categorized into the group “mixed” (eg, Dutch and Moroccan was categorized as mixed) and Native Dutch was used as the reference group in the analyses. As the intervention offers 1 version for Lower General Secondary Education (VMBO) and 1 version for Higher General Secondary and pre-university education (HAVO/VWO), these

Figure 1. CONSORT Flow Diagram of the Study



2 categories were used for educational level in the analyses.

**Social-cognitive determinants.**

*Knowledge.* Adolescents’ knowledge of sleep was measured with 10 statements based on the content of the CYB intervention. The statements covered topics such as the importance and function of sleep and sleep hygiene practices, eg, “Due to sleep deprivation you have more risk of becoming overweight” and “People of your age need an average of 6-7 hours of sleep per night.” A total knowledge score was created by summing up all correct answers (range

0-10). Psychometric properties of this questionnaire were not assessed.

*Attitude, subjective norm, perceived behavior control, and intention.* Social-cognitive determinants were assessed based on Fishbein and Ajzen’s theories and standard formulations for measuring constructs of the Theory of Planned Behavior.<sup>24</sup> Measurement of each social-cognitive determinant consisted of 4 items, with 1 item regarding each sleep health domain (ie, duration, timing, efficiency and quality). For example: attitudes toward having a regular bedtime (eg, “For me, going to bed around the same time every night



is...”), subjective norms regarding regular bedtimes (eg, “My parents want me to go to bed around the same time every night”), perceived behavioral control towards regular bed timing (eg, “I intend going to bed around the same time every night”). Items could be answered on a 5-point Likert scale ranging from  $-2$  to  $+2$  on importance, agreement, and difficulty. For each determinant (ie, attitude, subjective norm, perceived behavioral control, intention) a mean score was created from the 4 items related to the sleep health dimensions (ie, sleep duration, sleep timing, sleep efficiency and sleep quality). A higher score indicated a better score. Internal consistency for each determinant on each time point as checked with Cronbach alpha was sufficient.<sup>25</sup>

**Sleep hygiene.** Adolescents’ sleep hygiene questions were based on the validated Adolescent Sleep Hygiene Scale (ASHS).<sup>26</sup> The original instrument assesses sleep hygiene practices in adolescents on 28 items along 9 different sleep domains (eg, daytime sleepiness and bedtime routines).<sup>26</sup> Based on the pre-test study (see below), small adaptations to the ASHS were made. The item “I go to bed with a stomach-ache” was changed into “I go to bed with cold feet and/or hands” and the item “I check my clock several times during the night” was changed into “I check my phone several times during the night.” Furthermore, the item “I take my phone to my bedroom” was added and as the pre-test study indicated that the 4 items of the domain “sleep stability” were difficult to understand, those items were excluded from the questionnaire. Participants reported sleep hygiene on 24 items along a 5-point Likert scale ranging from never = 0 to always = 4, whereas the original instrument used a 7-point scale ranging from never = 0 to always = 6. Internal consistency of sleep hygiene as checked with Cronbach alpha was  $\alpha = 0.76$  at baseline,  $\alpha = 0.81$  at post-intervention and  $\alpha = 0.80$  at follow-up. A mean score was created of the 24 items in which a higher score indicated better sleep hygiene.

**Sleep outcomes.** Sleep duration and sleep quality were measured via the validated 7-day Consensus Sleep Diary (CSD).<sup>27</sup> Sleep duration was determined as the difference between the time participants tried to go to sleep and their wake time. Sleep quality was measured with the question “How would you rate the quality of your sleep last night?” which is part of the CSD, and the additional question “How do you feel when getting up this morning?” Both questions were scored on a 5-point Likert scale ranging from “very bad” ( $-2$  points) to “very good” ( $+2$  points) and from “not rested at all” ( $-2$  points) to “totally rested” ( $+2$  points). A mean score per night was calculated from both items, in which a higher score indicated a better sleep quality. All participants with data on either sleep duration or sleep quality were included in the analyses.

**Pre-test of measures.** The comprehensibility, relevance, and completeness of the questionnaire and the feasibility of the study procedures were tested via a pre-test study. In a focus group with students ( $N = 4$ ), the questionnaire and the sleep diary were tested on comprehensibility, relevance, and completeness by addressing relevant themes from the literature. The instruments were adjusted accordingly and then tested again by interviewing other students ( $N = 3$ ) until no further changes were needed. Via telephone interviews with teachers from participating schools ( $N = 11$ ) study procedures were discussed and adjusted based on their feedback.

## Data Analysis

After reporting descriptive statistics on the baseline study sample (ie, age, gender, perceived cultural group, educational level, grade), a series of linear mixed model analyses were performed to estimate the intervention effect on adolescents’ sleep duration, sleep quality, sleep hygiene, and social-cognitive determinants of sleep health. The (1) overall effects (post-intervention and follow-up); (2) post-intervention effects; and (3) follow-up effects of the intervention were assessed. Mixed models were used to best handle missing data in a flexible and robust manner, and account for the dependency of the repeated observations within the participants.<sup>28</sup> Participants that provided baseline data were included in the analyses. The data was tested for possible clustering on adolescent and school level, but only correcting for clustering on adolescent-level was required.

All analyses were adjusted for the baseline value of a particular outcome (longitudinal analysis of covariance).<sup>29</sup> The research condition (intervention or control group) was the independent variable in all analyses. To assess the effect per follow-up moment, time was added to the model, as well as a time-by-research condition interaction. Crude models were constructed first. Next, adjusted models were constructed, correcting for the potential confounders age, gender, perceived cultural group, educational level, and grade. For all analyses, a 2-tailed significance level of 0.05 was used. Mixed model analyses were performed using StataSE 14.

## RESULTS

### Study Population and Mean Scores of Sleep Outcomes, Sleep Hygiene, and Social-Cognitive Determinants (T0, T1, T2)

A total of 972 second and third-grade adolescents from 10 schools participated in the study, whereas a target population of 750 students was determined by the sample size calculation. As shown in Table 1 the intervention group consisted of 605 adolescents

**Table 1. Characteristics of the Study Population, Based on Filled in Questionnaires (N = 972)**

	Intervention (n = 605)				Control (n = 367)			
	N	%	Mean	SD	N	%	Mean	SD
Age			13.4	0.76			13.2	0.64
Gender								
Boys	247	40.8			194	52.9		
Girls	358	59.2			173	47.1		
Perceived cultural group								
Native Dutch	501	82.8			315	85.8		
Non-native/non-Western	17	2.8			6	1.6		
Non-native/Western	3	0.5			4	1.1		
Mixed	82	13.6			42	11.4		
Educational level								
Lower general secondary education	187	30.9			80	21.8		
Higher general secondary education/pre-university education	418	69.1			287	78.2		
Grade								
Grade 2	327	54.0			309	84.2		
Grade 3	278	46.0			58	15.8		

\*Statistically significant difference between groups.

and the control group of 367 adolescents. There were some imbalances in participant characteristics between study arms at baseline. When compared to the control group, participants in the intervention group were generally older (13.4 years vs 13.2 years), more likely to be female (59.2% vs 47.1%) and lower educated (69.1% vs 78.2% higher educational level). The intervention and control group mostly consisted of students in second grade (intervention: 54.0% and control 84.2%). The distribution of perceived cultural group was comparable in both groups.

Table 2 shows descriptive information for the 2 groups on social-cognitive determinants, sleep hygiene, and sleep outcomes at baseline (T0), post-intervention (T1), and at follow-up (T2). Sleep knowledge at T0 was comparable between the intervention and control group (5.82 vs 5.66) but increased for the intervention group at T1 (7.80 vs 5.81) and at T2 (7.34 vs 5.90). Also for attitude both groups were comparable at T0 (intervention: 0.71 and control: 0.68) whereas this increased in the intervention group at T1 (0.76 vs 0.65) and decreased for both groups at T2 (intervention: 0.67 and control: 0.59). On average, the control group had somewhat longer sleep duration than the intervention group (540.71 vs 528.43 minutes) and in both groups this reduced after baseline (intervention T1: 527.03 minutes, T2: 510.37 minutes; control T1: 534.73 minutes, T2: 539.33 minutes).

### Effectiveness of the Charge Your Brainzzz Intervention on Social-Cognitive Determinants, Sleep Hygiene, and Sleep Outcomes

As shown in Table 3 the intervention group's scores on sleep knowledge improved from T0 to T2, compared to the controls ( $b = 1.69$ ; 95%CI: 0.99-2.39). This

difference was larger post-intervention (T1 vs T0;  $b = 1.91$ , 95%CI: 1.22-2.60) than at longer term (T2 vs T0;  $b = 1.40$ , 95%CI: 0.70-2.10), yet overall changes in sleep knowledge were still significant. This was different regarding changes in attitude, which showed significant changes post-intervention (T1 vs T0;  $b = 0.10$ ; 95%CI: 0.01-0.19) yet not overall (T0 to T2). Overall, perceived behavioral control did change positively in comparison to the controls (T0 to T2;  $b = 0.10$ , 95%CI: 0.01-0.18) yet this effect was not sustained at follow-up (T2 vs T0). The intervention did not result in significant changes in sleep hygiene, subjective norm and intention between intervention group participants and controls. Overall, the sleep duration of the intervention group did not positively change compared to the controls. Moreover, the intervention group even reported a somewhat shorter sleep duration at follow-up (T2 vs T0;  $b = -21.16$ ; 95%CI:  $-31.89$  to  $-10.44$ ). No significant effects were found regarding sleep quality as a result of the intervention.

### DISCUSSION

This study evaluated the effects of the school-based intervention Charge Your Brainzzz (CYB) on social-cognitive determinants, sleep hygiene and sleep duration and sleep quality. Overall, CYB increased adolescents' sleep knowledge and their perceived behavioral control regarding healthy sleep post-intervention and at later follow-up. CYB also impacted adolescents' positive attitudes towards healthy sleep practices post-intervention. CYB did not positively affect sleep quality and a somewhat shorter sleep duration in the intervention group compared to the controls was found. Adolescents' sleep hygiene, subjective norm, and behavioral intentions to obtain

**Table 2. Means of Social-Cognitive Determinants, Sleep Hygiene, and Sleep Outcomes at Baseline, Post-Intervention, and Follow-Up**

	T0 (Baseline)		T1 (Post-Intervention)		T2 (Follow-Up)	
	Mean	SD	Mean	SD	Mean	SD
Knowledge (0-10)						
Intervention	5.82	1.92	7.80	1.86	7.34	2.05
Control	5.66	1.85	5.81	2.20	5.90	2.09
Attitude						
Intervention	0.71	0.62	0.76	0.60	0.67	0.64
Control	0.68	0.61	0.65	0.67	0.59	0.70
Subjective norm						
Intervention	0.94	0.66	0.91	0.66	0.94	0.66
Control	0.88	0.68	0.90	0.69	0.85	0.77
Perceived behavioral control						
Intervention	0.27	0.79	0.48	0.80	0.35	0.73
Control	0.26	0.78	0.42	0.76	0.27	0.81
Intention						
Intervention	0.90	0.67	0.83	0.66	0.79	0.74
Control	0.81	0.74	0.75	0.69	0.64	0.84
Sleep hygiene (1-5)						
Intervention	3.77	0.41	3.71	0.48	3.76	0.41
Control	3.81	0.42	3.81	0.45	3.73	0.54
Sleep duration (min.)						
Intervention	528.43	44.77	527.03	59.96	510.37	65.76
Control	540.71	43.76	534.74	64.49	539.33	74.22
Sleep quality						
Intervention	0.53	0.75	0.59	0.79	0.43	0.77
Control	0.57	0.54	0.63	0.75	0.66	0.76

Range for sleep quality scores and social-cognitive determinants (−2 to +2).

\*Statistically significant difference between intervention and control group.

**Table 3. Results of Linear Mixed Model Analysis Adjusted for Baseline Scores (T0) of the Effect of Charge Your Brainzzz**

	B (Overall)	95% CI	B (T1)	95% CI	B (T2)	95% CI
Knowledge (0-10)						
Crude	1.44	0.79 to 2.10	1.64	0.96 to 2.33	1.15	0.45 to 1.86
Adjusted	1.69	0.99 to 2.39	1.91	1.22 to 2.60	1.40	0.70 to 2.10
Attitude						
Crude	0.06	−0.02 to 0.13	0.07	−0.04 to 0.17	0.03	−0.08 to 0.14
Adjusted	0.08	−0.00 to 0.15	0.10	0.01 to 0.19	0.06	−0.04 to 0.15
Subjective norm						
Crude	−0.03	−0.19 to 0.14	−0.06	−0.23 to 0.11	0.03	−0.15 to 0.20
Adjusted	0.02	−0.07 to 0.11	−0.02	−0.12 to 0.09	0.07	−0.05 to 0.18
Perceived behavioral control						
Crude	0.04	−0.04 to 0.13	0.05	−0.05 to 0.15	0.05	−0.06 to 0.17
Adjusted	0.10	0.01 to 0.18	0.11	0.01 to 0.22	0.11	−0.00 to 0.22
Intention						
Crude	0.01	−0.12 to 0.14	0.02	−0.16 to 0.12	0.05	−0.10 to 0.20
Adjusted	0.03	−0.10 to 0.15	0.01	−0.13 to 0.15	0.07	−0.08 to 0.22
Sleep hygiene (1-5)						
Crude	−0.02	−0.12 to 0.08	−0.07	−0.17 to 0.03	0.06	−0.05 to 0.16
Adjusted	0.01	−0.08 to 0.09	−0.04	−0.14 to 0.05	0.08	−0.01 to 0.18
Sleep duration (min.)						
Crude	−8.09	−15.47 to 0.70	0.90	−7.59 to 9.40	−22.29	−32.81 to −11.76
Adjusted	−7.45	−15.26 to 0.34	2.49	−6.52 to 11.50	−21.16	−31.89 to −10.44
Sleep quality						
Crude	−0.11	−0.21 to −0.02	−0.06	−0.17 to 0.03	−0.17	−0.30 to −0.04
Adjusted	−0.08	−0.18 to 0.01	−0.01	−0.13 to 0.09	−0.14	−0.27 to −0.01

\*p < 0.05; adjusted models are corrected for age, gender, perceived cultural group and educational level (6 categories).

a healthy sleep pattern were unaffected by the CYB intervention.

Like other school-based interventions, CYB was able to positively impact adolescents' knowledge on healthy sleep.<sup>16-18</sup> Moreover, it was one of the first in which these changes were sustained up to 3 months after the program.<sup>14</sup> Yet, improving only knowledge showed to be insufficient in order to achieve (sustained) changes in sleep, which is in line with previous literature on adolescent sleep health<sup>30</sup> as well as with studies on different health behaviors such as dietary and physical activity behavior.<sup>19,31</sup> Intervention efforts that aim for (structural) behavioral changes should therefore move beyond improving just knowledge alone as a central determinant.

CYB also significantly affected adolescents' attitudes towards the importance of healthy sleep practices post-intervention and on adolescents' beliefs in their own ability to adopt healthy sleep habits (ie, perceived behavioral control). This is vital as attitude and perceived behavioral control are important prerequisites for behavioral change, and CYB is, to our knowledge, the first preventative sleep intervention to date to significantly impact these determinants.<sup>14</sup> The improvement in attitude is promising, as adolescents' attitudes and priorities with regards to sleep are often low<sup>16,32</sup> and consequently more immediately rewarding behaviors like social media use could get prioritized over a healthy night's sleep. Perceived behavioral control was previously found to be the strongest predictor for sleep intentions and sleep outcomes compared to the other TPB determinants.<sup>30</sup> However, since in the current study no effects were found on the actual sleep hygiene practices, a discrepancy still remains between students' perceived capability to apply healthy sleep practices and their actual sleep hygiene. Interventions apparently require more persisting methods to impact perceived behavioral control on the longer term and impact other relevant factors that influence sleep health.

The observed improvements in social-cognitive determinants might be attributed to the fact that CYB incorporated effective methods to target these determinants. By using methods like discussion, elaboration and active learning, and by relying on the power of serious gaming for education, CYB was able to impact knowledge, attitudes, and perceived behavioral control.<sup>33,34</sup> However, as CYB used a combination of methods the effects cannot be attributed to 1 specific method.

Despite the positive effects on several social-cognitive determinants, sleep duration and quality were unaffected. Even more unexpected, given the positive outcomes on social-cognitive determinants, some shorter sleep duration was noted in the intervention group compared to the controls. Strangely, shorter

sleep duration was only found at longer follow-up and not directly after the intervention. Such findings might point to methodological issues. A possible explanation might be that the response on the sleep diary was low (ie, on average 3.2 out of 14 days completed, range 0-14 days), which increases the likelihood of chance findings.<sup>35</sup> Completion of the sleep diary was affected by experienced time restraints at school through which participants had to complete the diary at home. However, adolescents indicated that they forgot to complete the sleep diary on a daily basis despite our efforts (eg, providing reminders and incentives). Despite their validity, using diaries for sleep measures in adolescent populations still have methodological and practical challenges. Perhaps an objective method such as actigraphy might be a viable addition better suited to measure sleep outcomes in this population and setting.

Generally, sleep education programs in the field of public health often lack effectiveness and might benefit from applying behavioral change theories<sup>15,21</sup> and theory-driven, evidence-based systematic intervention design methodologies such as the Behavioral Change Wheel or the Intervention Mapping Framework to increase effectiveness.<sup>17,19,21,36</sup> Moreover, existing research recognizes the difficulty of changing sleep health solely via school-based programs.<sup>15,16</sup> This may have only limited impact on sleep outcomes, because they often only aim at changing cognitive determinants,<sup>14,15,19</sup> while adolescent sleep health is a result of a complex interplay of determinants from different social-ecological levels such as the home- and school environment, the community, potentially up to regulatory, socio-political and cultural (belief) systems.<sup>37</sup> To incorporate the home environment, CYB offered a homework assignment with parents in which the method of social comparison was used.<sup>33</sup> It was suggested this would affect social influences on adolescents as they often need support from their social environment like their parents or friends to successfully adapt health behaviors.<sup>12,22,38,39</sup> However, no effects on subjective norms were found which suggests that adolescents' home environment should probably be more thoroughly engaged. Changing the complex health problem of sleep in adolescents therefore requires an approach that inherently respects and deals with the multilevel nature of sleep health. As such, a whole-systems approach is more promising in achieving sustained behavioral change by acknowledging this multilevel nature and by integrating the system and actions across a broad range of disciplines and levels.<sup>37,40,41</sup> Typically, these approaches are delivered at the individual, environmental, and societal level, which positively impacts their capacity to change sleep health.<sup>42</sup>



Effectiveness of sleep health interventions for adolescents may be further increased by tailoring them to their developmental stage. Adolescence is a crucial period in life in terms of psychological, cognitive, and social development, and this should also be acknowledged in interventions. This period is characterized by a greater need for autonomy and consequently more freedom from parents, as well as increased responsibility at home and at school.<sup>11</sup> These characteristics also influence sleep health in terms of fewer bedtime rules enforced by parents, problems with planning homework and the resulting stress that may impact sleep duration or sleep quality. Interventions should provide adolescents with tools and strategies to overcome these potential barriers. Including the interplay of sleep-related determinants and developmental science perspectives is currently lacking in much intervention design, yet may significantly benefit effectiveness.<sup>43</sup>

### Strengths and Limitations

A strong aspect of the current study is its cluster-randomized controlled trial design and sample size. Also, the research team was not involved in the development of the intervention. In addition, measuring all outcomes directly after the intervention as well as 3 months post-intervention provided valuable insights into the potentially sustained effects of the intervention. Furthermore, including social-cognitive and behavioral determinants instead of only assessing sleep outcomes helped to gain a better understanding of what future intervention methods and strategies might be most effective and necessary to achieve actual changes in sleep health.

However, our study also has limitations to consider. The first of which was the total dropout rate. At baseline, 972 students filled in the questionnaire, whereas this number dropped to 627 (64%) post-intervention and was eventually reduced to 538 students (55%) at follow-up. Although the dropout rate was somewhat lower than expected in the a priori power calculation (50%), the size of the sample at follow-up was lower than the pre-defined 750 students, which could have affected the power of the analyses. A second limitation is the validity of the measures of sleep knowledge and sleep hygiene. As currently no validated measures are available for measuring sleep knowledge the questions used in this study were based on the content of the intervention. Albeit modest in size, these questions were subject to a pre-test study. Regarding sleep hygiene, pre-tests' adjustments to the ASHS aided suitability for the target population, whereas this might have also led to implications for the validity. A last limitation was the measure of sleep duration which actually measured sleep opportunity as it did not account for

sleep onset latency or night awakening. Consequently, by measuring sleep opportunity, sleep duration could have been overestimated.

### Conclusions

This study demonstrated that the school-based intervention Charge Your Brainzzz was effective in improving young adolescents' sleep knowledge and showed positive effects on adolescents' attitude and perceived behavioral control. The intervention was not effective in improving adolescents' actual sleep, their sleep hygiene, subjective norm, and behavioral intention to obtain healthy sleep. These findings indicate that this school-based intervention is not sufficient to affect sleep health, but still a promising way of targeting young adolescents' sleep-related social-cognitive determinants. Effectively changing sleep health requires interventions that are theoretically and systematically developed. Lastly, yet crucially, the focus of interventions should move from an individual approach toward an approach in which the individual is viewed as part of a complex, multilevel system of interacting social-cognitive, behavioral, and environmental determinants.

### IMPLICATIONS FOR SCHOOL HEALTH

The results of this study demonstrated that the school-based intervention Charge Your Brainzzz positively influenced several social-cognitive determinants, such as knowledge and attitude, that play an important role in stimulating healthy adolescent sleep. The intervention can be delivered without implementation costs and the content is freely available. Also, a clear and practical implementation manual is available for schools. However, to have meaningful impact on adolescent sleep health educational interventions targeting social-cognitive determinants do not suffice. For such impact, an integrated systems approach is needed in which sleep education would be supported by a healthy school environment, healthy school policies, and parental involvement. Hence, Charge Your Brainzzz can serve as a starting point for a systems approach to positively influence adolescent sleep health and as a consequence adolescent learning and general health.

### Human Subjects Approval Statement

The study protocol was reviewed by the Medical Ethical Committee of the Amsterdam UMC (VUmc) and complied with ethical guidelines and did not fall under the Medical Research Involving Human Subject Acts (WMO) (reference number 2018.248). Further approval by the Medical Ethical Committee was therefore not required.

## Conflict of Interest

The authors declare no conflict of interest.

## REFERENCES

1. Buysse DJ. Sleep health: can we define it? Does it matter? *Sleep*. 2014;37(1):9-17.
2. Dewald JF, Meijer AM, Oort FJ, Kerkhof GA, Bögels SM. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: a meta-analytic review. *Sleep Med Rev*. 2010;14(3):179-189.
3. Miller MA, Krusik M, Wallace J, Ji C, Cappuccio FP. Sleep duration and incidence of obesity in infants, children, and adolescents: a systematic review and meta-analysis of prospective studies. *Sleep*. 2018;41(4):zsy018.
4. Shochat T, Cohen-Zion M, Tzischinsky O. Functional consequences of inadequate sleep in adolescents: a systematic review. *Sleep Med Rev*. 2014;18(1):75-87.
5. Leone S, Van der Poel A, Beers K, Rigter L, Zantinge E, Savelkoul M. *Slechte slaap: een probleem voor de volksgezondheid?* Utrecht: Trimbos Instituut, Netherlands Institute of Mental Health and Addiction; 2018.
6. Gradisar M, Gardner G, Dohnt H. Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep. *Sleep Med*. 2011;12(2):110-118.
7. Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health*. 2015;1(1):40-43.
8. Kocovska D, Lysen TS, Dotinga A, et al. Sleep characteristics across the lifespan in 1.1 million people from The Netherlands, United Kingdom and United States: a systematic review and meta-analysis. *Nat Hum Behav*. 2021;5(1):113-122.
9. Irish LA, Kline CE, Gunn HE, Buysse DJ, Hall MH. The role of sleep hygiene in promoting public health: a review of empirical evidence. *Sleep Med Rev*. 2015;22:23-36.
10. Bartel KA, Gradisar M, Williamson P. Protective and risk factors for adolescent sleep: a meta-analytic review. *Sleep Med Rev*. 2015;21:72-85.
11. Crowley SJ, Wolfson AR, Tarokh L, Carskadon MA. An update on adolescent sleep: new evidence informing the perfect storm model. *J Adolesc*. 2018;67:55-65.
12. Short MA, Gradisar M, Wright H, Lack LC, Dohnt H, Carskadon MA. Time for bed: parent-set bedtimes associated with improved sleep and daytime functioning in adolescents. *Sleep*. 2011;34(6):797-800.
13. Katz DL, O'Connell M, Njike VY, Yeh M-C, Nawaz H. Strategies for the prevention and control of obesity in the school setting: systematic review and meta-analysis. *Int J Obes*. 2008;32(12):1780.
14. Gruber R. School-based sleep education programs: a knowledge-to-action perspective regarding barriers, proposed solutions, and future directions. *Sleep Med Rev*. 2017;36:13-28.
15. Blunden S, Rigney G. Lessons learned from sleep education in schools: a review of dos and don'ts. *J Clin Sleep Med*. 2015;11(06):671-680.
16. Cassoff J, Knäuper B, Michaelsen S, Gruber R. School-based sleep promotion programs: effectiveness, feasibility and insights for future research. *Sleep Med Rev*. 2013;17(3):207-214.
17. Blunden SL, Chapman J, Rigney GA. Are sleep education programs successful? The case for improved and consistent research efforts. *Sleep Med Rev*. 2012;16(4):355-370.
18. Chung KF, Chan MS, Lam YY, Lai CSY, Yeung WF. School-based sleep education programs for Short sleep duration in adolescents: a systematic review and meta-analysis. *J Sch Health*. 2017;87(6):401-408.
19. Bartholomew Eldredge LK, Markham CM, Ruiter RA, Fernández ME, Kok G, Parcel GS. *Planning Health Promotion Programs: An Intervention Mapping Approach*. San Francisco: Jossey-Bass Inc.; 2016.
20. Lubas MM, Szklo-Coxe M. A critical review of education-based sleep interventions for undergraduate students: informing future directions in intervention development. *Adolesc Res Rev*. 2019;4(3):249-266.
21. Albakri U, Drotos E, Meertens R. Sleep health promotion interventions and their effectiveness: an umbrella review. *Int J Environ Res Public Health*. 2021;18(11):5533.
22. Ajzen I. From intentions to actions: a theory of planned behavior. In: *Action Control*. Berlin, Heidelberg: Springer; 1985:11-39.
23. Netherlands S. Begrippen: Migratieachtergrond 2020. Statistics Netherlands (CBS) 2020. Available at: <https://www.cbs.nl/nl-nl/onze-diensten/methoden/begrippen?tab=m#id=migratieachtergrond>
24. Fishbein M, Ajzen I. *Predicting and Changing Behavior: The Reasoned Action Approach*. New York: Psychology press; 2011.
25. Kline P. *Handbook of Psychological Testing*. London: Routledge; 2013.
26. de Bruin EJ, van Kampen RK, van Kooten T, Meijer AM. Psychometric properties and clinical relevance of the adolescent sleep hygiene scale in Dutch adolescents. *Sleep Med*. 2014;15(7):789-797.
27. Carney CE, Buysse DJ, Ancoli-Israel S, et al. The consensus sleep diary: standardizing prospective sleep self-monitoring. *Sleep*. 2012;35(2):287-302.
28. Twisk J, de Boer M, de Vente W, Heymans M. Multiple imputation of missing values was not necessary before performing a longitudinal mixed-model analysis. *J Clin Epidemiol*. 2013;66(9):1022-1028.
29. Twisk J, Bosman L, Hoekstra T, Rijnhart J, Welten M, Heymans M. Different ways to estimate treatment effects in randomised controlled trials. *Contemp Clin Trials Commun*. 2018;10:80-85.
30. Knowlden AP, Sharma M, Bernard AL. A theory of planned behavior research model for predicting the sleep intentions and behaviors of undergraduate college students. *J Prim Prev*. 2012;33(1):19-31.
31. Van Cauwenberghe E, Maes L, Spittaels H, et al. Effectiveness of school-based interventions in Europe to promote healthy nutrition in children and adolescents: systematic review of published and 'grey' literature. *Br J Nutr*. 2010;103(6):781-797.
32. Paterson JL, Reynolds AC, Duncan M, Vandelanotte C, Ferguson SA. Barriers and enablers to modifying sleep behavior in adolescents and young adults: a qualitative investigation. *Behav Sleep Med*. 2019;17(1):1-11.
33. Kok G, Gottlieb NH, Peters G-JY, et al. A taxonomy of behaviour change methods: an intervention mapping approach. *Health Psychol Rev*. 2016;10(3):297-312.
34. Gee JP. Learning by design: good video games as learning machines. *E-Learn Digital Media*. 2005;2(1):5-16.
35. Short MA, Arora T, Gradisar M, Taheri S, Carskadon MA. How many sleep diary entries are needed to reliably estimate adolescent sleep? *Sleep*. 2017;40(3):zsx006.
36. Michie S, Van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci*. 2011;6(1):42.
37. Hale L, Troxel W, Buysse DJ. Sleep health: an opportunity for public health to address health equity. *Annu Rev Public Health*. 2020;41:81-99.
38. Maxwell KA. Friends: the role of peer influence across adolescent risk behaviors. *J Youth Adolesc*. 2002;31(4):267-277.
39. Brand S, Gerber M, Hatzinger M, Beck J, Holsboer-Trachsler E. Evidence for similarities between adolescents and parents in sleep patterns. *Sleep Med*. 2009;10(10):1124-1131.

40. Carey G, Malbon E, Carey N, Joyce A, Crammond B, Carey A. Systems science and systems thinking for public health: a systematic review of the field. *BMJ Open*. 2015;5(12).
41. Bagnall A-M, Radley D, Jones R, et al. Whole systems approaches to obesity and other complex public health challenges: a systematic review. *BMC Public Health*. 2019;19(1):8.
42. Dahlgren G, Whitehead M. The “main determinants of health” model, version accessible. European strategies for tackling social inequities in health: Levelling up Part 2 1991
43. Dahl RE, Allen NB, Wilbrecht L, Suleiman AB. Importance of investing in adolescence from a developmental science perspective. *Nature*. 2018;554(7693):441-450.

## SUPPORTING INFORMATION

The following Supporting Information is available for this article:

**Appendix 1** Overview of Determinants, Theoretical Methods, Practical Strategies, and Theories of Change Your Brainzzz

Additional supporting information may be found online in the Supporting Information section at the end of the article.