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Original Article

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Midday napping in children: associations between nap frequency and duration across cognitive, positive psychological well-being, behavioral, and metabolic health outcomes

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Abstract

Study Objectives: Poor sleep and daytime sleepiness in children and adolescents have short- and long-term consequences on various aspects of health. Midday napping may be a useful strategy to reduce such negative impacts. The effect of habitual napping on a wide spectrum of cognitive, behavioral, psychological, and metabolic outcomes has not been systematically investigated.
Methods: This study characterized midday napping habits in 3819 elementary school children from the China Jintan Cohort Study. In 2011, weekly nap frequency and average duration were collected once from students at grades 4–6. Prior to their completion of elementary school at grade 6 (in 2011–2013 respective to each grade), the following outcomes were collected once: behavioral and academic achievement evaluated by teachers, and self-reported positive psychology measures including grit, self-control, and happiness. IQ tests were conducted on a subgroup. Metabolic indices, including body mass index and fasting glucose concentration, were measured through physical exams. For the whole sample, we assessed associations between napping and each outcome, adjusted for sex, grade, school location, parental education, and time in bed at night. We also conducted stratified analyses on grade 6 (cross-sectional), grade 4 (2-year gap), and grade 5 (1-year gap) data.
Results: Overall, napping was significantly associated with higher happiness, grit, and self-control, reduced internalizing behavior problem, higher verbal IQs, and better academic achievement, although specific patterns varied across frequency and duration for different outcomes. More limited significant associations were found for decreased externalizing behavior problems, compared to non-nappers, while no significant associations were found for performance IQ and metabolic outcomes.
Conclusions: Results indicate benefits of regular napping across a wide range of adolescent outcomes, including better cognition, better psychological wellness, and reduced emotional/behavioral problems. The current study underscores the need for further large-scale intervention studies to establish causal effects.

Statement of Significance

This study on a community sample of school children shows that overall habitual nappers had better academic achievement, greater happiness, grit, and self-control, and reduced internalizing behavioral problems. This study highlights the potential benefits of habitual midday napping on a variety of outcomes for school children. Given that sleep deprivation and daytime sleepiness are important public health concerns, this study may help inform future interventional studies that target adolescent sleepiness.

Key words: nap; sleep; cognition; positive psychology; psychological well-being; grit; self-control; happiness; academic achievement; behavior problems; internalizing; externalizing; metabolic health; glucose

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Introduction

Sleep insufficiency is an important public health concern, especially in children and adolescents [1]. Around the world, as many as one-third of all children experience sleep difficulties [2–4], and approximately 15%–20% of children report excessive daytime sleepiness [2, 5]. In adolescents, rates appear to be similar, if not higher [6–8]. Sleepiness can be detrimental to both development and functioning, including cognition and school performance [9], mood, behavior [10, 11], physical health, and quality of life [2, 12, 13]. Furthermore, excessive daytime sleepiness in children has been linked to lower cognitive abilities [14], including impaired receptive vocabulary, nonverbal learning, and overall academic performance [15]. It has also been associated with increased emotional and behavioral problems, and even later adult crime [16]. In the long-term, insufficient sleep has been linked to various public health consequences [17], including increased economic spending, reduced work performance, increased risk for many diseases, accidents, and deaths, and impaired quality of life [17–20].

Napping may help reduce sleepiness [21], recover fatigue, and improve alertness [22–24] and has also recently been considered as a health intervention to offset the negative consequences of sleep deprivation [20, 25]. In an early influential laboratory study, Dinges *et al.* [26] found that a single nap helped prevent sleepiness after prolonged sleep loss. Since then a growing body of research has demonstrated that napping is associated with positive outcomes in numerous areas of functioning. These include intellectual performance (e.g., memory and learning) [27, 28], behavior (e.g., self-regulation and attention), and emotion (e.g., mood and affect) [29]. More recently, a study by Saletin *et al.* [21] showed that daytime naps in adults provide short-term attenuation of sleepiness caused by sleep restriction. Despite these encouraging findings, the literature on the developmental effects of napping is limited, with only a few laboratory-based experiments examining the effect of single naps on learning [30–32], and emotional and behavioral regulation [33, 34]. A recent systematic review by Thorpe *et al.* [35] summarized the developmental impact of naps during the first 5 years of life and reported mixed findings on behavioral, emotional, and health-related outcomes. The effect of napping on glucose metabolism and diabetes in adults is controversial, with some studies reporting a negative effect of napping on glucose metabolism and diabetes and others failing to find a significant effect [36, 37]. Such inconsistencies may be due to uncontrolled confounding from sociodemographics, comorbidity, nighttime sleep, and inadequate measure of napping frequency and duration [38–41]. Few studies have examined napping and glucose metabolism in children. Furthermore, little is known about the effects of napping on applied cognitive ability such as academic performance other than intelligence. Few, if any, nap studies have examined habitual napping on emotional and behavioral outcomes in schoolchildren, with even less knowledge on psychological well-being and health. Such gaps in research call for more comprehensive studies to investigate the effects of napping on multiple outcomes.

In this community study, we conducted a comprehensive examination of associations between napping in Chinese schoolchildren and a wide range of outcomes. An existing cohort study in Jintan, China, where post-lunch napping is a common practice in all age groups, collected information on frequency and duration of napping habits. The overarching study design is illustrated in Figure 1. Outcomes include four areas of functioning: behavior problems, cognitive ability, psychological well-being, and health, many of which were constructed from multiple measures.

Methods

Study design and participants

This study draws on data from the China Jintan Preschool Cohort Study [42, 43], a prospective longitudinal study that aims to understand the impact of early health factors on children's and adolescents' long-term physical and mental health outcomes. The children were initially recruited in 2005 when they were in preschool in Jintan City, located in the southeastern coastal region of China. We selected four schools based on the type of location: rural (Xue Bu), suburban (Hua Cheng and He Bin), and urban (Hua Luo Geng) area. The original study was expanded from 2011 to 2013 to include both the original cohort participants and their later classmates in elementary school.

The current study consisted of 3819 students across three grade cohorts (grades 4–6; mean age 11.17 ± 0.98; 51.3% male) when the nap and nighttime sleep data was collected. However, 2928 (76.7%) students have complete data for nap frequency and duration, covariates and three major outcomes (emotion/behavior, cognition, and psychological well-being). Sample characteristics among study subjects and excluded subjects are presented in Supplementary Table 1. The sociodemographic profile and additional details of this location are reported in our cohort profile updates paper [43].

Data collection procedures

In China, elementary schools include grade 1 to grade 6. Napping and sleep data were collected in the later part of the spring term in 2011 when the three grade cohorts were in grades 4, 5, and 6, respectively. All outcome data, including covariates, were collected when the participants were in the last semester of grade 6 (2–3 months before graduation from elementary school). Data collection spans 3 years (2011–2013) based on the three grade cohorts. For each participant, napping patterns, cognitive ability, emotional/behavioral outcomes, and psychological well-being were measured through either self-reported questionnaires or teacher's reports. Children completed self-report questionnaires in their school classrooms under the supervision of a research

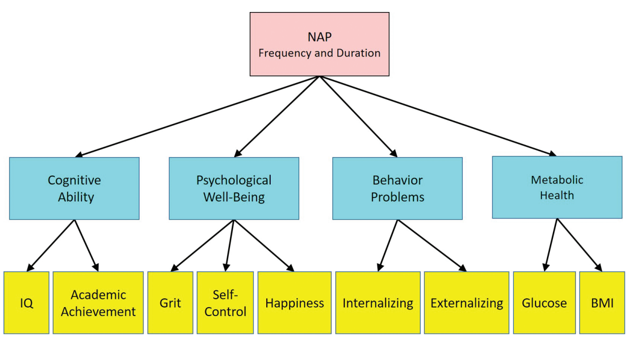

Figure 1. Overall nap study design, with four main outcomes (blue) and their indicators (yellow).

assistant. IQ testing was only conducted for the cohort children in a controlled laboratory in Jintan Hospital. Written informed consent was obtained from parents, and assent was obtained from children. Institutional Review Board approval was obtained from both the University of Pennsylvania and the Ethical Committee for Research at Jintan Hospital in China. Teachers' reports were collected in the school. Neither the teachers nor the students were aware of the hypotheses of the study.

Measures

Our measures included: (1) weekly post-lunch napping frequency and average duration; (2) four primary outcome domains with each including multiple indicators: cognitive ability, emotion/behavior, psychological well-being, health; and (3) sociodemographic variables and time in bed at night.

Chinese school schedule

In China, napping is a routine and well-accepted sleep practice in all age groups as part of a healthy lifestyle practice. Like most typical public schools in China, all schools in the Jintan school district begin at 08:00 am and end at 04:15 pm. Students have a long lunch break (in this study, between 11:10 am and 01:25 pm) before resuming their classes in the afternoon. This long break and the extended school day provides children with sufficient time to nap (~1–1.5 hours) after lunch, either at school or at home. Nevertheless, the frequency and duration of napping varied among individuals.

Nap frequency and duration

Two questions were asked to obtain the children's nap frequency and duration, which have been similarly implemented in previous studies [44, 45]. Frequency was assessed by asking, "During the past month, how often and how long did you usually take a post-lunch nap?" with the following options: never, <1/week, 1–2/week, 3–4/week, and 5–7/week. For nap duration, the following categories were asked: 0 minutes, 1–15 minutes, 15–30 minutes, 31–60 minutes, 1–2 hours, and 2+ hours. Categories with small frequencies were merged into adjacent categories in the statistical analysis. Nap frequency was recoded into four categories: never, ≤2, 3–4, and 5–7 times per week, while average nap duration was also recoded into 4 categories as follows: never, <30 minutes, 31–60 minutes, and >60 minutes. For anyone who responded "frequency- never," their duration was coded as 0 minutes; for anyone who responded "Duration- 0 minutes," their frequency was set to "0". These cutoffs were selected, since a midday nap with a duration of no more than 30 minutes is an advised practice to avoid deep non-rapid eye movement (NREM) sleep that can result in sleep inertia, and rapid eye movement (REM) sleep may occur in a nap that is more than 1 hour in length [46].

Cognitive ability

Within the domain of cognitive ability, IQ and school academic achievement were evaluated to reflect both trait intelligence and applied intelligence, respectively.

IQ was assessed by the Chinese version of the Wechsler Intelligence Scale for Children (WISC) [47] was used to assess the IQ of the participants [48]. Individual scores were calculated for verbal IQ (VIQ) and performance IQ (PIQ), with higher scores indicative of higher intelligence. Detailed procedures are described in Liu *et al.* [43]. Test results were only available for the original cohort (*N* = 819).

Academic achievement was determined by school grades for each child in the study. Standardized student grades in four major subjects (Chinese, Math, English, and Social Science) in the previous semester were provided by the teacher and converted to a five-point scale from 1 = very poor (grade F) to 5 = very good (grade A). The total score of the four subjects for each individual was computed and combined into a composite score for analysis. Further details are included in our previous publication [11].

Psychological well-being

Children's positive emotion and personality traits were assessed by three adolescent self-report measures reflecting psychological well-being.

Grit was assessed by the *Grit Scale* developed by Duckworth *et al.* [49], which contains 12 self-reported Likert scale items, such as "*setbacks don't discourage me*" to assess perseverance and consistency in pursuing long-term goals. The total grit score is calculated by averaging all twelve items to provide an estimation of individual grittiness that ranges from one to five. A higher average score is reflective of greater grit. Internal consistency of the measure was adequate and consistent with previous studies ($\alpha = .75$). This measure has been widely implemented within academic and professional settings, showing well-documented reliability and validity [49]. The Chinese version of Grit has been validated [50].

Self-control was assessed by the *Brief Self-Control Scale* developed by Tangney et al. [51]. The scale contains 13 self-reported items such as "*I am good at resisting temptation*," with each item rated on a five-point scale from 1, *not at all like me*, to 5, *very much like me*. The total self-control score was calculated by averaging the ratings for all items, with higher scores indicating higher self-control. The scale has well-documented reliability and validity [52]. The Chinese version of Brief Self-Control Scale has been validated [53].

Happiness was assessed by the *Oxford Happiness Questionnaire* developed by Hills & Argyle [54]. The scale contains 29 self-reported items such as "laugh a lot," "happy memories," "life is rewarding," with each item rated from 1 (*strongly disagree*) to 6 (*strongly agree*). The total happiness score was calculated as a mean of the ratings for the 29 items. Internal reliability and construct validity have been well-documented [55]. The Chinese version of Oxford Happiness Questionnaires has been validated [56].

Internalizing and externalizing behavior

Children's behavior was assessed by the child's primary class teacher using the Teacher-Child Rating Scale [57], a 40-item measure based on core aspects of school-related competence such as frustration tolerance, task orientation, and social skills. Each item was scored on a five-point scale from 1 (not at all) to 5 (very well), to create internalizing and externalizing behavior scale scores which have been validated in Chinese children [58].

Metabolic health

Fasting blood specimens from cohort children were collected and analyzed for glucose concentrations during the summer between 2011 and 2013 when children were in the last 2–3 months of 6th grade. Fasting plasma glucose concentrations were dichotomized into normal (<5.5 mmol/L) and impaired (≥5.6 mmol/L) fasting glucose (IFG) levels [59]. Body mass index (BMI) was calculated using self-report weight (kg) divided by height squared (m^2) as an indirect measure of body fat. Metabolic health data were only available for the original cohort ($N = 771$).

Covariates

Demographics. Children completed a questionnaire on sociodemographic information, including the child's gender, grade/age, and parental education. The education levels of both parents were coded as middle school or below, high school, and college or above. Four schools were selected to represent the different residential areas from urban to rural [42].

Time in bed at night. Children were asked to report their bedtimes and rise-times. We calculated time in bed as a proximity measure for nighttime sleep duration. We considered time in bed at night as a key covariate because napping might be associated with nighttime sleep [35].

Statistical analyses

Of the participants, 2928 children had complete data for nap and outcomes (except for IQ and metabolic health) and were included in data analyses. All demographic and potential confounding variables, including gender, grade, parental education, school location, and nighttime in bed were summarized as mean (s.d.) or frequencies by weekly nap frequency and average duration categories. The marginal associations between sex and nap frequency/duration were tested using χ^2 tests; the association between nap and school locations was tested using analysis of variance (ANOVA); and the correlations between nap and any ordinal variable, including grade, parental education, and time in bed at night, were assessed using Spearman's correlation coefficient.

The nap frequency and average duration were modeled separately for association with each outcome because they were highly correlated (Spearman's correlation= 0.51, $p < 0.0001$).

All variables with a significant marginal association with nap were considered to be included as covariates in multivariate linear or logistic models to assess the napping effect on each outcome. All variables with a significant marginal association with nap were considered to be included as covariates in multivariate linear or logistic models to assess the napping effect on each outcome. We used the backward selection algorithm with a cutoff p-value of 0.05 to obtain final models that always included nap frequency or duration variables. The effect size d between nappers and non-nappers was calculated by dividing the adjusted mean difference by the pooled standard deviation (*SD*) in each model [60]. The effect size, if without any covariate adjustment, is Cohen's d [60]. Here we chose a covariate-adjusted d to be consistent with the hypothesis testing in the regression setting. Its unit is SD of the outcome residual after removing the confounding effects.

Because night time in bed might confound the napping effects, we also conducted complementary sensitivity analyses by including and excluding night time in bed as a covariate. If the covariates in the final model contained night time in bed, we refitted the model by excluding it. Otherwise, we refitted the model by including it. Two sets of complementary models were compared to assess the confounding effect of night time in bed on the nap effect.

In order to ascertain what specific combinations of duration with frequency are optimal for positive outcomes, nap frequency and duration were broken down into nine groups (based on three frequency and three duration categories) and compared to the non-nappers, using linear or logistic models, adjusted for the same set of covariates selected for each outcome. To assess for potential bias in missing data, we compared the demographics of the subjects with missing nap data with those of subjects with nap data available but missing outcomes. All statistical tests were two-tailed with a significance level of 0.05. All analyses were performed in SAS9.4 and R3.4.3.

Furthermore, because nap, night time in bed, and outcome data were collected almost simultaneously for 6th graders but with a 1- or 2-year gap for 4th and 5th graders, we also conducted separate analyses for each grade, using the same linear and logistic final models except without adjusting for grade.

Results

Nap Frequency and Average Duration as a Function of Sample Characteristics.

Means (*SDs*) and frequencies (percentages) for demographic and confounding variables by nap frequency and duration categories are presented in Table 1. There were significant gender differences in both nap frequency ($\chi^2 = 22.81$, $p < 0.0001$) and nap duration ($\chi^2 = 21.24$, $p < 0.0001$). The results of Spearman's correlations showed that father's education levels were positively associated with nap frequency ($r_s = 0.04$, $p = 0.04$) and negatively associated with nap duration ($r_s = -0.09$, $p < 0.0001$). There was a trend toward increasing nap duration with higher maternal education ($r_s = -0.09$, $p < 0.0001$). Girls had higher percentages in frequent napping compared to boys (3–4 naps/week: 29.8% vs. 27.6%; 5–7 naps/week: 39.1% vs. 34.8%). Frequent napping is more prevalent among 6th graders than 4th (40.3% vs. 35.9%) and 5th graders (40.3% vs. 34.1%). For the nap duration of 31–60 minutes, 6th graders were also the most prevalent group compared with 4th (41.8% vs. 38.7%) and 5th graders (41.8% vs. 33.7%), although the percentages in the >60 minutes were similar across the three grades. Children whose father had a higher education napped more often ($p = 0.04$). The school geographic district showed a nonuniform relationship with nap frequency. Two suburbs, Hua Cheng (42.36%) and He Bin (28.13%) districts, had different profiles in terms of the percentage of frequent napping (5–7 naps/week) ($p < 0.0001$). Night time in bed significantly differed across different nap-frequency groups. Overall, frequent nappers spent more time in bed at night compared to non-nappers ($p = 0.0041$), but there was no significant correlation between nap duration and in-bed time at night ($p = 0.2540$). There was a decreasing trend for the night time in bed from the 4th grade to 6th grade (mean 9.65, 9.32, and 9.09 hours for 4th, 5th, 6th graders, respectively) (Table 1).

Associations Between Nap and Cognitive/Academic Achievement

Verbal IQ

Mean VIQ scores were higher in nappers compared with non-nappers (Figure 2). For frequency, the difference between

Table 1. Sample characteristics across nap frequency and duration groups

		Weekly nap frequency					Average nap duration				
	Total	Never	≤2	3–4	5–7	*p-value*	0	1–30	31–60	>60	*p-value*
Study sample	2928	13.8%	21.6%	29.1%	35.5%		14.1%	14.6%	37.0%	34.3%	
Gender						<0.0001[a]					<0.0001[a]
Boys	1460	16.6%	21.0%	27.6%	34.8%		16.6%	13.2%	37.7%	32.5%	
Girls	1468	10.8%	20.2%	29.8%	39.1%		10.8%	14.9%	38.9%	35.4%	
Grade						0.0066[b]					0.0002[b]
4th grade (age 10.5 ± 0.3 years)	936	15.2%	19.8%	29.2%	35.9%		15.2%	12.1%	38.7%	34.1%	
5th grade (age 11.5 ± 0.3 years)	907	14.2%	24.0%	27.7%	34.1%		14.2%	17.9%	33.7%	34.2%	
6th grade (age 12.5 ± 0.3 years)	1085	12.0%	18.5%	29.2%	40.3%		12.0%	12.5%	41.8%	33.6%	
Mother's education						0.0721[b]					<0.0001[b]
Middle school or lower	1120	14.3%	22.8%	27.9%	35.1%		14.3%	13.0%	32.9%	39.9%	
High School	976	12.4%	20.0%	29.7%	37.9%		12.40%	13.0%	40.6%	34.0%	
College or higher	832	14.4%	18.5%	28.7%	38.3%		14.42%	16.7%	43.0%	25.8%	
Father's education						0.0396[b]					<0.0001[b]
Middle school or lower	892	14.0%	23.1%	27.5%	35.4%		14.0%	13.0%	33.1%	39.9%	
High School	1020	12.7%	22.3%	29.0%	36.1%		12.7%	12.9%	38.4%	36.0%	
College or higher	1016	14.5%	16.8%	29.5%	39.2%		14.5%	16.0%	42.8%	26.7%	
Schools						<0.0001[c]					<0.0001[c]
Hua Luogeng (urban)	1044	11.2%	19.4%	29.6%	39.8%		11.2%	17.4%	47.1%	24.2%	
Hua Cheng (suburb)	897	9.1%	20.0%	28.5%	42.4%		9.1%	10.3%	29.2%	51.4%	
He Bin (suburb)	686	23.2%	21.0%	27.7%	28.1%		23.2%	15.0%	41.0%	20.9%	
Xue Bu (rural)	301	14.3%	25.9%	28.6%	31.3%		14.3%	11.3%	28.9%	45.5%	
Night time in bed[d]	9.34 ± 0.77	9.26 ± 0.87	9.40 ± 0.80	9.32 ± 0.74	9.35 ± 0.75	0.0041[b]	9.26 ± 0.87	9.35 ± 0.80	9.35 ± 0.72	9.36 ± 0.78	0.2540[b]

[a]χ^2 Test.
[b]Spearman's correlation.
[c]ANOVA.
[d]Night time in bed for 6th grade is 9.09 ± 0.78; 5th grade is 9.32 ± 0.72; and 4th grade is 9.65 ± 0.69.

napping 5–7 times per week and non-napping was statistically significant, with a mean score increase of 4.28 points ($p = 0.013$, $d = 0.39$) (Table 2). For duration, the difference between napping 31–60 minutes per nap and non-napping was also statistically significant, with a mean score increase of 3.58 points ($p = 0.037$, $d = 0.33$). For other frequency and duration groups, differences were not statistically significant. When frequency and duration groups were combined, the 5–7 frequent nappers with 31–60 minutes per nap had the best VIQ score mean which was five points higher than non-nappers ($p = 0.0129$, $d = 0.46$) (Table 3). After adjusting for grade, maternal education, and schools, these results remained significant. However, night in-bed time was not significant (Table 2). For the 6th graders, the mean difference between napper groups and non-nappers were larger ($d = 0.57$ for both 3–4 and 5–7 times per week, $d = 0.58/0.54$ for 31–60 and >60 minutes per nap, respectively) than for the whole sample (Table 4). However, for the 4th and 5th graders, there were no significant differences between nappers and non-nappers.

Performance IQ

The change in PIQ with napping had no clear direction and none of the mean differences were significant for nap frequency or duration, partially due to the large variation in PIQ across nap groups (Figure 2). These effects were adjusted for covariates, and the results remained insignificant in the multivariate models for sex, grade, and schools, but not maternal education or night in-bed time (Table 2). However, when combining both nap frequency and duration, the group with ≤2 naps per week and 31–60 minutes per nap showed the highest PIQ ($p = 0.0377$, $d = 0.42$) (Table 3). Stratified analyses in three grades showed no statistically significant differences in PIQ.

Academic achievement

Compared to non-nappers, nappers showed higher school academic achievement scores (Figure 2). For nap frequency, napping three or more times per week showed a statistically significant increase, with 5–7 times per week exhibiting score increases of up to 0.27 units ($p = 0.001$ for 3–4 naps per week, $d = 0.21$; $p < 10^{-4}$ for 5–7 naps per week, $d = 0.29$) (Table 2). For nap duration, napping more than 30 minutes per nap demonstrated a statistically significant increase, with 31–60 minutes per nap having a mean score increase of up to 0.22 units ($p < 10^{-4}$ for 31–60 minutes, $d = 0.23$ and $p = 0.0004$ for >60 minutes, $d = 0.21$) compared to non-napping. Furthermore, when nap frequency and duration were examined in combination, significant associations with academic achievement were found in those who napped longer than 30 minutes for 3–4 times per week ($p = 0.0020$, $d = 0.22$ for 31–60 minutes and $p = 0.0045$, $d = 0.22$ for >60 minutes) and 5–7 times per week ($p < 0.0001$, $d = 0.35$ for 31–60 minutes and $p = 0.0001$, $d = 0.27$ for >60 minutes) (Table 3). The model was adjusted for covariates including sex, grade, mothers' education, fathers' education, and night in-bed time, and all prior results remained

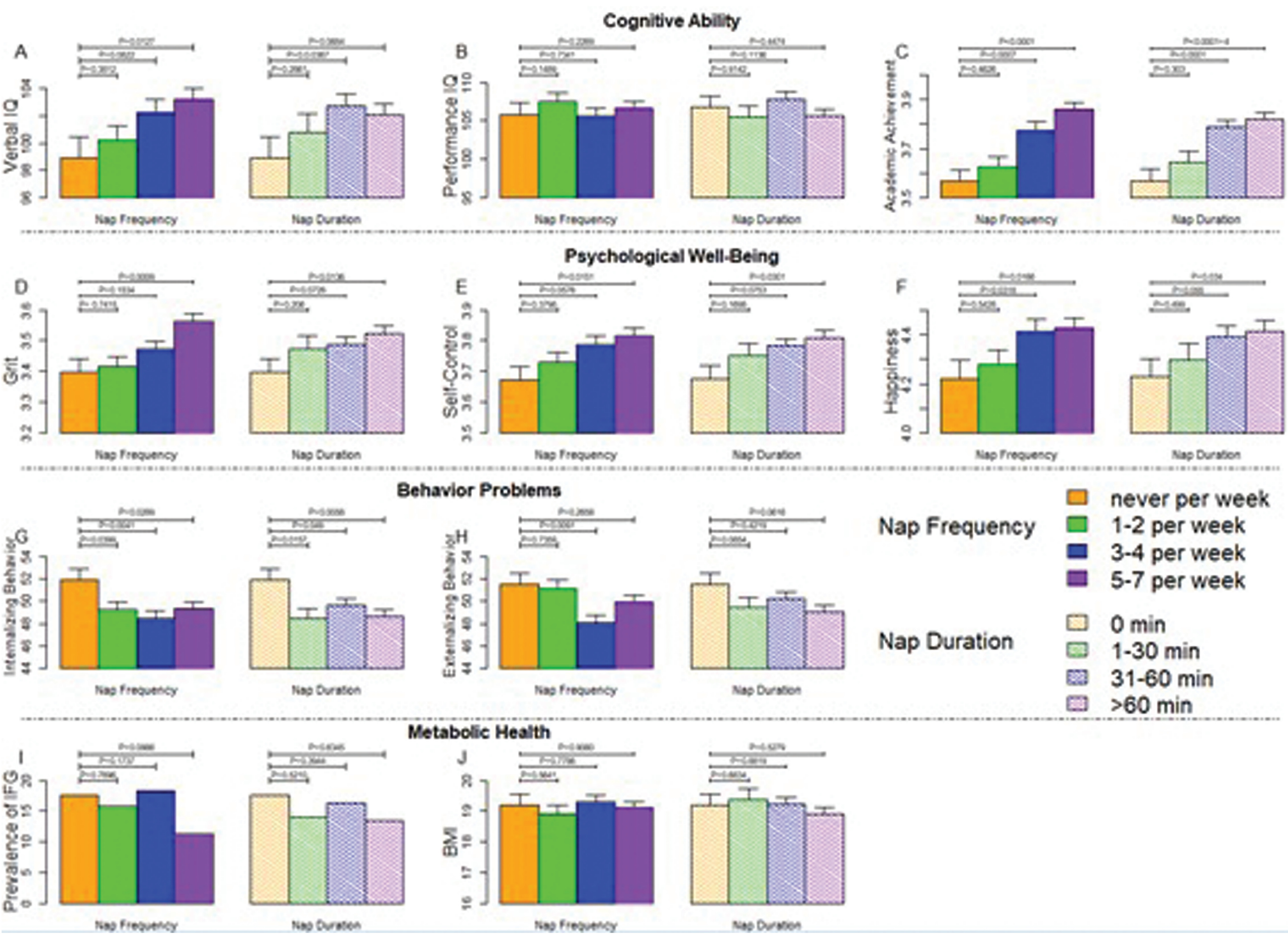

Figure 2. Nap frequency and duration on cognitive ability, psychological well-being, behavior problems, and metabolic health. Verbal IQ (A), Performance IQ (B), and Metabolic Health (I, J) were objective assessments. Academic Achievement (C) was based on standardized tests. Grit (D), Self-control (E), and Happiness (F) were self-reported. Internalizing (G) and Externalizing (H) Behavior were rated by teachers.

significant (Table 2). The grade-stratified analyses showed that for each grade, at least one frequency and one duration napper group showed significant differences from non-nappers; significant effect sizes were in scales that were comparable to those in the whole sample (Table 4). Specifically, for nap frequency, the most interesting result was that children in all three grades who consistently napped 5–7 times per week showed a statistically significant increase in academic achievement scores: for grade 4, up to $d = 0.33$ ($p = 0.002$), for grade 5, $d = 0.32$ ($p = 0.003$), for grade 6, $d = 0.22$ ($p = 0.042$), suggesting that a longer gap in time from baseline is associated with a higher achievement score. For nap duration, statistical significance varied across grades. Napping for >60 minutes in grades 5 and 6 was associated with a statistically significant increase in achievement, with a mean score increase of $d = 0.23$ for grade 6 ($p = 0.032$) and $d = 0.24$ for grade 5 ($p = 0.025$).

Association Between Nap and Psychological Well-Being

Grit

Mean self-reported grit scale scores were higher in nappers compared with non-nappers (Figure 2). Specifically, for frequency comparisons, the mean difference of 0.17 units between the most frequent nappers (5–7 times per week) and non-nappers was statistically significant ($p = 0.001$, $d = 0.29$) (Table 2). For duration comparisons, the mean difference of 0.13 between the longest average nap duration and non-nap was statistically significant ($p = 0.014$, $d = 0.22$). For other groups, mean grit scores were not statistically significant. When the frequency and duration groups were combined, most frequent nappers with 31–60 and >60 minutes had highest grit mean scores, 0.17 and 0.15 units higher than the non-nappers ($p = 0.0023$, $d = 0.29$ and $p = 0.0054$, $d = 0.26$), respectively (Table 3). Both maternal education and night in-bed time were also positively associated with grit. Additionally, grade-stratified analyses showed that for the 6th graders, the mean difference was $d = 0.38$ ($p = 0.0001$) between 5–7 times napper and non-nappers, and $d = 0.24$, 0.34 ($p = 0.015$, and 0.001) between 31–60, >60 minutes nappers and non-nappers, respectively (Table 4). There were no significant differences in grades 4 and 5.

Self-control

Similar to grit, only the differences between the most frequent nappers and non-nappers, and between the longest duration nappers and non-nappers were statistically significant (Figure 2).

Table 2. Regression coefficients/odds ratios, effect size (*p*-values) in the final regression models for each outcome

	Cognitive ability			Psychological well-being			Behavior problems		Metabolic health	
	Verbal IQ	Performance IQ	Academic achievement	Grit	Self-control	Happiness	Internalizing	Externalizing	IFG	BMI
Weekly nap frequency (Ref: Never)										
≤2	1.60, 0.15 (0.381)	2.64, 0.24 (0.149)	0.05, 0.05 (0.463)	0.02, 0.03 (0.742)	0.05, 0.10 (.0380)	0.06, 0.09 (.543)	−2.58, −0.28 (.040)	−0.42, −0.05 (.736)	0.96, −(.790)	−0.26, −0.08 (.564)
3–4	3.07, 0.28 (.082)	0.60, 0.06 (.734)	0.20, 0.21 (.001)	0.07, 0.12 (.153)	0.10, 0.18 (.058)	0.19, 0.29 (.032)	−3.43, −0.37 (.004)	−3.14, −0.34 (.009)	1.54, −(.174)	0.12, 0.04 (.779)
5–7	4.28, 0.39 (.013)	2.08, 0.19 (.227)	0.27, 0.29 ($<10^{-4}$)	0.17, 0.29 (.001)	0.12, 0.22 (.015)	0.20, 0.30 (.017)	−2.53, −0.28 (.029)	−1.31, −0.14 (.266)	0.79, −(.087)	−0.05, −0.02 (.906)
Night in-bed time				0.05, 0.09 (.009)	0.09, 0.16 ($<10^{-4}$)	0.09, 0.14 (.007)	−1.39, −0.15 (.005)			
Sex (boys)		4.07, 0.37 (.007)	−0.34, −0.36 ($<10^{-4}$)	−0.12, −0.21 ($<10^{-4}$)	−0.19, −0.35 ($<10^{-4}$)			3.20, 0.35 ($<10^{-4}$)	0.68, −(.026)	
Grade (ref: 4thgrade)										
5th	−3.02, −0.28 (.017)		0.14, 0.15 (.001)		−0.11, −0.20 (.046)		−2.64, −0.29 (.004)	0.71, 0.08 (.424)		
6th	−0.35, −0.03 (.775)		0.11, 0.12 (.011)		0.22, 0.40 ($<10^{-4}$)		−3.01, −0.33 (.001)	−4.71, −0.51 ($<10^{-4}$)		
Mother education (ref: < middle school)										
High school	2.80, 0.26 (.019)	2.64, 0.24 (.028)	0.06, 0.06 (.174)	0.09, 0.16 (.008)	0.07, 0.13 (.013)		−1.10, −0.12 (.193)			
College +	4.66, 0.43 (.001)	4.73, 0.43 (.001)	0.21, 0.22 (.001)	0.17, 0.29 ($<10^{-4}$)	0.15, 0.27 (.001)		−2.50, −0.27 (.005)			
Father education (ref: < middle school)										
High school			0.05, 0.05 (.316)							
College+			0.19, 0.20 (.002)							
School area (ref: Hua Luogeng)										
Hua Cheng	−2.57, −0.24 (.048)	−3.01, −0.28 (.020)	0.25, 0.27 ($<10^{-4}$)		−0.04, −0.07 (.372)			0.76, 0.08 (.372)	0.96, −(.959)	−0.53, −0.16 (.081)
He Bin	−3.52, −0.32 (.024)	0.43, 0.04 (.782)	0.08, 0.09 (.130)		−0.10, −0.18 (.020)			2.19, 0.24 (.038)	1.76, −($<10^{-4}$)	−0.84, −0.26 (.029)
Xue Bu	−7.27, −0.67 (.0002)	−8.22, −0.75 ($<10^{-4}$)	0.14, 0.15 (.054)		−0.01, −0.02 (.903)			0.33, 0.04 (.794)	2.97, −(.165)	−1.43, −0.44 (.001)
Average nap duration (ref: 0 minutes)										
1–30	2.15, 0.20(.286)	0.22, 0.02 (.914)	0.07, 0.07 (.303)	0.08, 0.14 (.206)	0.08, 0.15 (.170)	0.07, 0.10 (.499)	−3.30, −0.36 (.016)	−2.37, −0.26 (.085)	1.20, −(.521)	0.20, 0.06 (.683)
31–60	3.58, 0.33(.037)	2.70, 0.25 (.114)	0.22, 0.23 ($<10^{-4}$)	0.09, 0.16 (.073)	0.09, 0.16 (.075)	0.16, 0.24 (.055)	−2.28, −0.25 (.049)	−0.94, −0.10 (.422)	1.16, −(.394)	0.06, 0.02 (.882)
>60	3.18, 0.29(.068)	1.32, 0.12 (.447)	0.20,0.21 (.0004)	0.13, 0.22 (.014)	0.11, 0.20 (.030)	0.18, 0.27 (.034)	−3.19, −0.35 (.006)	−2.22, −0.24 (.062)	0.90, −(.635)	−0.27, −0.08(.528)
Night in-bed time				0.05, 0.09 (.014)	0.09, 0.16 ($<10^{-4}$)	0.09, 0.13 (.015)	−1.37, −0.15 (.006)			
Sex (boys)		4.28, 0.39 ($<10^{-4}$)	−0.35, −0.37 ($<10^{-1}$)	−0.13, −0.22 ($<10^{-4}$)	−0.19, −0.35 ($<10^{-4}$)			3.40, 0.37 ($<10^{-4}$)	0.70, −(.036)	
Grade (ref: 4th grade)										
5th	−2.94, −0.27 (.021)		0.14, 0.15 (.001)		−0.11, −0.20 (.044)		−2.52, −0.27 (.006)	0.95, 0.10 (.296)		
6th	−0.11, −0.01 (.930)		0.12, 0.13 (.006)		0.23, 0.42 ($<10^{-4}$)		−3.00, −0.33 (.001)	−4.81, −0.52 ($<10^{-4}$)		
Mother education (ref: < middle school)										
High school	2.87, 0.26 (.017)	2.58, 0.23 (.032)	0.07, 0.07 (.160)	0.10, 0.17 (.006)	0.09, 0.16 (.013)	0.08, 0.12 (.187)	−1.14, −0.12 (.174)			
College+	4.73, 0.43 (.001)	4.58, 0.42 (.001)	0.21, 0.22 (.001)	0.18, 0.31 ($<10^{-4}$)	0.14, 0.25 (.001)	0.13, 0.19 (.045)	−2.55, −0.28 (.004)			
Father education (ref: < middle school)										
High school			0.05, 0.05 (.348)							
College+			0.20, 0.21 (.001)							
School area (ref: Hua Luogeng)										
Hua Cheng	−2.46, −0.23 (.066)	−2.90, −0.27 (.028)	0.25, 0.27 ($<10^{-4}$)		−0.04, −0.07 (.305)			0.95, 0.10 (.275)	1.06, −(.931)	−0.43, −0.13 (.165)
He Bin	−3.76, −0.34 (.016)	0.26, 0.02 (.865)	0.07, 0.07 (.178)		−0.10, −0.18 (.015)			2.10, 0.23 (.047)	1.86, −($<10^{-4}$)	−0.84, −0.26 (.028)
Xue Bu	−7.56, −0.69 (.0002)	−8.12, −0.74 ($<10^{-4}$)	0.12, 0.13 (.091)		−0.02, −0.04 (.734)			0.62, 0.07 (.632)	3.17, −(.091)	−1.38, −0.42 (.002)

Shaded cells correspond to insignificant covariates that were not included in the final model.

Table 3. Adjusted outcome difference/odds ratios, effect size (*p*-values) between napper groups and non-nappers

Weekly nap frequency	Average nap duration (minutes)	Cognitive ability			Psychological well-being			Behavior problems		Metabolic health	
		Verbal IQ	Performance IQ	Academic achievement	Grit	Self-control	Happiness	Internalizing	Externalizing	IFG	BMI
Never	0	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
≤2	1–30	2.22, 0.20 (0.3768)	1.70, 0.16 (0.4987)	0.01, 0.01 (0.8921)	−0.04, −0.07 (0.6498)	0.04, 0.07 (0.6164)	0.05, 0.07 (0.7029)	−2.58, −0.28 (0.1413)	−1.03, −0.11 (0.5557)	0.79, −(0.6970)	−0.15, −0.05 (0.8182)
≤2	31–60	0.20, 0.02 (0.9287)	4.60, 0.42 (0.0377)	0.05, 0.05 (0.4891)	0.02, 0.03 (0.8175)	0.02, 0.04 (0.7021)	0.10, 0.15 (0.4091)	−1.23, −0.13 (0.4228)	1.34, 0.15 (0.3840)	0.98, −(0.9679)	−0.72, −0.22 (0.1962)
≤2	>60	2.60, 0.24 (0.2856)	1.70, 0.16 (0.4839)	0.06, 0.06 (0.5118)	0.07, 0.12 (0.3459)	0.09, 0.16 (0.2174)	−0.03, −0.04 (0.7860)	−4.48, −0.49 (0.0087)	−2.34, −0.25 (0.1710)	0.53, −(0.2436)	0.23, 0.07 (0.7066)
3–4	1–30	0.51, 0.05 (0.8595)	−2.31, −0.21 (0.4200)	0.14, 0.15 (0.1402)	0.14, 0.24 (0.0958)	0.10, 0.18 (0.2161)	0.09, 0.13 (0.5396)	−2.93, −0.32 (0.1317)	−4.10, −0.45 (0.0350)	2.86, −(0.0551)	0.32, 0.10 (0.6593)
3–4	31–60	4.83, 0.44 (0.0187)	1.47, 0.13 (0.4729)	0.21, 0.22 (0.0020)	0.04, 0.07 (0.5516)	0.10, 0.18 (0.0923)	0.19, 0.28 (0.0762)	−3.79, −0.41 (0.0077)	−3.31, −0.36 (0.0196)	0.99, −(0.9765)	0.42, 0.13 (0.4095)
3–4	>60	2.30, 0.21 (0.2905)	0.13, 0.01 (0.9513)	0.21, 0.22 (0.0045)	0.10, 0.17 (0.1117)	0.10, 0.18 (0.1338)	0.19, 0.28 (0.0885)	−3.26, −0.35 (0.0233)	−2.62, −0.28 (0.0703)	0.86, −(0.7386)	−0.28, −0.09 (0.5901)
5–7	1–30	4.24, 0.39 (0.1753)	1.58, 0.14 (0.6134)	0.11, 0.12 (0.2848)	0.18, 0.31 (0.0519)	0.13, 0.24 (0.1546)	0.05, 0.07 (0.7186)	−4.79, −0.52 (0.0179)	−2.49, −0.27 (0.2194)	[a]	0.64, 0.20 (0.3832)
5–7	31–60	5.00, 0.46 (0.0129)	2.07, 0.19 (0.3017)	0.33, 0.35 (<0.0001)	0.17, 0.29 (0.0023)	0.12, 0.22 (0.0406)	0.15, 0.22 (0.1216)	−1.68, −0.18 (0.2214)	−0.37, −0.04 (0.7880)	0.55, −(0.1636)	0.24, 0.07 (0.6204)
5–7	>60	3.74, 0.34 (0.0485)	2.01, 0.18 (0.2889)	0.25, 0.27 (0.0001)	0.15, 0.26 (0.0054)	0.13, 0.24 (0.0241)	0.24, 0.36 (0.0135)	−2.71, −0.29 (0.0365)	−1.85, −0.20 (0.1619)	0.73, −(0.4585)	−0.42, −0.13 (0.3637)

[a]No subjects in that group had prediabetes, merged it into next group; all adjusted covariates are the same in Table 2.

Table 4. Regression coefficients/odds ratios, effect size (p-values) for each outcome for each grade, adjusted for the same covariates (except grade) as in Table 2

		N	Cognitive ability			Psychological well-being			Behavior problems		Metabolic health	
			Verbal IQ	Performance IQ	Academic achievement	Grit	Self-control	Happiness	Internalizing	Externalizing	IFG	BMI
	Weekly nap frequency (Ref: Never, n = 130)											
Grade 6	≤2	201	5.17, 0.43 (0.132)	1.30, 0.11 (0.701)	−0.02, −0.02 (0.872)	0.10, 0.18 (0.098)	0.15, 0.27 (0.028)	0.08, 0.12 (0.589)	−4.75, −0.54 (0.016)	−3.71, −0.49 (0.029)	0.52, −(0.516)	0.31, 0.09 (0.678)
	3–4	317	6.91, 0.57 (0.025)	−0.15, −0.01 (0.960)	0.08, 0.08 (0.449)	0.10, 0.18 (0.079)	0.14, 0.25 (0.027)	0.22, 0.32 (0.114)	−1.33, −0.15 (0.441)	−2.72, −0.36 (0.069)	1.11, −(0.898)	0.44, 0.13 (0.516)
	5–7	437	6.87, 0.57 (0.021)	−0.83, −0.07 (0.775)	0.21, 0.22 (0.042)	0.21, 0.38 (0.0001)	0.16, 0.29 (0.008)	0.15, 0.22 (0.242)	−2.43, −0.28 (0.151)	−3.30, −0.44 (0.024)	0.52, −(0.424)	0.31, 0.09 (0.637)
	Average nap duration (ref: 0 minutes, n = 130)											
	1–30	136	5.31, 0.44 (0.143)	1.17, 0.10 (0.741)	−0.07, −0.07 (0.591)	0.10, 0.18 (0.150)	0.13, 0.23 (0.065)	0.05, 0.07 (0.732)	−2.29, −0.26 (0.254)	−3.65, −0.48 (0.033)	0.57, −(0.653)	1.43, 0.43 (0.067)
	31–60	454	7.01, 0.58 (0.019)	1.32, 0.11 (0.648)	0.09, 0.09 (0.370)	0.13, 0.24 (0.015)	0.13, 0.23 (0.029)	0.19, 0.28 (0.155)	−3.67, −0.42 (0.032)	−3.37, −0.45 (0.022)	0.43, −(0.336)	0.07, 0.02 (0.913)
	>60	365	6.52, 0.54 (0.031)	−2.20, −0.19 (0.454)	0.22, 0.23 (0.032)	0.19, 0.34 (0.001)	0.18, 0.32 (0.003)	0.19, 0.28 (0.148)	−1.32, −0.15 (0.438)	−2.75, −0.37 (0.062)	0.89, −(0.878)	0.20, 0.06 (0.760)
	Weekly nap frequency (Ref: Never, n = 129)											
Grade 5	≤2	218	0.42, 0.04 (0.880)	4.34, 0.42 (0.126)	0.19, 0.21 (0.055)	−0.09, −0.14 (0.570)	−0.08, 0.14 (0.548)	0.20, 0.31 (0.226)	−4.03, −0.43 (0.072)	−0.48, −0.05 (0.850)	3.01, −(0.002)	0.43, 0.13 (0.607)
	3–4	251	−0.63, −0.06 (0.829)	−3.10, −0.30 (0.297)	0.29, 0.32 (0.004)	0.09, 0.14 (0.548)	0.07, 0.13 (0.627)	0.16, 0.25 (0.339)	−7.33, −0.79 (0.002)	−6.29, −0.60 (0.014)	4.51, −(0.328)	0.72, 0.22 (0.394)
	5–7	309	3.54, 0.35 (0.205)	4.99, 0.49 (0.080)	0.29, 0.32 (0.003)	0.28, 0.44 (0.057)	0.22, 0.39 (0.111)	0.43, 0.67 (0.008)	−6.47, −0.70 (0.003)	−4.23, −0.40 (0.083)	1.11, −(0.927)	−0.10, −0.03 (0.906)
	Average nap duration (ref: 0 minutes, n = 129)											
	1–30	162	1.75, 0.17 (0.557)	−0.89, −0.08 (0.775)	0.20, 0.22 (0.067)	0.19, 0.29 (0.246)	0.09, 0.16 (0.557)	0.26, 0.40 (0.146)	−6.42, −0.69 (0.007)	−4.60, −0.43 (0.087)	3.70, −(0.254)	−0.05, −0.02 (0.955)
	31–60	306	0.59, 0.06 (0.832)	4.06, 0.38 (0.160)	0.33, 0.37 (0.001)	0.14, 0.22 (0.360)	0.12, 0.21 (0.367)	0.31, 0.48 (0.064)	−4.03, −0.43 (0.068)	−1.22, −0.11 (0.622)	2.59, −(0.002)	0.56, 0.17 (0.489)
	>60	310	1.62, 0.16 (0.576)	3.95, 0.37 (0.190)	0.22, 0.24 (0.025)	0.02, 0.03 (0.900)	−0.04, −0.07 (0.783)	0.36, 0.55 (0.031)	−7.19, −0.77 (0.001)	−5.16, −0.48 (0.035)	1.88, −(0.581)	0.35, 0.11 (0.676)
	Weekly nap frequency (Ref: Never, n = 142)											
Grade 4	≤2	185	0.50, 0.05 (0.892)	2.67, 0.27 (0.470)	−0.04, −0.04 (0.676)	−0.28, −0.43 (0.095)	−0.25, −0.49 (0.063)	−0.07, −0.11 (0.693)	−0.41, −0.04 (0.869)	2.48, 0.26 (0.305)	0.55, −(0.292)	−1.74, −0.54 (0.040)
	3–4	273	4.04, 0.40 (0.259)	2.87, 0.29 (0.424)	0.19, 0.21 (0.053)	−0.11, −0.17 (0.(0. (0.500)	−0.05, −0.10 (0.707)	0.14, 0.21 (0.396)	−3.11, −0.32 (0.196)	−0.98, −0.10 (0.675)	0.72, −(0.529)	−1.02, −0.32 (0.208)
	5–7	336	4.79, 0.48 (0.185)	0.57, 0.06 (0.875)	0.30, 0.33 (0.002)	−0.19, −0.29 (0.244)	−0.15, −0.30 (0.240)	0.08, 0.12 (0.591)	0.17, 0.02 (0.942)	3.19, 0.34 (0.159)	0.39, −(0.081)	−0.94, −0.29 (0.242)
	Average nap duration (ref: 0 minutes, n = 142)											
	1–30	113	0.76, 0.08 (0.871)	3.03, 0.30 (0.519)	0.07, 0.08 (0.579)	−0.17, −0.26 (0.416)	−0.23, −0.44 (0.171)	−0.03, −0.05 (0.878)	−1.92, −0.20 (0.530)	1.79, 0.19 (0.553)	0.70, −(0.590)	−1.07, −0.33 (0.289)
	31–60	362	4.70, 0.46 (0.190)	1.85, 0.18 (0.602)	0.25, 0.27 (0.008)	−0.23, −0.35 (0.155)	−0.15, −0.29 (0.250)	0.03, 0.05 (0.844)	0.27, 0.03 (0.909)	2.14, 0.22 (0.350)	0.66, −(0.421)	−0.65, −0.20 (0.408)
	>60	319	2.36, 0.23 (0.503)	2.17, 0.21 (0.538)	0.14, 0.14 (0.156)	−0.15, −0.23 (0.334)	−0.12, −0.23 (0.336)	0.06, 0.09 (0.719)	−2.23, −0.23 (0.339)	1.23, 0.13 (0.592)	0.38, −(0.073)	−1.75, −0.55 (0.026)

Specifically, for frequency, the mean score was 0.12 units higher for those who napped 5–7 times per week (p = 0.015, d = 0.22) (Table 2). For duration, the mean score was 0.11 units higher for those who napped >60 minutes per nap (p = 0.030, d = 0.20), after adjusting for gender, in-bed time, and mother's education. For other frequency and duration groups, the difference from non-nappers was not significant. When frequency and duration groups were combined, the most frequent nappers with 31–60 and >60 minutes per nap had better self-control, with means of 0.12 and 0.13 units higher than non-nappers (p = 0.0406, d = 0.22 and p = 0.0241, d = 0.24, respectively) (Table 3). In addition, grade-stratified analyses showed that in 6th graders, the mean difference was d = 0.25–0.29 (p = 0.008–0.028) between each frequency napping group and non-nappers, all of which were significant; there were significant differences of d = 0.23 (p = 0.029) and 0.32 (p = 0.003) between the 31–60 and >60 minutes group and non-nappers, respectively (Table 4). Again, there were no significant differences in grades 4 and 5.

Happiness

Happiness scale scores increased with both nap frequency and nap duration compared with the non-nappers (Figure 2). For frequency comparisons, the differences between napping 3–4 times per week showing score increases of 0.19 units (p = 0.032, d = 0.29), and 5–7 times per week showing score increases of 0.20 units (p = 0.017, d = 0.30) (Table 2). For duration, the difference between napping over 60 minutes per nap and non-nappers was also statistically significant, with a mean score increase of 0.18 units (p = 0.034, d = 0.27). For other frequency and duration groups, the mean happiness scale score was not statistically significant. When frequency and duration groups were combined, the difference of happiness scores between children with 5–7 naps per week and >60 minutes for each nap was significantly higher than the non-nappers, with a mean score increase of 0.24 units (p = 0.0135, d = 0.36) (Table 3). Grade-stratified analyses showed a significant difference between the most frequent group and non-nappers (p = 0.008, d = 0.67), and the longest duration group and non-nappers (p = 0.031, d = 0.55) in the 5th graders (Table 4). There was no significant difference for the 4th or 6th graders, although effects sizes for grade 6 were very close to the whole sample.

Association Between Nap and Emotional/ Behavior Problems

Internalizing behavior problem

Compared to non-nappers, nappers had statistically significant lower teacher-reported internalizing behavior scores across all frequency and duration groups (Figure 2). Specifically, for frequencies, the mean scores were 2.58, 3.43, and 2.53 units lower for those who napped ≤2, 3–4, 5–7 times, respectively (p = 0.040, d = −0.28; p = 0.004, d = −0.37; and p = 0.029, d = −0.28, respectively) (Table 2). For duration, the mean scores were 3.30, 2.28, and 3.19 units lower for those who napped 1–30, 31–60, and >60 minutes per nap (p = 0.016, d = −0.36; p = 0.049, d = −0.25; and p = 0.006, d = −0.35, respectively). When frequency and duration categories were combined, students who napped 5–7 times for 1–30 minutes per nap had the lowest average internalizing behavior score, which was 4.79 (p = 0.0179, d = −0.52) units lower than non-nappers (Table 3). Furthermore, grade-stratified analyses showed that for grade 5, two frequency (3–4 [p = 0.002, d = −0.79] and 5–7 [p = 0.003, d = −0.70] times) and two duration (1–30 [p = 0.007, d = −0.69], >60 minutes [p = 0.001, d = −0.77]) napper groups had significantly better scores than non-nappers (Table 4). For grade 6, one frequency (≤2 times, p = 0.016, d = −0.54) and one duration (31–60 minutes, p = 0.032, d = −0.42) had significantly better scores than non-nappers. For grade 4, there were no significant differences between any napper groups and non-nappers.

Externalizing behavior problem

Similar to internalizing behavior problems, there were lower externalizing behavior scores among napper versus non-nappers, although not all findings were statistically significant (Figure 2). Specifically, for frequency comparisons, napping 3–4 times per week showed a statistically significant decrement of 3.14 units (p = 0.0091, d = −0.41), while other frequency group comparisons were nonsignificant (Table 2). Furthermore, no duration comparisons were statistically significant. However, when frequency and duration groups were combined, there was a variation in externalizing behavior scores across groups (Table 3). Students who napped 3–4 times for 1–30 minutes (p = 0.0350, d = −0.45) and 31–60 minutes per nap (p = 0.0196, d = −0.36) had the best average reduction in externalizing behavior scores, being up to 4.1 units lower than the non-napper group (Table 3). Furthermore, grade-stratified analyses showed that for grade 6, two frequency (≤2 [p = 0.029, d = −0.49] and 5–7 [p = 0.024, d = −0.44] times) and two duration (1–30 [p = 0.033, d = −0.48], 31–60 [p = 0.022, d = −0.45] minutes) napper groups had significantly better scores than non-nappers (Table 4). For grade 5, one frequency (3–4 times, p = 0.014, d = 0.60) and one duration (>60 minutes, p = 0.035, d = −0.48) had significantly better scores than non-nappers. For grade 4, there was no significant difference between any napper group and non-nappers.

Association Between Nap and Metabolic Health

For IFG, there were no significant differences (all p values >0.05) among all frequency and duration groups compared with the never-napped group (Figure 2). Nappers with different frequencies (ORs = 0.96, 1.54, 0.79) and lengths (ORs = 1.20, 1.16, 0.90) showed a mixed trend of IFG risk as relative to non-nappers, although magnitudes were small and lacked statistical significance (Table 2). Similarly, neither nap frequency nor duration was associated with BMI in our sample (all p > 0.05). However, grade-stratified analyses showed that BMI was statistically significant for frequency of <2 (p = 0.040, d = −0.54) and duration of >60 minutes (p = 0.026, d = −0.55) in grade 4, indicating that some napping and longer nap duration may be associated with lower BMI (Table 4). There were no significant changes for grades 5 and 6. For IFG, there were no significant associations among any napper group and non-nappers except for one frequency (<2 times, OR = 3.0, p = 0.002) and one duration (31–60 minutes, OR = 2.6, p = 0.002) group in grade 5 that had significantly higher IFG risks than non-nappers. There were no significant differences in IFG risk between any napper group and non-nappers for grades 4 and 6. All the above analyses were replicated by adjusting and without adjusting night time in bed, in addition to other relevant covariates, and the results were consistent (Table 2 and Supplementary Table 2).

The Conditional Independent Effect of Night Time in Bed

Longer night time in bed was associated with a lower level of internalizing behavior problems ($\beta = -1.39$ and $p = 0.005$ when controlling for nap frequency and other covariates; or $\beta = -1.37$ and $p = 0.006$ when controlling for nap duration and other covariates), and higher levels of grit ($\beta = 0.05$, $p = 0.009$ or 0.014), self-control ($\beta = 0.09$, $p < 0.0001$) and happiness ($\beta = 0.09$, $p = 0.007$ or 0.015). The effect of napping on outcomes had little change with and without adjustment for night time in bed (Table 2 and Supplementary Table 2).

Discussion

The key findings from this study of 3819 school children are that overall, napping is better than not napping with regards to academic achievement, higher VIQ scores, more positive psychological well-being, and reduced internalizing behavioral problems. However, the exact pattern varied with specific outcomes based on nap frequency and duration, or a combination of the two, as indicated in Tables 2 and 3 and Figure 2. More limited significant associations were found for externalizing behavior problem and metabolic health, compared to non-nappers. Results remained significant after adjusting for sociodemographic variables. Overall results from stratification analyses on grades 4, 5, and 6 showed variations in the napping effects, although concurrent findings for napping (grade 6) were associated with most of the outcomes (except for happiness) and were largely consistent with results based on the entire sample, suggesting that nap habits from one (grade 5) or 2 years (grade 4) in the past is less associated with the present day outcomes. Although such findings might be limited by the smaller sample sizes in stratified analyses, the larger concurrent effects suggest that even if children did not nap previously, starting a new regimen of taking naps can improve outcomes. Interestingly, while concurrent measurements of napping on other outcomes in grade 6 were more pronounced than in grades 4 and 5, academic achievement was the exception: napping 5–7 times per week showed significant increases in academic achievement scores across all three grades, with a longer time gap resulting in the highest scores.

Results were unchanged after adjusting for time in bed at night (Supplementary Table 2). In addition, time in bed at night was associated with reduced internalizing behavior and better psychological well-being independent of napping behavior. Overall, frequent napping was not the result of insufficient nighttime sleep. We found in our sample that frequent napping is more prevalent in girls and in children with parents with college education or higher. To our knowledge, these epidemiological findings are the first and largest to show that napping is associated with a wide range of positive outcomes in schoolchildren.

Moreover, in contrast to the standard trend in Western countries and other parts of the world to stop napping around preschool, we found in our sample that frequent napping is more prevalent among 6th graders than 4th and 5th graders. Furthermore, 6th graders were more prevalent in the 31- to 60-minute nap duration group compared with the other two grades, although interestingly, 4th graders also had a longer nap duration compared to 5th graders. In China, 6th grade is the final year of elementary school and consequently, 6th graders typically experience the academic pressure of preparing for middle school entry exams. For example, 6th graders are required to stay after school until the late evening to review for these entry exams. As a result, 6th graders may need to nap more frequently during the day to be prepared for their extended academic day. This academic pressure might also explain the decreasing nighttime in-bed from 4th to 6th grade as they advanced through school. On the other hand, the decreased nighttime in-bed could be a result of age [61, 62]. Alternatively, more frequent napping among 6th graders could be a result of shorter nighttime in-bed.

The robustness of our findings is demonstrated in several ways. First, our nap assessment included both frequency and duration, which independently contributed to several outcome measures, which was also confirmed by our combination of frequency and duration analysis. Second, multiple measures were implemented for each outcome to demonstrate construct validity. For example, psychological well-being was assessed by three separate validated measures. Similarly, cognitive functioning was objectively assessed by comprehensive IQ tests, and academic achievement was based on standardized test scores, which avoid self-report response bias. Likewise, child and adolescent behavior were assessed by teachers rather than by self-report. The fact that significant findings were obtained for some of the objective and subjective indicators is viewed as a strength. Third and most importantly, the associations between napping and reduced behavioral problems and enhanced psychosocial well-being were consistent whether controlling for time in bed at night or not, suggesting that frequent napping may contribute independently to child health and development, and does not function as a compensatory measure for insufficient nighttime sleep, as previously suggested [35].

Napping Effects on Cognitive Ability and Academic Achievement

Our study demonstrates that the effect of napping on cognitive ability is evident in VIQ, with a moderate effect size for children who napped most frequently. This is particularly notable for cross-sectional analysis on the 6th graders, showing that students who had nap frequency of only three times or more per week or napped longer than an average of 31 minutes demonstrated a VIQ increase of up to 7 points. Nap benefits for memory have been consistently shown in laboratory studies of young adults [27, 63–65]. For children and adolescents, however, previous studies were limited to experimental observations of toddlers and younger children, with inconsistent findings. For example, Kurdziel *et al.* found that classroom naps in preschoolers benefited learning by enhancing memories, with a stronger effect in habitual napping [30]. Interestingly, although Sandoval *et al.* found no difference between non-habitual and habitual nappers, they did find that successful verb generalization occurred only if toddlers napped after learning [31]. On the other hand, others have shown that napping in preschoolers is associated with decreased nighttime sleep and lower performance on language learning and memory, which the authors interpret to imply less mature brain development in nappers [32, 35]. The mixed findings have been criticized for not controlling for either nighttime sleep or sociodemographic variables, and only focusing on a simple or single aspect of cognition. To better address this issue, the current study examined the effect of habitual napping in school children on both their trait intelligence (IQ) and applied cognitive ability (school academic achievement), and adjusted for sociodemographic variables and time in bed at night.

Notably, no obvious association between napping frequency/duration and PIQ was observed. Several factors may account for this null result. First, napping may have a stronger effect on applied intelligence (day to day academic achievement) which may be influenced more by daily sleep than trait IQ, which in relative terms may have a somewhat stronger genetic contribution. In this context, Tucker *et al.* [66] showed no correlation between nap sleep and verbal and PIQ, but did find a strong association between napping and both verbal and motor learning. Second, the null result in the current study may also be due to the coarse measure of sleep used and the lack of EEG, which would have allowed for the analysis of sleep spindles. Prior studies have found a correlation between sleep spindles and measures of verbal memory [67], visuospatial memory [68], selective attention [69, 70]), and fluid intelligence [71]. More research into the role of sleep for intelligence in general, and thalamocortical tract efficiency as reflected by spindle activity specifically, is needed. Lastly, our sample exhibited a large variation in PIQ across nap groups, which may contribute to the nonsignificance of napping on PIQ scores. However, when the frequency and duration combination was examined, the group of ≤2 naps per week and 31–60 minutes per nap showed statistical significance. The exact phenomenon is not well-understood.

For academic achievement in our study, children who napped 3 times or more per week or longer than an average of 31 minutes demonstrated an academic achievement increase of up to 0.27 units, representing a 7.6% increase. The academic achievement score increased even more, up to 0.22 (5.4% increase) and 0.33 (8.2% increase) units, when children napped 5–7 times per week, measured 1 (5th graders) and 2 (4th graders) years prior respectively. One prior meta-analysis reported an association between sleepiness and poor school performance [14]. There are few prior studies for napping on academic achievement. However, most of them used single-question self-reports on academic achievement and only focused on nap frequency. These studies demonstrated either null or nonsignificant findings, which may be due to a lack of standardized assessment of academic achievement or a lack of adjustment for nighttime sleep and other covariates [40, 41]. Here, we addressed these methodological issues by using teacher-reported academic achievement (based on standardized test scores) that derived a composite score from four core subjects (Chinese, Math, English, and Social Science). Furthermore, our data included two dimensions of napping (frequency and duration), with findings suggesting that maximal benefits are obtained from high frequency combined with a longer duration. Taken together, our results suggest that daytime napping has a positive benefit on multiple cognitive domains, and further research into the mechanisms underlying this facilitation effect is needed.

Napping Effects on Positive Psychological Well-Being

The effects of napping on psychological well-being (as measured by grit, self-control, and happiness in our study) have rarely been investigated. Interestingly, our study shows that children who napped the greatest frequency per week and the longest duration per nap demonstrated significant increases across all three measures, with effect sizes of approximately d = 0.3. In one study of nap-restricted toddlers, behavioral self-regulation, attention, and positive emotions were reduced [33, 34]. Although the impact of napping on grit has not been investigated, one recent study examining the effect of napping on motivation in young adults reported an inverse relationship [72]. However, this study was limited to a small sample of primarily female participants, and did not control for nighttime sleep, which may explain the negative findings. For happiness, several adult studies have reported that daytime napping elevates positive mood, joy and relaxation, and decreases sadness and anger [29, 73]. Conversely, toddlers missing one afternoon-nap show increased negative facial emotion displays [34]. Nevertheless, all these studies are based on non-habitual naps in the laboratory or an experimental setting, and only test one aspect of positive psychology. In our study, we adopted a whole-spectrum approach to assessing psychological well-being and found better grit, self-control, and happiness among habitual nappers as compared to non-nappers. Particularly, the most frequent nappers (5–7 times/week) and the longest duration (>60 minutes) of nappers had better overall psychological well-being than non-nappers. One caveat is that for cross-sectional 6th-grade analysis, we did not find significant results for happiness. This may be due to the academic pressure of preparing for middle school entry exams in 6th grade. While grade-stratified analyses for 4th and 5th graders did not show a significant difference of napping on grit and self-control, the increase in happiness was significant for grade 5. These intriguing results require further experimental testing to tease apart the contribution of culture and other factors that may influence napping behavior and its benefits.

Napping Effects on Emotional and Behavioral Problems

Previous studies on napping and emotional/behavioral problems have been limited to young children, with conflicting findings. Some small-sample experimental studies found that acute daytime sleep restriction in habitually napping preschoolers is associated with impaired self-regulation and emotion processing [33, 34, 74], which are risk factors for child behavior problems [75]. Interestingly, two epidemiological studies found no significant relationship between napping and behavior problems in preschoolers [39], which could be due to a lack of consistency in nap assessment and not controlling for covariates [38]. Furthermore, there may be delayed benefits that were not measured [38]. In all cases, time in bed at night, which has been implicated in behavioral problems, was not controlled. In addressing these issues, our study targeted older children and the preadolescent age group using consistent nap groupings (30-minute intervals) and adjusted for both nighttime sleep and social demographics. We found that the habitual nappers with any napping frequency and duration, compared with non-nappers, showed less teacher-rated internalizing behavior problems. For externalizing behavior, significance was only observed in those who napped 3–4 times a week in whole sample analysis. Grade-stratified analysis also revealed variable patterns of napping on both internalizing and externalizing behavior problems, though with some duration and frequency nappers among 5th and 6th graders showing significant reductions in behavior scores compared to non-nappers. Such variation in results for behavioral problems indicates the need for further research to consider a variety of factors, including children's developmental stage as well as pressures from the external environment. Overall, these associations not only support the notion that napping is linked with less emotional and behavioral problems, but also strongly support the investigation of targeted nap interventions for children and adolescents with behavioral problems. Indeed, prior experimental work that increased nighttime sleep in adolescents reported significant decreases in behavior problems associated with attention deficit hyperactivity disorder [76].

It has been suggested that napping may compensate for sleep insufficiency [20, 77], which has been linked to increased emotional lability and impulsivity, slowed reaction times in children [78, 79] and criminal behavior in adults [16]. However, in our study, the significant effects of napping on preadolescent behavior were observed even after adjusting for nighttime sleep duration, highlighting the benefits of napping on behavioral development independent of nighttime sleep. Since we also found that night in-bed time was significantly associated with reduced internalizing behavior, which is consistent with previous studies [11, 80], and that the effects of napping on internalizing behavior was attenuated by night in-bed time, it possible that nighttime sleep may play a more critical role in the reduction of emotional problems than daytime napping.

Napping Effects on Metabolic Health

We did not find significant associations of nap duration/frequency with IFG among school children in the whole sample. While prior research has supported the cognitive benefits of napping, the impact of habitual daytime napping on metabolic health has been controversial. Daytime napping has been associated with increased risk for impaired glucose metabolism and diabetes [36], microvascular disease [81], and metabolic syndrome [37] in adults. Yamada and colleagues further examined the dose-response relationship and reported that napping up to about 40 minutes/day showed no association with the risk of developing type 2 diabetes or metabolic syndrome versus no nap, followed by a sharp increase in risk at longer nap times [37]. Such adverse effect was not present in the whole sample, but it was evident in the 5th graders of our study. It could be that physiological responses to napping behaviors may differ by developmental stages. Additionally, given that our sample were healthy school children, the lack of variability in metabolic outcomes as a function of napping may produce different results with other populations elsewhere. To our knowledge, this is the first study to examine the effect of napping on blood glucose in this population.

Although there were no significant associations between napping and BMI in the whole sample, in the subgroup of 4th graders, participants who napped on average at least 60 minutes or <2 times/week had lower BMI than non-nappers. Prior evidence for daytime napping and BMI remains limited and inconsistent. A case-control study reported higher odds ratios of overweight/obesity among those with a napping habit versus non-nappers [82]. Conversely, other studies in younger children have not found significant relationships between daytime napping and subsequent obesity [83, 84]. To our knowledge, this is one of the first studies to examine the nap-BMI association in a preadolescent age group. Despite the significant findings in 4th graders, the nap group with the highest average BMI (1–30 minutes and 5–7 times/week) of (19.29 ± 0.39) was within the normal BMI range for children of the same age in the United States (16.44–21.02), as well as nearly 5 units below the overweight reference range (24–28) for Chinese children [85]. Additionally, the significant association was not present in the whole sample of this study. Thus, the clinical implication of our findings is inconclusive. More research is needed to understand the role of napping on cardio-metabolic risk factors among children and adolescents.

Possible Mechanisms

Although the exact mechanism(s) of these positive nap effects are not known, we propose several candidate factors, including (1) physiological functions, (2) psychological functions, and (3) moderation by cultural norms. Regarding physiological functioning, circadian and sleep homeostatic regulation on sleep functions may play a role. One meta-analysis compared the effect of sleep indicators on school performance and showed that daytime sleepiness revealed the strongest negative impact on performance, followed by sleep duration and sleep quality [14]. As such, one potential mechanism for the nap-school performance link may be via reduced daytime sleepiness, since timing of the nap (12:00 to 02:00 pm) in our study approached the peak of daytime sleepiness [20, 28, 86]. In addition, we found that optimal academic achievement and positive psychology was associated with longer naps (31–60 minutes and >60 minutes, respectively), and most frequent napping (5–7 times/week). These results are confirmed when combining frequency and duration grouping, as indicated in Table 3. This suggests that higher nap frequency and duration additionally influence outcome measures. Generally, naps between 31–60 minutes during this time of day provide a substantial amount of NREM deep sleep, and naps longer than 60 minutes include dream-rich REM sleep [87]. Prior studies have demonstrated a wide range of cognitive benefits from naps with both NREM and REM sleep [64, 88, 89]. Our current findings suggest that along with these known increases to cognition, naps with NREM and REM sleep may also benefit psychological and emotional domains, a notion supported by current theories of emotional processing during REM sleep [90].

Second, the relationship between habitual napping and positive psychology outcomes may also be explained by adolescents' own traits of regularity and routineness. For example, people high in the personality trait "conscientiousness" live longer lives because they engage in more health-promoting behaviors, including more physical activity, healthier diets, lower substance use, and fewer risky behaviors [91], and because they have more stable relationships and better integration into their communities [92]. Furthermore, highly conscientiousness individuals have better sleep, including good sleep hygiene, high sleep quality, and decreased sleepiness, consistent with other research on predictors of poor health and mortality risk. In addition, studies have shown that individuals who have regularity and rituals in their daily lives have been shown to have better grit, self-control, and greater happiness [93, 94]. For napping practices, regularity could be a trait that predisposes some people to nap more, and this napping may further enhance regularity and positive psychology measures. The current data may contribute to this consideration by adding napping as a daily health ritual that promotes a range of psychosocial benefits. Nevertheless, the directionality of effects cannot be teased out in this study.

Third, cultural norms or tradition practice could constitute another influence [95]. Cultural values and expectations play a role in the degree to which an action will have a negative or positive effect on an individual inside that culture. For example, while parental corporal punishment is generally associated with negative child behavioral outcomes, including aggression and anxiety, this effect is moderated by perceived cultural norms (i.e., in cultures where corporal discipline is expected, there is less anxiety and aggression in the child). Similarly, the benefits of positive developmental outcomes from a culturally-embedded practice such as napping may also vary by degree of cultural normativeness. In China, napping is a common practice and is promoted as a way to facilitate children's broadening scope of awareness and building of the individual's resources [96]. Indeed, the extended lunch periods routinely provided by many educational institutions and government agencies factor in napping time. These positive traditions or cultural expectations may facilitate the constructive effects of napping, whereas in Western countries napping in older children is negatively perceived, which may dampen the perceived benefits of napping and outcomes. Future cross-cultural research is needed to understand the complex interplay between biological, social, and cultural mechanisms.

Limitations, Strengths, and Future Directions

Several limitations of this study need to be acknowledged. First, due to the cross-sectional nature of the present study, causal directions cannot be concluded. It could be that children who have better grit and self-control are more likely to stick with the routine of napping, and children with prosocial behavior are more likely to follow the class routine of post-lunch napping. Conversely, children who have aggressive behaviors and depression may be less likely to follow school recommendations for post-lunch napping. This psychosocial argument may be relevant for the associations with nap frequency, as children who are more conscientious and compliant may nap whenever suggested by a parent or teacher. However, this argument is less relevant for associations with nap duration that demonstrate positive outcomes with more sleep. These data suggest a functional benefit of sleep itself that is independent of psychosocial factors, a result in accordance with laboratory studies of napping effects on cognition and emotion regulation. Future longitudinal studies with temporal ordering of variables, as well as experimental interventions to manipulate napping, may help tease out these relationships.

Second, nap duration was derived from subjective reports. While previous studies [97] have shown moderate correlations between objective and subjective sleep data, future research with objective assessments such as actigraphy is warranted to confirm our findings. In addition, possible confounding factors might play a role in napping, such as physical activity levels. Furthermore, the place where participants took naps and the distance from school if taking naps at home, were not included in the study. This could be explained by potential distance effects due to some children living in peripheral suburban or rural areas having reduced nap durations. The highest and lowest nap frequencies both existing within suburban areas could be due to distance effects. Although Hua Cheng is considered a suburban, it lies immediately adjacent to the city. He Bin is located further towards the periphery of the city than Hua Cheng. Based on our results, it seems that children residing in the city and immediate city-adjacent suburban areas have highest nap frequencies compared to suburbs located in the periphery. However, if we had recorded the nap location, this distance effect could be further elucidated. Additionally, whereas an individual's inter-daily variability in nap/sleep schedule may have downstream effects on adolescent outcomes, such as obesity in adolescents [98] and negative mood in adolescents [99], we only assessed the average nap frequency/duration and night time in bed duration over the past 1 month. Finally, given that some statistically significant results have small effect sizes, the implications of these results should be viewed with caution. Despite these limitations, our study utilized a large sample size and implemented multiple measures to demonstrate similar constructs.

Conclusion

In this large community study of schoolchildren, our findings suggest that habitual napping is associated with several positive outcomes, including better cognitive ability and psychological well-being, and reduced emotional and behavioral problems. Several potential physiological, social and cultural mechanisms have been proposed to account for these effects. Napping is not found to increase the risk of negative metabolic health outcomes. Given that sleep deprivation and daytime sleepiness are important public health concerns, these results may help inform future interventional studies that target adolescent sleepiness.

Supplementary Material

Supplementary material is available at *SLEEP* online.

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Author Contributions

J.L. designed the study. J.L. and S.M. developed the first draft of the manuscript, and A.R. shaped a later draft of the manuscript. R.F. led a statistical group to perform the data analysis, and X.J. also contributed to analysis. X.J. and N.C. prepared, cleaned the data, as well as provided scientific input. All authors contributed to interpretation of data, were involved in the development of manuscript, and provided critical revisions, and approved the final submitted manuscript.

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