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Bedtime procrastination and chronotype differentially predict adolescent sleep on school nights and non-school nights

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ABSTRACT

Objectives: Bedtime procrastination (BTP) refers to the tendency to delay sleep beyond an intended bedtime, in favor of continuing evening activities. BTP has been associated with negative sleep outcomes (later timing, shorter duration, poorer quality), and is viewed as a problem of exercising self-control. BTP could be particularly challenging in adolescents, given the combined effects of increasing bedtime autonomy, later chronotype, and a still developing self-control capacity. Thus far, research on BTP has only been based on self-report measures. Here we examined the influence of BTP on adolescent sleep, using objective measures of sleep.
Methods: About 121 adolescents aged 14-19 years completed a survey on BTP, sleep quality, chronotype, and mental health. Subsequently, habitual sleep was actigraphically monitored for up to 2 weeks, and participants completed a temporal discounting task (a proxy for impulsivity). Associations between BTP, chronotype, and actigraphy-measured sleep were examined for school nights and non-school nights separately.
Results: Greater BTP was associated with poorer subjective sleep, eveningness chronotype, and higher daytime fatigue, as well as higher anxiety/depression scores. Measured using actigraphy, greater BTP predicted later bedtimes and shorter sleep duration on school nights, even when controlling for chronotype. On non-school nights, eveningness chronotype, but not BTP, predicted later bedtimes and wake-up times. BTP was not correlated with temporal discounting.
Conclusions: Bedtime procrastination exerts significant influence on subjective and objective sleep measures in adolescents. Its effects are most prominent on school nights and can be separated from the effects of chronotype, which has stronger effects on sleep timing on non-school nights.

Introduction

Insufficient sleep is a pervasive problem in modern society, negatively impacting health, quality of life, and productivity.[1] Sleep insufficiency has often been attributed to factors outside of one's control (eg, urgent deadlines). However, in many cases, people also voluntarily curtail their sleep by delaying bedtimes in favor of leisure activities (eg, watching TV, or browsing social media). Bedtime procrastination refers to "going to bed later than intended without having external reasons for doing so",[2] emphasizing that some activities during the pre-bedtime period are non-essential.[3-6]

Bedtime procrastination has been viewed as a problem of self-regulation.[2,7-10] Studies have indicated that delayed bedtimes often stem from difficulties in disengaging from night time activities,[3,7] resulting in shorter sleep duration,[2,5,7-10] higher levels of daytime fatigue,[2,8,9] and poorer sleep quality.[5,7,10] Furthermore, individuals endorsing high levels of bedtime procrastination often report to indulge in pre-bedtime leisure activities, despite being aware of the negative impact of curtailed sleep.[2,9,11]

An additional factor influencing one's choice of bedtime is circadian preference (ie, chronotype). Several studies have found that individuals with later circadian preference (evening types) report higher scores on the bedtime procrastination scale.[8,12] This has led some researchers to argue that chronotype might be a main driver of bedtime procrastination behaviors and resultant late bedtimes. Evening type individuals may plan a desired bedtime, however this planned bedtime might be earlier than their biologically preferred time[13,14] (eg, when aiming to adhere to fixed early work or school schedules). As such, they may not feel sleepy at the time of their

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planned bedtime, inviting engagement in leisure activities.[8,13] Other researchers have argued that evening chronotype may exacerbate, but not fully explain, the tendency to engage in bedtime procrastination.[13]

Previous studies reporting associations between bedtime procrastination and sleep variables were based on subjective reports of sleep. Although subjective sleep measures can estimate sleep over a longer time period (eg, the past month), they might characterize sleep differently from objective sleep measures[15-17] and might in fact be differentially related to emotional well-being.[16] It is therefore important to extend earlier findings concerning bedtime procrastination with objective sleep recording.

Differences in bedtime procrastination on weekday and weekend nights have not been explicitly studied with most prior work either not specifying this distinction or focused only on weekday night sleep.[2,8,9] Sleep in adolescents is likely affected by different factors during school nights compared to non-school nights. Bedtime planning on school nights, for example, might be more heavily influenced by school schedules.[18] Accordingly, a recent survey study by Li and colleagues[19] found that procrastination in general was associated with shorter weekday (but not weekend) night sleep duration, and also larger differences between weeknight and weekend night sleep. However, this study did not specifically measure procrastination behaviors related to sleep and bedtime, nor did it examine the contribution of chronotype to these effects.

The present study sought to fill the aforementioned gaps by examining relations between bedtime procrastination, chronotype and sleep on school and non-school nights in an adolescent sample. Students in our sample underwent 1-2 weeks of actigraphic monitoring of habitual sleep patterns, before and after which they provided self-reported information on sleep habits and psychological well-being. The interplay between bedtime procrastination and chronotype might be especially pertinent amongst adolescents, who experience a developmental shift towards later circadian timing,[20] but at the same time are bound by fixed and early school start times. Furthermore, adolescence is characterized by a still developing capacity to exercise self-control.[21] As bedtime procrastination can be thought of as a tendency to engage in immediately rewarding activities, while putting off choices that would have longer term benefit (eg, going to bed early), we also included an intertemporal choice task.[11] This task provides a behavioral assessment of impulsive choice, and is associated with health behaviors in various domains.[22]

Methods and materials

Participants and procedures

About 121 school-going adolescents aged 14-19 years signed up for an experimental sleep study (the Need For Sleep 5; NFS5),[23] which was the fifth study in a series of experimental studies that aim at characterizing adolescents' cognitive functions under different sleep manipulations. While only a subset of participants entered the main NFS5 study (see Lo et al 2020 for details),[23] all 121 participants underwent a screening process, part of which comprised a period of actigraphic monitoring of habitual sleep schedules, and completion of sleep and well-being questionnaires. The present study is based on data collected during this screening process. At the time of the screening process, all participants were attending secondary schools or junior colleges with fixed daily school start times, except for 3, whose educational institutions allowed more flexible start times. The protocol was approved by the Institutional Review Board of the National University of Singapore. Consent was obtained from all participants and their legal guardians.

Participants paid 2 visits to the laboratory 1-2 weeks apart to complete the screening process. During their first visit, participants completed computer-based questionnaires probing demographic, lifestyle, sleep and psychological well-being information. To measure sleep patterns objectively, at the end of the first visit each participant was given an actiwatch, which they were instructed to wear throughout a period of 1-2 weeks. After this interval, participants paid a second visit to the laboratory to return the actiwatch and also completed an intertemporal choice task measuring delay discounting of reward. Participants received 5 Singapore dollars for completing all the questionnaires during the first visit, and on the second visit received an additional 30 dollars for wearing the actiwatch, filling in a sleep diary and completing the intertemporal decision-making task.

Demographics

All 121 participants answered questions about their age, sex, race, school, body mass index (BMI), number of caffeinated drinks consumed per day and number of hours spent on physical exercise per day.

Sleep measures

Pittsburgh Sleep Quality Index.[24] The PSQI is a 19-item self-report questionnaire assessing sleep quality and disturbances over the past month. The questionnaire has 7 components, each with scores ranging from 0 to 3. The total score is obtained by summing scores across all 7 subscales, making the range of the total score 0-21. Higher scores indicate poorer sleep quality.

Chronic Sleep Reduction Questionnaire.[25] The CSRQ is a 20-item self-report questionnaire assessing 4 daytime consequences of chronic sleep reduction, namely shortness of sleep, irritation, loss of energy and sleepiness, with higher scores indicating greater symptoms of chronic sleep reduction.

Epworth Sleepiness Scale.[26] The ESS is an 8-item self-report questionnaire assessing daytime sleepiness. Each item can score from 0 to 3, making the range of the total scores 0-24. Higher scores indicate higher levels of daytime sleepiness.

Morningness-Eveningness Questionnaire.[27] The MEQ is a 19-item self-report questionnaire measuring chronotype. Questions probe respondents' habitual and ideal bedtimes and wake-up times as well as preferred times for cognitive and physical activities. The total score is obtained by summing responses to all 19 items and can range from 16 to 86. Lower scores indicate more eveningness preference while higher scores indicate more morningness preference.

Bedtime Procrastination Scale.[2] The BPS is a 9-item self-report questionnaire measuring the extent to which respondents engage in bedtime procrastination (Cronbach's α = 0.85). Each item can score from 1 (almost never) to 5 (almost always) while items 2, 3, 7, and 9 are reverse coded. Hence, the range of total scores is 9-45, with larger scores indicating higher frequency of engaging in bedtime procrastination. The BPS was developed for adults, but has been used in adolescent populations in prior studies.[7,28-30]

Psychological well-being measures

Beck Anxiety Inventory.[31] The BAI is a 21-item self-report questionnaire measuring general anxiety levels by evaluating the severity of anxiety symptoms experienced over the past month (Cronbach's α = 0.92). Each item can score from 0 (not at all) to 3 (severely), making the range of total score 0-63, with higher scores indicating higher levels of anxiety.

Beck Depression Inventory for Youth.[32] The BDI-Youth is a 20-item self-report questionnaire assessing symptoms of depression experienced by children and adolescents aged 7-18 years old. Each item can score from 0 (never) to 3 (always), making the range of total score 0-60, with higher scores indicating higher levels of depression.

Actigraphy

Participants wore a Philips Respironics Actiwatch 2 throughout the period between their first and second visits to the lab (1-2 weeks). Data were collected in 2-min epochs and scored by Actiware software (version 6.0.7, Philips Respironics Inc., Pittsburgh, Pennsylvania) with a medium wake-sensitivity threshold (activity count ≥ 40). Bed and wake times were determined based on the participant's self-reported timings recorded in a sleep diary, and participant-initiated event markers on the actogram. Where necessary, changes in light and activity levels were referred to for defining the sleep period. Additional sleep measures were derived from actigraphy data, including time in bed (TIB, defined as the time between bedtime and wake-up time), total sleep time (TST, calculated by summing all the sleep epochs within TIB), sleep efficiency (SE = (TST/TIB)*100), sleep onset latency (SOL, calculated by as summing all the wake epochs [epochs with above threshold activity] before the first sleep epoch), wake after sleep onset (WASO, calculated by summing all the wake epochs [epochs with above threshold activity] after the first sleep epoch) and number of awakenings (#Awak, defined as the number of transitions from a sleep epoch to a wake epoch across the TIB period).

Intertemporal choice task

To obtain a behavioral measure of delay discounting, which is defined as the preference for smaller but immediate rewards over larger but delayed rewards, participants completed an intertemporal choice task.[33] Higher delay discounting of rewards has been associated with negative outcomes in multiple health behaviors such as diet, exercise, smoking cessation, and may be linked to bedtime procrastination.[11,22] In this task, participants were required to make a series of choices between a small, immediately available reward, or a larger reward ($20) available at a later point in time (1, 2, 3, 4, or 5 months). Participants complete a total of 50 choices from which a discounting curve is constructed. The area under the discounting curve is taken as a summary metric of impulsive choice.

Data analysis and statistics

For each night of actigraphy recording, participants were instructed to indicate whether it was a school night or a non-school night. Nights for which these data were missing (n = 77, out of n = 1163 total nights) were labelled a non-school night, if the next day was on weekend, a national holiday or school holiday, or if the wake-up time was later than the school start time. Otherwise, the night was labelled a school night. This resulted in 630 nights of sleep data for school nights and 533 for non-school nights, across 115 participants (6 participants did not comply with actigraphy procedures). For participants who had sleep data for at least 3 school nights (n = 92), data on these nights were averaged to obtain school night averages. Participants with only 1 or 2 school nights' data were excluded from school night analysis. The same was performed to obtain person-level average non-school night sleep parameters (n = 104).

To investigate the relationships between bedtime procrastination and demographic, sleep and psychological well-being variables, linear bivariate correlations were performed. Next, we compared actigraphy-measured sleep parameters on school nights and non-school nights. Lastly, to examine the contributions of bedtime procrastination and chronotype to actigraphy-measured sleep on school nights and non-school nights, linear hierarchical multiple regression analyses were performed. First, the effects of chronotype (MEQ) on sleep variables (bedtime, wake-up time, TIB, TST) were examined (Step 1 model), while controlling for age and sex. Subsequently, bedtime procrastination score was added to the model (Step 2 model) as an additional predictor to examine its effects on sleep variables while controlling for age, sex and chronotype. All statistical tests were performed on SPSS, version 26.0 (IBM Corporation). Regression analyses were corrected for multiple comparisons (4 sleep variables [bedtime, wake-up time, TIB, TST] across school days and non-school days) using the Benjamini-Hochberg method[34] (alpha = 0.05, False Discovery rate [FDR] = 0.05).

Results

Sample characteristics

Table 1 outlines descriptive characteristics of our sample. The 121 adolescents had a mean age of 15.90 (SD = 1.14), with 66 female participants (54.55%) and 55 male participants. The sample scored an average of 29.69 (SD = 6.90) on the Bedtime Procrastination Scale (total possible scores range from 9 to 45), indicating that participants on average reported their frequency of engaging in a variety of bedtime procrastination behaviors as being between "sometimes" and "frequently" (Fig. 1A). This finding suggests that bedtime procrastination is common in this sample.

Actigraphy-measured sleep characteristics

Actigraphically-measured sleep showed non-school night vs. school night differences (Table 2). On non-school nights students slept later compared to school nights (bedtime: +47 minutes; wake-up time: +2 hours 23 minutes). They nonetheless had longer sleep on non-school nights (time in bed: +1 hour 37 minutes; total sleep time: +1 hour 17 minutes). However, higher WASO (+18 minutes) and awakenings (+4.76) were observed on non-school nights compared to on school nights. Sleep latency and efficiency did not significantly differ between nights.

Associations between bedtime procrastination demographics, sleep, and well-being variables

Independent samples t-tests showed that female participants scored higher on bedtime procrastination than male participants (Mean ± SD: 31.09 ± 6.66 vs. 28.00 ± 6.86; t = 2.51, P = .01). Bivariate correlations (Table 3) indicated that higher bedtime procrastination was associated with poorer sleep quality (PSQI, Pearson's r = 0.34, P < .001; Fig. 1B), increased daytime sleepiness (ESS, Pearson's r = 0.31, P = .001), increased signs of chronic sleep reduction in all 4

Table 1
Descriptive statistics for study measures (n = 121)

	Mean (SD) or n (%)
Age	15.90 (1.14)
Sex, female	66 (54.55)
Bedtime Procrastination Scale	29.69 (6.90)
Pittsburgh Sleep Quality Index	4.90 (2.43)
Epworth Sleepiness Scale	7.77 (3.31)
Chronic Sleep Reduction Questionnaire	
Shortness of sleep	13.59 (2.00)
Irritation	6.85 (1.76)
Loss of energy	8.02 (2.09)
Sleepiness	8.31 (1.79)
Morningness-Eveningness Questionnaire	48.61 (6.97)
Beck Anxiety Inventory	11.37 (9.68)
Beck Depression Inventory for Yyouth	13.12 (11.03)
Delay discounting	56.46 (18.14)

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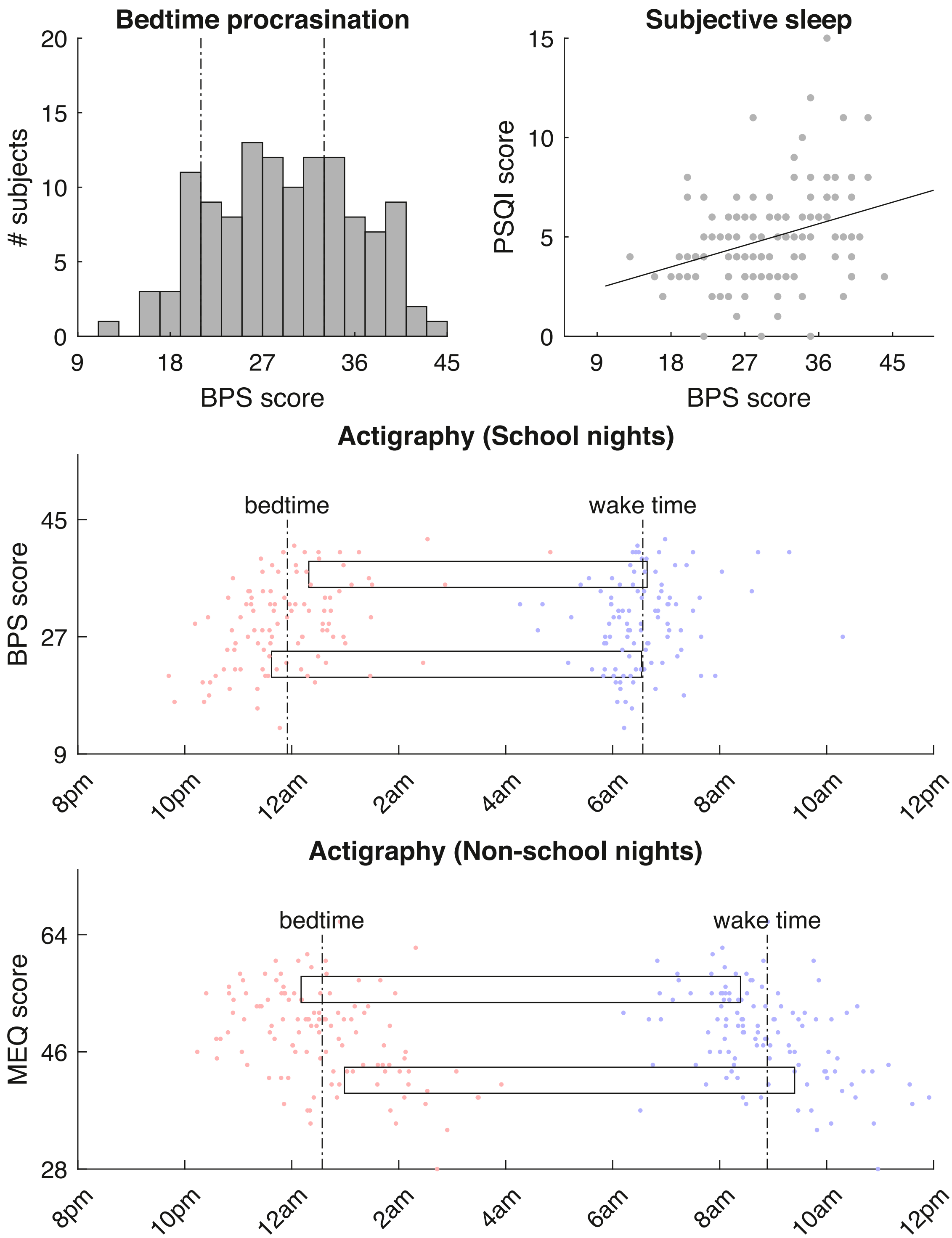

Fig. 1. (A) Histogram of bedtime procrastination (BPS) scores, (B) correlation between bedtime procrastination score and PSQI scores, (C) actigraphy-measured sleep timings on school nights, showing individual bedtimes (red dots), raw wake-up times (blue dots), and estimated sleep periods for high bedtime procrastinators (BPS score mean + 1 stdev) and low bedtime procrastinators (BPS score mean - 1 stdev), (D) actigraphy-measured sleep on non-school nights, showing raw bedtimes (red), wake-up times (blue), and estimated sleep periods for morning chronotypes (MEQ mean + 1stdev) and evening types (MEQ mean − 1 stdev). Vertical dotted lines depict mean bedtimes and wake-up times for the entire sample. Sleep periods estimated from regression models, controlling for age, sex, MEQ, BPS. PSQI = Pittsburgh Sleep Quality Index, BPS = Bedtime Procrastination Scale, MEQ = Morningness-Eveningness Questionnaire.

subdomains (CSRQ, Pearson's rs $\geq$ 0.25, Ps $\leq$ 0.006), greater eveningness (MEQ, Pearson's r = -0.47, $P < .001$), higher anxiety (BAI, Pearson's r = 0.21, $P = .02$) and higher depression (BDI-Youth, Pearson's r = 0.33, $P < .001$). No significant correlations between bedtime procrastination and age or delay discounting were found.

Associations between bedtime procrastination, chronotype, and actigraphy-measured sleep

Finally, to examine the relationship between bedtime procrastination, chronotype, and actigraphy-measured sleep, 2 hierarchical

Table 2
Actigraphy-measured sleep parameters on school nights (n = 92) and non-school nights (n = 104)

	School nights Mean (SD)	Non-school nights Mean (SD)	t	*P*
Bedtime (hh:mm)	23:49 (00:56)	00:36 (01:10)	-5.93	<**.001**
Wake-up time (hh:mm)	06:33 (00:41)	08:56 (01:11)	-19.44	<**.001**
Time in bed (hr)	6.74 (0.98)	8.35 (0.91)	-12.70	<**.001**
Total sleep time (hr)	5.30 (0.79)	6.59 (0.91)	-11.46	<**.001**
Sleep efficiency (%)	78.92 (7.35)	79.05 (7.10)	-0.24	.81
Sleep onset latency (min)	11.42 (9.03)	11.43 (10.89)	0.17	.87
Wake after sleep onset (min)	60.95 (30.91)	79.05 (32.42)	-7.73	<**.001**
Number of awakenings	16.08 (5.46)	20.84 (5.44)	-10.21	<**.001**

Bold face values are significant at $p < .05$.

multiple regression models were run for school night and non-school night sleep variables separately (Table 4). For school nights, in Step 1, chronotype was not significantly associated with sleep timing or duration. In Step 2, when bedtime procrastination was additionally included, bedtime procrastination significantly explained later bedtime (B = 0.05, *P* = .003), and shorter TST (B = -0.04, *P* = .008). Neither chronotype nor bedtime procrastination predicted wake-up time (*P* = .39). Fig. 1C illustrates the modeled sleep periods for individuals with high bedtime procrastination scores (mean + 1 stdev) and low scores (mean − 1 stdev) showing that bedtime procrastination was associated with later bedtimes but not wake times on school days (individual bed and wake times represented by red and blue dots respectively).

For non-school nights, the model in Step 1 indicated that evening chronotype significantly predicted later bedtime (B = -0.09, *P* < .001, Table 5) and later wake-up time (B = -0.09, *P* < .001) but not TST or TIB. Furthermore, female sex (B = 0.44, *P* = .01) and younger age (B = -0.17, *P* = .04) both predicted longer non-school night TST. After adding bedtime procrastination to the model in step 2, we found that evening chronotype remained a significant predictor of later bedtime (B = -0.08, *P* < .001) and wake-up time (B = -0.09, *P* < .001), while bedtime procrastination score was not significantly associated with sleep timing or duration. Accordingly, Fig. 1D shows the modeled shift in sleep timing (later bed and wake time) for evening vs. morning types (mean MEQ± 1 stdev).

To examine the possibility that the association between bedtime procrastination and sleep outcomes was modulated by chronotype (ie, different associations are observed for different chronotype), we ran an additional set of regression analyses, including a BPS x MEQ interaction term. These analyses, however, did not yield any significant interaction effect (all p's > .05), while leaving the main effects of BPS and MEQ intact (see Supplementary Materials for details).

Table 3
Bivariate correlations between bedtime procrastination (BPS) and other study measures

	Pearson's r	*P*
Age	0.12	.19
Pittsburgh Sleep Quality Index	**0.34**	<**.001**
Epworth Sleepiness Scale	**0.31**	<**.001**
Chronic Sleep Reduction Questionnaire		
Shortness of sleep	**0.44**	<**.001**
Irritation	**0.25**	**.006**
Loss of energy	**0.46**	<**.001**
Sleepiness	**0.32**	<**.001**
Morningness-Eveningness Questionnaire	**-0.47**	<**.001**
Beck Anxiety Inventory	**0.21**	**.02**
Beck Depression Inventory for Youth	**0.33**	<**.001**
Delay discounting	-0.04	.71

Bold face values are significant at $p < .05$.

Exploratory analyses

To examine the influence of bedtime procrastination and chronotype on sleep variability measures, correlations and multiple regression analyses were repeated with sleep variability (stdev bedtime, wake time, TIB, TST) among school nights, and school vs. non-school night differences (social jetlag, sleep extension on non-school nights) were included as outcome variables. While higher bedtime procrastination score was significantly correlated with more variability in sleep timing and duration among school nights (stdev. Bedtime: r = 0.229, *P*= .028; stdev. wake time: r = 0.23, *P* = .027; stdev. TIB: r = 0.28, *P* = .007; stdev. TST: r = 0.268, *P* = .01), these effects did not survive when controlled for chronotype in multiple regression analysis (all p's > .1; see Supplementary Materials for details). Later chronotype, but not bedtime procrastination, was associated with more severe social jetlag (MEQ: B = -.045, *P* = .001; BPS: B = -.02, *P* = .135), while sleep extension on non-school nights was not associated with chronotype or bedtime procrastination (see Supplementary Materials for details).

Discussion

We found that bedtime procrastination was associated with negative subjective sleep and well-being outcomes (higher PSQI, more daytime sleepiness, higher symptoms of chronic sleep reduction, higher anxiety and depression), confirming previous findings.[2,5,8-10] Further, higher bedtime procrastination score was correlated with later chronotype.[8,12] Importantly, using objectively measured sleep (actigraphy), bedtime procrastination was found to predict school night but not non-school night sleep timing and duration. In particular, more bedtime procrastination was associated with later bedtimes and shorter sleep duration on school nights. In contrast, on non-school nights, sleep timing was explained by chronotype (but not bedtime procrastination). These findings implicate bedtime procrastination as an important driver of sleep insufficiency in adolescents, especially on school nights.

Bedtime procrastination on school nights

The effects of bedtime procrastination on school night sleep were substantial. A 10-point increase on the Bedtime Procrastination Scale (possible scores range from 9 to 45) translated to a 30-minute delay in bedtime and a 24-minute reduction in TIB and TST. Combined with the observation that sleep duration on school nights (mean TIB = 6.7 hours) was far below the recommended 8-10 hours duration for this age group,[35] these findings implicate bedtime procrastination as an important factor influencing adolescent sleep patterns.

School night sleep is heavily influenced by fixed school schedules, in particular school start time.[36] The combination of a developmental shift towards delayed circadian timing in adolescence, and increasing autonomy to decide on bedtimes,[20,37] leads to sleep curtailment. In turn, the latter is associated with impaired learning, negative well-being outcomes and increased accidents.[38] Importantly, the effects of bedtime procrastination on school night sleep in this study were still present after controlling for chronotype. This indicates that bedtime procrastination on school nights negatively affects sleep timing and duration, over and above the influence of circadian preference.

Sleep on non-school nights

On non-school nights, sleep timing was mainly predicted by chronotype. This likely indicates that in the absence of externally imposed schedules adolescents shift their bedtimes to align with their preferred sleep timing. Accordingly, average bedtime was 47 minutes later on

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Table 4
Results of hierarchical multiple regression of school night sleep parameters on age, sex, chronotype (MEQ) and bedtime procrastination (BPS)

	School night bedtime			School day wake-up time			School night time in bed			School night total sleep time		
	B	SE	*P*	B	SE	*P*	B	SE	*P*	B	SE	*P*
Step 1	ΔR^2 = 0.08			ΔR^2 = **0.11**			ΔR^2 = 0.005			ΔR^2 = 0.02		
Age	0.09	0.09	.32	0.12	0.06	.06	0.03	0.09	.76	-0.04	0.08	.63
Sex	0.24	0.20	.22	0.14	0.14	.32	-0.10	0.21	.65	0.08	0.17	.64
MEQ	-0.03	0.01	.05	-0.02	0.01	.03	0.01	0.02	.73	0.02	0.01	.20
Step 2	ΔR^2 = **0.09**			ΔR^2 = 0.008			ΔR^2 = **0.05**			ΔR^2 = **0.08**		
MEQ	-0.01	0.02	.51	-0.02	0.01	.10	-0.01	0.02	.60	0.001	0.01	.94
BPS	**0.05**	**0.02**	**.003**	0.01	0.01	.39	-0.04	0.02	.04	**-0.04**	**0.01**	**.008**

MEQ, Morningness-Eveningness Questionnaire; BPS, Bedtime Procrastination Scale.
Units for scales, age and sleep measures are point, year and hour, respectively. For sex, female = 1, male = 0. B values denote unstandardized regression coefficients.
SE values denote coefficient standard errors.
Bolded values indicate statistically significant effects at alpha = 0.05, FDR = 0.05.

non-school nights compared to school nights, while waketime shifted later by 2 hours and 23 minutes.

This pattern of bedtime procrastination influencing school night sleep more strongly than non-school night sleep, resembles the findings of procrastination in other behavioral domains (general procrastination).[19] Li et al reported that general procrastination score was associated with weekday (but not weekend) night sleep duration, and with greater social jetlag. The authors suggest procrastinators may push back bedtime as they need time to finish tasks that were postponed in the daytime, or they may engage in bedtime-specific procrastination behavior.

Several factors could play into the observed lesser influence of bedtime procrastination on sleep during non-school nights. First, the absence of strict schedules on non-school nights may allow adolescents the flexibility to sleep enough by sleeping in later (even when having later bedtimes). Additionally, a recent study found that adolescents were less likely to have a planned bedtime on non-school nights compared to school nights.[18] Therefore, without a set bedtime, late bedtimes on non-school nights may not be perceived as bedtime procrastination (ie, delaying a planned bedtime). Furthermore, leisure activities before bedtime may serve the purpose of winding down and detaching from work or school-related stressors before going to sleep.[39] As such, bedtime procrastination might be particularly prevalent on stressful days,[7,40,41] and less so on free days when work and school demands are expected to be lower.

Bedtime procrastination and delay discounting

A secondary aim of this study was to evaluate the relation between bedtime procrastination and delay discounting (ie, the tendency to prefer immediate rewards over larger delayed rewards). Bedtime procrastination could be conceptualized as a similar decision problem (ie, choosing behaviors that are rewarding in the moment over the benefits that sleeping well may have for the next day).[2] For example, individuals may indulge in enjoyable activities before bedtime (eg, watching tv, browsing social media, playing video games), but find it hard to disengage from these activities at the time of a planned (or desired) bedtime. Contrary to our expectations however, we did not find a significant correlation between bedtime procrastination and delay discounting in the intertemporal choice task. It is possible that the financial decisions as presented in this task, do not immediately translate to decisions about bedtime behaviors, or that specific task features or sample characteristics have limited the sensitivity of the task in this study. However, as similar intertemporal choice tasks have been repeatedly found to correlate with other health behaviors (eg, diet, exercise, or substance abuse),[22] a more elaborate exploration of the proposed relationship in future studies may still be merited.

Limitations

Although this study has notable strengths, several limitations should be mentioned. First, the study was based on a cross-sectional design so causal direction cannot be inferred. However, as bedtime procrastination and chronotype were measured prior to the period of actigraphy sleep monitoring, it is unlikely that objectively measured sleep behavior influenced how participants responded to the questionnaires. Relatedly, bedtime procrastination behavior may vary from night to night. Some studies, for instance, have found that individuals report more bedtime procrastination on stressful days

Table 5
Results of hierarchical multiple regression of non-school night sleep parameters on age, sex, chronotype (MEQ) and bedtime procrastination (BPS)

	Non-school night bedtime			Non-school day wake-up time			Non-school night time in bed			Non-school night total sleep time		
	B	SE	*P*	B	SE	*P*	B	SE	*P*	B	SE	*P*
Step 1	ΔR^2 = **0.30**			ΔR^2 = **0.27**			ΔR^2 = 0.05			ΔR^2 = **0.09**		
Age	0.13	0.09	.16	-0.02	0.10	.82	-0.16	0.10	.05	**-0.17**	**0.08**	**.04**
Sex	0.02	0.20	.93	0.20	0.20	.33	0.21	0.20	.25	**0.44**	**0.18**	**.01**
MEQ	**-0.09**	**0.02**	<**.001**	**-0.09**	**0.02**	<**.001**	-0.004	0.01	.79	0.008	0.01	.52
Step 2	ΔR^2 = 0.02			ΔR^2 = 0.001			ΔR^2 = **0.05**			ΔR^2 = 0.03		
MEQ	**-0.08**	**0.02**	<**.001**	**-0.09**	**0.02**	<**.001**	-0.02	0.01	.22	-0.003	0.01	.86
BPS	0.03	0.02	.10	-0.006	0.02	0.74	-0.03	0.02	.03	-0.03	0.02	.10

MEQ, Morningness-Eveningness Questionnaire; BPS, Bedtime Procrastination Scale.
Units for scales, age and sleep measures are point, year and hour, respectively. For sex, female = 1, male = 0. B values denote unstandardized regression coefficients.
SE values denote coefficient standard errors.
Bolded values indicate statistically significant effects at alpha = 0.05, FDR = 0.05.

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compared to non-stressful days.[7] A daily diary design could help to capture these behavioral dynamics.

Interestingly, a study by Kuhnel et al,[12] showed that working adults who were evening types, reported more bedtime procrastination during the work week compared to morning types. According to the authors, evening chronotypes may engage in procrastination behavior during the week, because they are unable to sleep at earlier timings. Moreover, for evening types, bedtime procrastination was strongest on Mondays, and declined over the course of the work week, potentially due the build-up of sleep debt over the week. In our study based on school-going adolescents, bedtime procrastination and chronotype seemed to be independent predictors of sleep timing which did not show statistical interaction. However, the cross-sectional design did not probe the changes in bedtime procrastination over different days.

Another limitation of the current study is that no details on specific pre-bedtime activities were collected. Several studies have indicated that pre-bedtime leisure, often through electronic means, is associated with bedtime procrastination and of late bedtimes.[2-4] In highly competitive environments however, sleep timing and duration may be influenced by productivity demands. A recent study in Singaporean adolescents for example found that curtailed sleep on weekdays was primarily driven by time spent on homework.[42] Although the concept of bedtime procrastination would not include such external factors into its definition, it is possible that respondents may have interpreted the wording of the survey questions as such. Future studies should collect information about specific activities engaged in before bedtime, to disentangle the respective contributions of academic pressure and leisure activities to sleep behaviors.

Lastly, details on other interpersonal and environmental factors that affect sleep behaviors could help to identify causes and determinants of bedtime procrastination. Sociodemographic factors such as social economic status, family dynamics, and ethnic/racial background are known to influence sleep health. In the current study, a fairly homogenous population of participants was polled. However, extension of this research to include such factors could further elucidate the mechanisms by which bedtime procrastination behaviors would propagate. Other factors to note in future studies would be the influence of sleep disorders on bedtime procrastination (eg, insomnia).[3] Issues such as pre-sleep arousal may play into delaying of bedtimes, and treatment may require a different approach than addressing procrastination per se.

Conclusion

Bedtime procrastination significantly influences adolescent sleep timing and duration, particularly during school nights superseding the effects of chronotype. When restrictions on sleep timing are eased, on non-school nights, sleep timing becomes more influenced by chronotype. Bedtime procrastination was associated with poorer subjective and objective sleep metrics, higher daytime fatigue, and poorer mental well-being. It will be vital to uncover environmental, developmental, and individual factors that underlie it in future research.

Declaration of conflict of interest

All authors declare no conflict of interest.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.sleh.2022.09.007.

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