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Article

Do procrastinators get worse sleep? Cross-sectional study of US adolescents and young adults

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ABSTRACT

Procrastination is a widespread habit that has been understudied in the realm of health behaviors, especially sleep. This study aimed to examine the cross-sectional relationships between procrastination and multiple dimensions of sleep in a large national sample of US adolescents and young adults. A random sample of 8742 students from 11 US universities provided self-reports of procrastination (measured by the General Procrastination Scale-Short Form with scores ranging from 1 to 5) and sleep behaviors including social jetlag (the absolute difference between mid-sleep times on weeknights and weekend nights), sleep duration (mean weekly, weeknight, and weekend night), insomnia symptoms (trouble falling/staying asleep), daytime sleepiness, and sleep medication use. Multiple linear regression and Poisson regression models adjusted for socio-demographic and academic characteristics as well as response propensity weights. Higher levels of procrastination were significantly associated with greater social jetlag ($\beta = 3.34$ min per unit increase in the procrastination score; 95% CI [1.86, 4.81]), shorter mean weekly sleep duration ($\beta = -4.44$ min; 95% CI [-6.36, -2.52]), and shorter weeknight sleep duration ($\beta = -6.10$ min; 95% CI [-8.37, -3.84]), but not weekend night sleep duration. Moreover, procrastination was associated with insomnia symptoms (Relative Risk (RR) = 1.27; 95% CI [1.19, 1.37]) and daytime sleepiness (RR = 1.32; 95% CI [1.27, 1.38]), but not sleep medication use. The results were robust to adjustment for anxiety and depressive symptoms. Procrastination was associated with greater social jetlag, shorter sleep duration, and worse sleep quality. If causal, the results suggest that interventions to prevent and manage procrastination might help students to improve their sleep health.

1. Introduction

Procrastination, or the tendency to voluntarily delay the beginning or completion of intended tasks (despite expecting to be worse off for the delay), is a common form of self-regulatory failure (Ferrari, 1993; Sirois & Pychyl, 2016). It is widely prevalent in modern societies with potential deleterious consequences for many aspects of people's lives (Ferrari, O'Callaghan, & Newbegin, 2005; Steel & Ferrari, 2013). Although most individuals have experienced putting off an action in order to avoid tasks that are associated with boredom, anxiety, frustration, or resentment, certain segments of the population in technologically-advanced societies (especially students) are known to suffer from chronic/habitual procrastination. It is estimated that almost half of undergraduate and graduate students habitually procrastinate on academic tasks such as writing a term paper, studying for an examination, and keeping up with weekly reading assignments (Anthony J. Onwuegbuzie, 2004; Hill, Hill, Chabot, & Barrall, 1978; Solomon & Rothblum, 1984). The procrastination prevalence remains high despite the procrastinators' stated intentions to reduce the behavior (O'Brien, 2000).

A substantial literature has documented the detrimental effects of procrastination in different domains of life, such as completing work-related tasks, filing taxes on time, and saving for retirement (Akerlof, 1991; Solomon & Rothblum, 1984; Steel, 2007; Steel, Brothen, & Wambach, 2001; Wesley, 1994). By contrast, less attention has been paid to the effects of procrastination in health behaviors and outcomes

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(Kroese, De Ridder, Evers, & Adriaanse, 2014; Sirois, Melia-Gordon, & Pychyl, 2003). Procrastination is plausibly linked to behaviors that exhibit the profile of "pain today – gain tomorrow"; for example, regular exercise, receiving seasonal flu shots, regular dental checkups, or screening colonoscopy(Sirois, 2007; Sirois et al., 2003). However, the relationship between procrastination and sleep has been minimally explored. Initial investigations have indicated that procrastination increases vulnerability for sleep problems (Hairston & Shpitalni, 2016; Kroese, De Ridder et al., 2014; Kroese, Evers, Adriaanse, & Ridder, 2014; Sirois, Eerde, & Argiropoulou, 2015). These findings, while suggestive, are limited by the small samples involved and the few sleep measures used.

The Procrastination-Health Model proposed by Sirois and colleagues (Sirois et al., 2003) could be used to explain the possible associations between procrastination and poor sleep. The model posits that procrastination may affect health through both direct and indirect pathways. The direct pathway relates to the excessive stress that habitual procrastinators frequently experience from last-minute rushing to finish tasks or from missing deadlines (Sirois et al., 2015). The indirect pathway concerns behavioral routes: procrastinators might engage more in unhealthy behaviors that bring instant gratification and delay health-protective behaviors that incur costs and efforts at the moment. Both stress and unhealthy behaviors are known predictors of suboptimal sleep (Branstetter, Horton, Mercincavage, & Buxton, 2016; Lund, Reider, Whiting, & Prichard, 2010; Phillips & Danner, 1995), and thus might explain the relationships between procrastination and sleep.

Our goal is to assess the cross-sectional associations between chronic/habitual procrastination and multiple dimensions of sleep (social jetlag, sleep duration, and sleep quality) using data from a large national sample of US undergraduate and graduate students from the Healthy Minds Study. To our knowledge, this study is the first to evaluate the relationship between procrastination and social jetlag in a large national sample of adolescents and young adults (Roenneberg, Allebrandt, Merrow, & Vetter, 2012; Wittmann, Dinich, Merrow, & Roenneberg, 2006). Social jetlag reflects the discrepancy that arises between circadian and social clocks (Roenneberg et al., 2012). The circadian clock regulates physiological processes (e.g., sleep and energy homeostasis) to occur at distinct times over the course of a 24-h day. But people often use alarm clocks and/or medications to align their sleep and wake times with social obligations (e.g., work and school schedules), fighting the circadian signals from the brain. This results in differences in sleep timing between work/school and free days that lead to a form of jetlag due to social factors. While the travel-induced jetlag is transient (symptoms disappear when the clock re-entrains), social jetlag could be chronic throughout the years of schooling and working (Roenneberg et al., 2012). Moreover, social jetlag has been linked to obesity, psychological well-being, and consumption of stimulants (e.g., nicotine, alcohol, and caffeine) (Wittmann et al., 2006). Given its high prevalence and negative health consequences, social jetlag is of high societal relevance. An understanding of how procrastination relates to social jetlag would shed light on whether procrastination behaviors also relate to circadian misalignment, which might expose people to various health risk factors. This study is also innovative in that it investigates the distinct associations between procrastination and mean weekly sleep duration, weeknight sleep duration, and weekend night sleep duration, which would shed light on a deeper understanding about how procrastination is related to quantity of sleep on different types of days.

2. Materials and methods

2.1. Study participants and study design

Data came from the Healthy Minds Study (HMS) conducted by the Healthy Minds Network for Research on Adolescent and Young Adult Mental Health (HMN). The HMS is an ongoing nationwide annual web-based survey addressing mental health and related issues among undergraduate and graduate students aged 18 and older. At each participating campus, a random sample is selected from the full student population using the databases of school registrars. Mostly this initial sample is 4000 students. Since its establishment in 2007, HMS has collected information on 200,000 survey respondents from over 180 colleges and universities. The study was approved by the institutional review boards at all participating schools and all participants gave informed consent. More information is available at http://healthymindsnetwork.org/. The secondary data analyses were reviewed and approved by the human subjects committee of the Harvard T.H. Chan School of Public Health.

This study used HMS data collected in 2011, the only year when questions about procrastination were included. In 2011, 11 schools participated in the survey. Out of 33,257 students invited, 9596 started the survey, among whom 92.4% completed it, yielding a sample of 8870 students (overall participation rate 26.7%).

We excluded participants who reported very short or very long sleep duration (<3 h or > 13 h) as they were likely to have serious sleep disorders. We also excluded participants with extreme values of sleep timing (midpoint later than noon) and participants who were potentially shift workers as they were likely to have irregular sleep patterns. Participants who identified themselves as "transgender" were excluded as well since the group sample size (8) was too small to make meaningful inferences. In total, 128 were excluded and the final sample consisted of 8742 participants (for data cleaning protocols, see Table A1).

Response propensity weights were constructed by the HMN to address the possibility that students who completed the survey were different in important ways from those who did not. Administrative data on all students randomly selected for the study were provided by most participating schools, including gender, race/ethnicity, academic level (undergraduate or graduate), and GPA. These variables were used in a logistic regression to estimate the probability of response, the inverse of which equaled response propensity weights. These weights were used in all analyses.

2.2. Assessment of outcomes

Social jetlag was quantified as the absolute difference between mid-sleep times on weeknights and weekend nights. Respondents were asked at approximately what times they had typically gone to sleep and woken up on weeknights and weekend nights during the school year (four separate questions). Apparent data entry errors in sleep timing reporting were corrected (see details in supplementary materials). A person who went to sleep at midnight and woke up at 7:00am during weeknights had a mid-point of sleep at 3:30am on weeknights. If this person's sleep onset and offset times shifted to 1:00am and 9:00am during weekend nights, respectively, the mid-point of sleep on weekend nights would be 5:00am and he/she would have a social jetlag of 1.5 h.

Mean weekly sleep duration, weeknight sleep duration, and weekend night sleep duration were assessed separately. *Weeknight sleep duration and weekend night sleep duration* were evaluated by taking the differences between sleep offsets and onsets on weeknights and weekend nights, respectively. *Mean weekly sleep duration* was calculated as the average duration of five weeknights and two weekend nights.

Insomnia symptoms was measured by the question: "Over the last 4 weeks, how often have you been bothered by trouble falling asleep or staying asleep?" Responses ranged from 1 (not at all) to 3 (more than half the days). Respondents who indicated that they had the problems for more than half the days were regarded as suffering from insomnia symptoms. The variable was dichotomized according to clinical relevance as experiencing insomnia most of the time has been linked to increased risk of mortality (Li et al., 2014).

Daytime sleepiness was evaluated by the question: "Over the last 2 weeks, how often have you been bothered by feeling tired or having little energy?" Responses were rated on a scale ranging from 1 (not at all) to 4 (nearly every day). Those who were bothered by the problem for more than half the days were defined as suffering from daytime sleepiness.

Sleep medication use was assessed by one yes-no item: “In the past month, have you taken any prescribed sleep medications (e.g., zolpidem (Ambien), zaleplon (Sonata), etc.)? Please count only those you took, or are taking, several times per week.”

2.3. Assessment of exposure

Procrastination was assessed by 3 items from a previously psychometrically-validated scale – the General Procrastination Scale, which assesses the global tendencies towards chronic/habitual procrastination across a variety of daily tasks (Lay, 1986). In the 3-item procrastination scale, respondents were asked how well the statements described themselves: 1) “I often find myself performing tasks that I had intended to do days before”, 2) “I generally delay before starting on work I have to do”, and 3) “I am continually saying ‘I'll do it tomorrow’”. Reponses to these items were given along a five-point Likert scale (extremely unlike me, moderately unlike me, neutral, moderately like me, and extremely like me). A continuous composite procrastination score was calculated by taking the mean of the items, with higher values indicating higher levels of procrastination. The 3-item scale was estimated to have good internal consistency reliability (Cronbach alpha = .86) in the 2011 HMS data. The variable was centered at the sample mean in all regression analyses.

2.4. Covariates

Given that participants' gender and age may determine both procrastination and sleep behaviors (Steel, 2007; Wittmann et al., 2006), we controlled for these two variables to reduce potential confounding bias. We also controlled for respondents' sociodemographic and academic characteristics to increase precision as they are known correlates of sleep (Ertel, Berkman, & Buxton, 2011). Adjusted variables include race/ethnicity, relationship status, living arrangement (with parents/guardians or not), past financial status, parental education (highest level of education completed by mom or dad), academic level, and daily school work time. Additionally, dummy variables of schools were included to account for systematic differences that might affect students' sleep such as school start times. In sensitivity analyses we also adjusted for anxiety and depressive symptoms. Anxiety was assessed by the Patient Health Questionnaire (PHQ) algorithm. Generalized anxiety was diagnosed if the subject had been bothered by “feeling nervous, anxious, on edge, or worrying a lot about different things” for at least more than half the days in the past 4 weeks and if 3 or more of the symptom criteria had been present at least more than half the days (Spitzer, Kroenke, Williams, & Group, 1999). Depressive symptoms were assessed by the PHQ-9, the depression module. Major depression was diagnosed if 5 or more of the symptom criteria had been present at least more than half the days in the past 2 weeks, and 1 of the symptoms was depressed mood or anhedonia (Kroenke, Spitzer, & Williams, 2001).

2.5. Statistical analyses

For the main analyses, we ran simple and multiple survey linear regression models to examine the associations of procrastination with social jetlag and sleep duration. Survey Poisson regression models were used to evaluate the relationships between procrastination with binary sleep quality indicators (insomnia symptoms, daytime sleepiness, and sleep medication use) (Zou, 2004). To estimate 95% confidence intervals for the relative risks and Wald-based p-values, we used the robust sandwich estimator of the variance. Sensitivity analyses were conducted to assess if the results were influenced by data cleaning by excluding observations with identified sleep timing data entry errors. We also conducted sensitivity analyses by adjusting anxiety and depressive symptoms. Additionally, we assessed the relationships between the sleep outcomes and procrastination based on quartiles of the procrastination score. Inverse probability weighting were applied to all analyses using weights provided by HMN to improve representativeness of the full student population in terms of the available administrative variables (Seaman & White, 2013).

All analyses were performed using STATA version 15.1 (StataCorp LP, College Station, Texas). All tests were two-sided, with a significance level of 5%.

3. Results

Descriptive traits of the analytic sample are presented in Table 1. Slightly more than half (58.0%) of the weighted sample were female. About three-quarters (78.6%) of the total were between the ages 18 and 22. The racial/ethnic composition was 77.2% white, 7.0% black, 5.3% Hispanic/Latino, 4.5% Asian, and 5.9% other. Approximately 1 in two (52.9%) were single; 9.9% were living with parents or guardians. Few participants (2.7%) grew up in a very poor financial situation without enough to get by, 29.7% enough to get by, about half (56.3%) comfortable, and 11.3% well to do; 12.0% had a parent with high school education or less, 22.5% with an associate's degree or some college, 29.5% with a college degree, 36.1% with a graduate degree. The majority (81.1%) were undergraduate students. Slightly more than one-third (39.8%) spent 2 h or less per day on school work, 36.2% spent 3–4 h, and 24.0% spent 5 h or more.

The mean of procrastination score was 3.3 (SD: 1.1) on a 1–5 scale

Table 1
Descriptive traits of HMS cohort, N=8,742

	% / Mean (SD)		% / Mean (SD)
Socio-demographics		**Academic factors**	
Gender		Degree level	
Female	58.0%	Undergraduate	81.1%
Male	42.0%	Graduate	12.1%
Age (y)		Other	6.9%
18-22	78.6%	School work time (h/day)	
23-25	8.6%	<= 2	39.8%
26-30	5.5%	3-4	36.2%
31+	7.3%	>= 5	24.0%
Race/ethnicity		**Mental health factors**	
White	77.2%	Major depression	
Black	7.0%	Yes	9.8%
Hispanic/Latino	5.3%	No	90.2%
Asian	4.5%	Generalized anxiety	
Other	5.9%	Yes	5.9%
Relationship status		No	94.1%
Single	52.9%	**Procrastination**	
In a relationship	37.0%	Procrastination (1-5 scale)	3.32 (1.10)
Married	9.3%	**Sleep**	
Divorced/widowed	0.7%	Social jetlag (h/week)	1.76 (.99)
Living with parents or guardians		Mean weekly sleep duration (h/day)	8.06 (1.26)
Yes	9.9%	Weeknight sleep duration (h/day)	7.84 (1.46)
No	90.1%	Weekend night sleep duration (h/day)	8.60 (1.40)
Past financial situation		Insomnia symptoms	
Very poor, not enough to get by	2.7%	Yes	20.8%
Enough to get by	29.7%	No	79.2%
Comfortable	56.3%	Daytime sleepiness	
Well to do	11.3%	Yes	31.6%
Parental education		No	68.4%
High school or less	12.0%	Sleep medication use	
Associate's degree or some college	22.5%	Yes	3.9%
College degree	29.5%	No	96.1%
Graduate degree	36.1%		

Response propensity weights applied.

(see Fig. 1 for its distribution). The mean of social jetlag was 1.8 h (SD: 1.0). Fig. 2A presents its distribution. About four-fifths (81.3%) of the sample suffered from at least 1 h of social jetlag. Fig. 2B presents the relationship between social jetlag and age, highlighting that social jetlag peaked at the end of adolescence and decreased afterwards. Respondents slept longer on weekend nights (mean: 8.6 h; SD: 1.4) than on weeknights (mean: 7.8 h; SD: 1.5); the mean of weekly average sleep duration was 8.1 h (SD: 1.3) (see Fig. 3 for distributions of sleep duration). About one-fifth were bothered by insomnia symptoms, 31.6% daytime sleepiness, and 3.9% sleep medication use.

Table 2 reports results from multiple linear regression models separately estimating social jetlag, mean weekly sleep duration, weeknight sleep duration, and weekend night sleep duration (all assessed in minutes). Procrastination was positively linked to social jetlag (β = 3.34 min; 95% CI [1.86, 4.81]), indicating that procrastinators suffer more circadian misalignment than non-procrastinators.

For sleep duration, higher procrastination scores were significantly associated with shorter mean weekly sleep duration (β = −4.44 min; 95% CI [-6.36, −2.52]) and shorter weeknight sleep duration (β = −6.10 min; 95% CI [-8.37, −3.84]), after controlling for sociodemographic and academic factors. On the other hand, procrastination was not significantly associated with weekend night sleep duration. Thus, the shorter mean weekly sleep duration experienced by procrastinators were driven by their shorter weeknight sleep duration. Specifically, with a one-unit increase in procrastination score, weeknight sleep duration decreased by 6 min, resulting in a total 24 min sleep/night difference between the lowest and the highest levels of procrastination per night. For mean weekly sleep duration, an average of 4 min less sleep per night was associated with a one-unit increase in procrastination score, which was approximately half an hour per week decrease in sleep.

Table 3 reports results from multiple Poisson regression models separately estimating indices of sleep quality, including insomnia symptoms, daytime sleepiness, and sleep medication use. Higher levels of procrastination were associated with elevated risks of insomnia symptoms (Relative Risk (RR) = 1.27; 95% CI [1.19, 1.37]) and daytime sleepiness (RR = 1.32; 95% CI [1.27, 1.38]). However, there was no evidence that procrastination was associated with sleep medication use.

In sensitivity analyses, we re-estimated all models restricting the sample to respondents with no data entry errors to evaluate if data cleaning had an impact on the inferences, as well as adjusting for anxiety and depressive symptoms. Results were similar to those from the main analyses, which spoke to the robustness of our findings. Results based on quartiles of the procrastination score were similar to those from the main analyses as well. Specifically, compared to individuals in the lowest quartile of the procrastination score, those in the highest quartile of the procrastination score had greater social jetlag (β = 10.98 min; 95% CI [6.30, 15.65]), shorter mean weekly sleep duration (β = −15.34 min; 95% CI [-21.45, −9.24]), and shorter weeknight sleep duration (β = −20.52 min; 95% CI [-27.73, −13.31]) (Table A2). Those who procrastinated the most also had greater odds of insomnia symptoms (RR = 2.06; 95% CI [1.70, 2.51]) and daytime sleepiness (RR = 2.21; 95% CI [1.96, 2.49]) compared to those who procrastinated the least (Table A3).

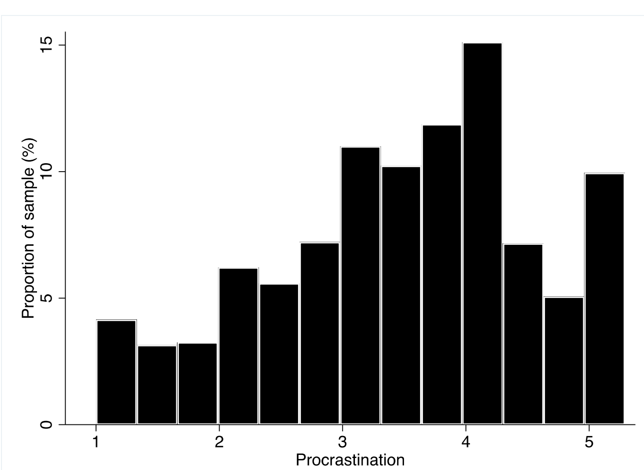

Fig. 1. Distribution of procrastination score.

4. Discussion

This study investigated the relationships between self-reported procrastination and a variety of sleep behaviors (social jetlag, sleep duration, insomnia symptoms, daytime sleepiness, and sleep mediation use) among US undergraduate and graduate students. Procrastination was positively associated with social jetlag, a delay in sleep timing from weeknights to weekend nights, indicating that procrastinators experienced more circadian misalignment than non-procrastinators. Second, higher levels of procrastination were associated with shorter mean weekly sleep duration driven by shorter weeknight sleep duration experienced by procrastinators. In contrast, weekend night sleep duration was not linked to procrastination. Lastly, greater procrastination was also associated with increased risks of insomnia symptoms and daytime sleepiness, but not sleep medication use.

While this study, guided by the Procrastination-Health Model, postulated that procrastination might be a determinant of poor sleep. Some prior studies have, on the other hand, argued that the causal direction could be the opposite (van Eerde & Venus, 2018). Namely, sleep deprivation results in depleted self-control resources, which make the affected individuals more likely to procrastinate (Kühnel, Bledow, & Feuerhahn, 2016). There might indeed exist feedback loops between procrastination and sleep such that procrastination compromises sleep, which in turn results in a reduction in self-regulation resources, which further exacerbates the tendency to procrastinate. Yet, research has shown that chronic procrastination is trait like in that there might be genetic underpinnings to chronic procrastination measured by the General Procrastination Scale (Gustavson, Miyake, Hewitt, & Friedman, 2014, 2015), making it conceptually difficult to argue that over a short period of time that lack of sleep would turn into chronic/habitual procrastination.

Kroese and colleagues introduced the concept of bedtime procrastination, "failing to go to bed at the intended time, while no external circumstances prevent a person from doing so" (Kroese, De Ridder et al., 2014; Kroese, Evers, et al., 2014). They found that bedtime procrastination was linked to reports of insufficient sleep in an Amazon Mechanical Turk sample (N = 177) and a Dutch adult sample (N = 2431) (Kroese, De Ridder et al., 2014; Kroese, Evers, et al., 2014). However, these two studies addressed only one specific domain of procrastination – bedtime procrastination, but not general procrastination. Two other studies examined the link between general procrastination and sleep. Hairston surveyed 598 individuals and found that procrastination was related to insomnia symptoms (Hairston & Shpitalni, 2016). Sirois and colleagues evaluated the problem in two samples, one of Greek undergraduate students (N = 141) and one of Canadian students (N = 339). Results revealed that procrastination was associated with indices of poor sleep quality and that higher stress seemed to play a role in explaining the association (Sirois et al., 2015). Our finding that procrastination was linked to insomnia symptoms and daytime sleepiness is consistent with previous findings (Hairston & Shpitalni, 2016; Sirois et al., 2015). A prior study found an association between procrastination and sleep medication use (Sirois et al., 2015) whereas we did not. A reason for the difference could be that the question in the HMS survey was very strict in asking respondents to only count "prescribed" sleep medications they took or were taking "several times per week", which could signal serious sleep disorders. In contrast, other surveys usually ask respondents how often they took prescribed or over-the-counter sleep medications.

The fact that procrastination was only associated with weeknight but

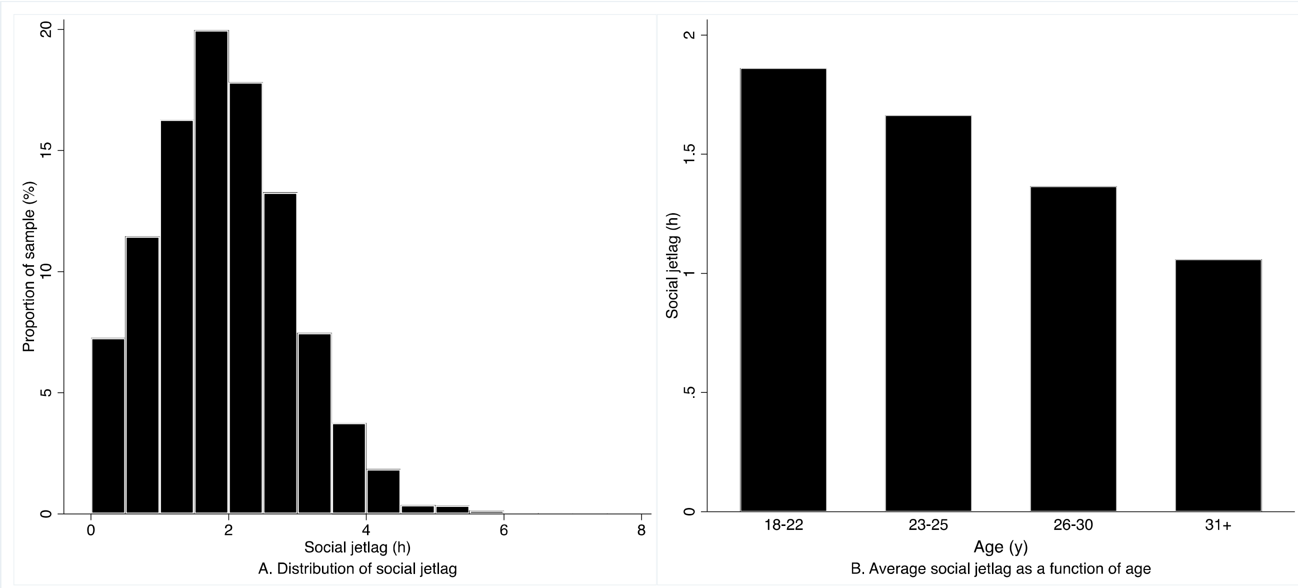

Fig. 2. Distribution of social jetlag (A) and average social jetlag as a function of age (B).

not weekend night sleep duration could arise from different sleep patterns (times) on weeknights and weekend nights based on levels of procrastination. Specifically, procrastinators had later sleep onsets compared to non-procrastinators on both weeknights and weekend nights (observation from the HMS data, summary available upon request). This is consistent with prior research showing that procrastinators tend to be evening owls (Díaz-Morales, Ferrari, & Cohen, 2008; Digdon & Howell, 2008). This resulted in shorter sleep duration on weeknights (because of early sleep offsets – schools start at the same time regardless of students' bedtime) and slightly longer sleep duration on weekend nights (because of late sleep offsets thanks to fewer external constraints on free days). Procrastinators' shifted sleep times between weeknights and weekend nights also explained the greater social jetlag they experienced: the difference between their mid-sleep times on weekdays and weekends were bigger than that of non-procrastinators'.

There are a few possible explanations for procrastinators' late sleep onsets. First, procrastinators might have to stay up late to finish the tasks they had postponed doing (thereby displacing the hours available for sleep). Second, they might simply delay the action of going to bed (bedtime procrastination (Kroese, De Ridder et al., 2014)) by not quitting other activities such as checking social media or devices, or other screen-based activities. The extra (primarily blue) light exposure they receive (e.g., from using electronic devices) before bedtime may additionally suppress melatonin levels (Chang, Aeschbach, Duffy, & Czeisler, 2015), which in turn would delay sleep onsets.

One emerging sleep health component related to social jetlag is sleep regularity, which is important for understanding sleep disorders such as insomnia and circadian rhythm disorders (Buysse, 2014). Studies have linked sleep regularity to cardiometabolic outcomes – increased variability in sleep duration and timing was associated with metabolic abnormalities (Huang & Redline, 2019; Taylor et al., 2016). While social jetlag describes sleep timing differences between weeknights and weekend nights, sleep regularity captures more general, night-to-night variability in sleep patterns. Procrastination might be more strongly associated with night-to-night sleep regularity than social jetlag, since sleep schedules are more likely to be influenced by procrastination behaviors on a daily basis depending on whether there is an urgent task. Although our data did not allow us to assess sleep regularity, future research might consider investigating the relationship between procrastination and sleep regularity.

This study contributes to the literature in four ways. First, our study is the first that has evaluated the relationship between procrastination and social jetlag in a large national student sample. Second, this study is innovative in that it investigates the distinct associations between procrastination and mean weekly sleep duration, weeknight sleep duration, and weekend night sleep duration. Prior research has only investigated whether procrastination is linked to average/typical sleep duration during the past month (Sirois et al., 2015) or just weekday sleep duration (Kroese, De Ridder et al., 2014). A differentiation between mean weekly, weeknight, and weekend night sleep duration would elucidate the how procrastination is tied to sleep duration on different types of days. Third, we investigate the relationships between procrastination with indices of sleep quality, including insomnia symptoms, daytime sleepiness, and sleep medication use. Combined with social jetlag and sleep duration, these different aspects of sleep paint a comprehensive picture of sleep health. Fourth, this study focuses on US adolescents and young adults, populations that suffer from serious problems of both procrastination and sleep deprivation (Edens, 2006; Hill et al., 1978). The large national sample used would afford generalizable insights on procrastination and sleep among US undergraduate and graduate students.

This study has limitations. First, the cross-sectional nature of the data constrained our ability to make causal inferences. Given the potential cyclic relationship between procrastination and sleep, more studies with longitudinal or experimental designs are warranted. Efforts could also be devoted to investigating the potential mediating roles of health behaviors. Second, while applying the response propensity weights constructed by the HMN to analyses increased our confidence that the weighted estimates were representative of the full student population in terms of administrative variables, our results were not immune from selection bias as it was possible that students who were procrastinators and whose sleep was suboptimal were less likely to respond to the survey. Lastly, both procrastination and sleep measures were self-reported by respondents in the HMS data, which might induce common-method bias. Prior research has shown that self-reported sleep duration overestimated sleep duration by about 1 h when compared with actigraphy-measured total sleep time or polysomnography-defined sleep time. The self-reported sleep only moderately correlated with objectively measured sleep (Jackson, Patel, Jackson, Lutsey, & Redline, 2018). Furthermore, procrastination might affect the accuracy of individuals' self-reported sleep times and the extent of over-reporting of sleep duration, or affect how individuals perceive their sleep quality, which

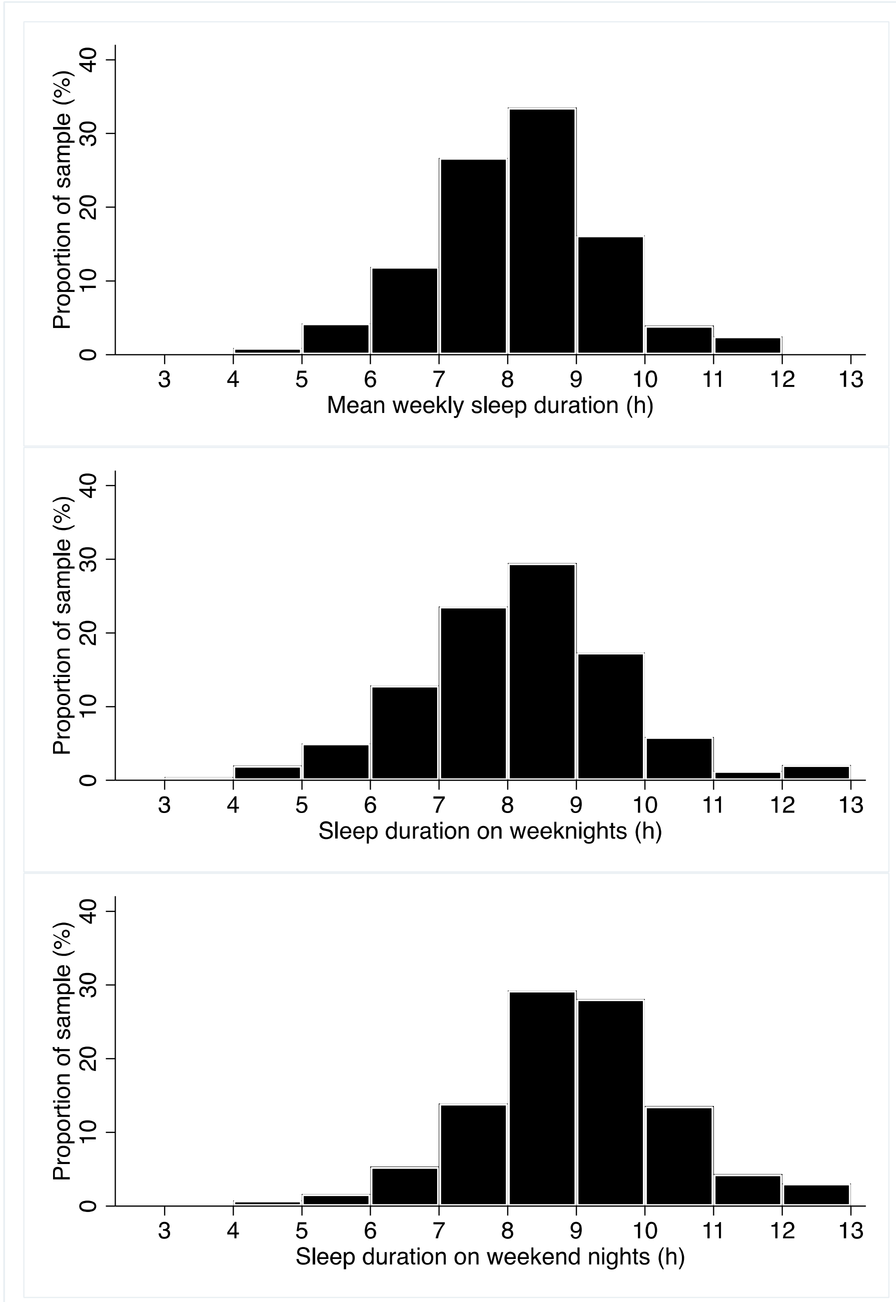

Fig. 3. Distributions of sleep durations.

Table 2
Linear regression models estimating continuous sleep outcomes.

	Social jetlag		Mean weekly duration		Weeknight duration		Weekend night duration	
	Beta	[95% CI]	Beta	[95% CI]	Beta	[95% CI]	Beta	[95% CI]
Procrastination (centered)								
Unadjusted	**5.26**	**[3.75,6.78]** ***	**−2.11**	**[-4.07,-0.15]** *	**−3.41**	**[-5.70,-1.12]** **	1.13	[-0.98,3.25]
Adjusted	**3.34**	**[1.86,4.81]** ***	**−4.44**	**[-6.36,-2.52]** ***	**−6.10**	**[-8.37,-3.84]** ***	−0.29	[-2.39,1.82]

95% confidence intervals in brackets.
$^{+} p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
Adjusted analyses controlled for gender, age, race/ethnicity, relationship status, living arrangement, past financial status, parental education, academic level, daily school work time, and school dummies. Response propensity weights applied.

Table 3
Poisson regression models estimating binary sleep outcomes.

	Insomnia symptoms		Daytime sleepiness		Sleep medication use	
	RR	[95% CI]	RR	[95% CI]	RR	[95% CI]
Procrastination (centered)						
Unadjusted	**1.27**	**[1.18,1.36]** ***	**1.31**	**[1.26,1.37]** ***	1.09	[0.93,1.29]
Adjusted	**1.27**	**[1.19,1.37]** ***	**1.32**	**[1.27,1.38]** ***	1.11	[0.95,1.29]

Exponentiated coefficients; 95% confidence intervals in brackets.
$^{+}$ $p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Adjusted analyses controlled for gender, age, race/ethnicity, relationship status, living arrangement, past financial status, parental education, academic level, daily school work time, and school dummies. Response propensity weights applied.

might result in differential classification of the sleep outcomes. If the inaccurate reporting is non-differential with respect to procrastination, it would drive the associations towards the null. However, if there is differential misclassification – e.g., procrastinators over-estimate how much sleep they are getting compared to non-procrastinators, this would drive associations away from the null (the actual associations might be stronger than what we observed). It would be of interest for future research to use objective measures of sleep (e.g., longitudinal actigraphy data) to elucidate the relationships between procrastination and multiple dimensions of sleep.

Although the magnitudes of the observed associations are modest, the effect sizes for the sleep outcomes, when accumulated over an extended period of time for habitual procrastinators, might have substantial implications on their health and cognitive performance. For instance, the Sleep Continuity Theory posits that a period of 10 min of uninterrupted sleep is required for restoration to take place (Downey & Bonnet, 1987). Experimental research has shown that sleeping as brief as 10 min could improve subjective and objective alertness and increase feelings of vigor and decrease fatigue (Lovato & Lack, 2010).

5. Conclusions

Our study showed that procrastination was associated with more social jetlag, shorter sleep duration, and worse sleep quality among US undergraduate and graduate students. The findings highlight that procrastination might be a vulnerability factor for poor health, but not just something prevalent and relatively harmless. With the increasing prevalence and availability of temptations (e.g., ubiquity of electronic devices and 24/7 entertainment industry), people are facing more distractions than before and the problem of procrastination might continue to increase (Kroese, Evers, et al., 2014; Steel, 2007). Findings from this study inform potential targeted interventions to help adolescents and young adults prevent and manage procrastination and to improve their sleep health, which in turn, could promote their overall well-being (mental and physical health) and performance. Procrastination treatment programs that improve people's time management skills would be of value, as would recommendations tailored to reduce procrastination on going to bed. For instance, by simply adjusting proximity to temptations (e.g., keep the cell-phone out of the bedroom), procrastination could be reduced. In addition, training programs targeting emotion regulation skills might also be of value, as research has shown that training of emotion-focused strategies decreases procrastination (Eckert, Ebert, Lehr, Sieland, & Berking, 2016).

Ethics approval

The study was approved by the institutional review boards at all participating schools and all participants gave informed consent. More information is available at http://healthymindsnetwork.org/. The secondary data analyses were reviewed and approved by the human subjects committee of the Harvard T.H. Chan School of Public Health. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2019.100518.

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