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TYPE:	Article CC:CCG
JOURNAL TITLE:	Archives of suicide research
USER JOURNAL TITLE:	Archives of Suicide Research
ARTICLE TITLE:	Social Jetlag and Other Aspects of Sleep Are Linked to Non-Suicidal Self-Injury Among College Students
ARTICLE AUTHOR:	Tubbs, Andrew S.,
VOLUME:	Online first (April
ISSUE:	
MONTH:	4
YEAR:	2022
PAGES:	1-
ISSN:	1381-1118
OCLC #:	

Processed by RapidX: 7/18/2022 2:55:06 PM

Archives of Suicide Research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/usui20

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To cite this article: Andrew S. Tubbs, Sierra Hendershot, Sadia B. Ghani, Michael R. Nadorff, Christopher W. Drapeau, Fabian-Xosé Fernandez, Michael L. Perlis & Michael A. Grandner (2022): Social Jetlag and Other Aspects of Sleep Are Linked to Non-Suicidal Self-Injury Among College Students, Archives of Suicide Research, DOI: 10.1080/13811118.2022.2057262

To link to this article: https://doi.org/10.1080/13811118.2022.2057262

Published online: 07 Apr 2022.

ARCHIVES OF SUICIDE RESEARCH
https://doi.org/10.1080/13811118.2022.2057262

Social Jetlag and Other Aspects of Sleep Are Linked to Non-Suicidal Self-Injury Among College Students

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ABSTRACT

Introduction: Disrupted sleep is associated with non-suicidal self-injury (NSSI) in young adults, but many specific features of sleep continuity and timing have yet to be examined. Additionally, the psychological mechanisms linking sleep to NSSI are unclear. The present study evaluated 14 sleep variables as classifiers of lifetime or recent NSSI and examined potential confounding and mediating factors.

Methods: A sample of 885 college students provided measures of sleep continuity (e.g., duration, timing, fragmentation), nightmares, insomnia, and perceived sleep control. Lifetime and past 3-month NSSI were measured using a self-report version of the Columbia Suicide Severity Ratings Scale. Bidirectional stepwise regression identified significant sleep classifiers and subsequent models examined their associations with NSSI after adjusting for covariates and through potential psychological mediators.

Results: Only absolute social jetlag was associated with recent NSSI, even after adjusting for covariates, such that each additional hour difference between weekday and weekend sleep schedules was associated with a 17% greater risk of recent NSSI. Nightmares, weekend sleep efficiency, and perceived sleep control were associated with lifetime NSSI, although only weekend sleep efficiency remained associated after adjusting for covariates. Bootstrap mediations identified negative urgency as a partial mediator for recent and lifetime NSSI, and lack of premeditation and perceived burdensomeness as partial mediators for lifetime NSSI.

Conclusions: The timing and consistency of young adults' sleep schedules may be of greater importance to NSSI among college students than insomnia or insufficient sleep. Future studies of sleep and NSSI should include these measures as potential risk factors.

HIGHLIGHTS

- Differences between weekday/weekend sleep timing are linked to recent NSSI.
- Negative urgency partially mediates poor sleep on recent and lifetime NSSI.
- Sleep shares a multifaceted relationship with NSSI risk in college students.

KEYWORDS

Circadian rhythms; college students; non-suicidal self-injury; sleep

Supplemental data for this article can be accessed at publisher's website.

INTRODUCTION

Non-suicidal self-injury (NSSI) is associated with two-fold greater odds of suicidal thoughts and behaviors and a 1.5-fold greater likelihood of suicide (Ribeiro et al., 2016). The prevalence of NSSI is particularly high among adults aged 18–24; 8.4% of college students report NSSI in the last 12 months and up to 18% report a lifetime history of NSSI compared to a 5.5% lifetime prevalence among adults 25 and older (Kiekens et al., 2021; Sivertsen et al., 2019; Swannell, Martin, Page, Hasking, & St John, 2014). The elevated prevalence of NSSI among college students may translate to greater danger for suicidal behavior, as students who report NSSI have a 2.8-fold greater likelihood of subsequent suicidal ideation and 5.5-fold greater odds of attempting suicide (Kiekens et al., 2018). Given that suicide is at the highest rates ever recorded among individuals 15–24 (Drapeau & McIntosh, 2020; Hedegaard, Curtin, & Warner, 2018; Xu, Murphy, Kochanek, & Arias, 2020), and that the prevalence of NSSI tends to peak in adolescence and young adulthood (Plener, Schumacher, Munz, & Groschwitz, 2015; Swannell et al., 2014), efforts to understand and mitigate the causes of NSSI in college students may reduce future suicide risk. Sleep and circadian rhythms are a promising place to start.

Current data connect sleep problems with NSSI through emotional dysregulation, suicidal cognitions such as thwarted belongingness (Chu, Buchman-Schmitt, et al., 2017; Grove et al., 2020; Van Orden et al., 2010), and depression (Khazaie et al., 2020; Russell et al., 2019). Unfortunately, these findings are limited by their focus on broad concepts (e.g., poor sleep quality, sleep disturbances) that do not differentiate between specific and distinct facets of sleep. For example, up to 60% of college students report poor quality sleep (Becker et al., 2018; Lund, Reider, Whiting, & Prichard, 2010), but poor sleep quality is a notoriously broad and subjective experience (Harvey, Stinson, Whitaker, Moskovitz, & Virk, 2008; Krystal & Edinger, 2008). As a more specific example, 42% of students report taking 30 min or more to fall asleep at least once a week (Becker et al., 2018). Difficulty initiating sleep (or early morning awakenings) may occur as part of insomnia, but may also result from circadian misalignment (Baron & Reid, 2014), in which an attempt to sleep is misaligned with the individual's biological rhythm of sleep and wake as governed by the 24-h light/dark cycle. Circadian misalignment can be assessed by comparing the midpoint of sleep on weekdays/workdays to the midpoint of sleep on weekends/non-workdays (i.e., their chronotype) when individuals typically follow their preferred sleep pattern. Circadian misalignment is of particular relevance to adolescents and young adults, for whom a natural shift to later sleep/wake schedules conflicts with early school start times and can lead to cognitive impairments that confer greater vulnerability to addiction and risky behaviors (Logan et al., 2018; Touitou, Touitou, & Reinberg, 2016). Similarly, difficulties maintaining sleep and nighttime awakenings may result from insomnia, nightmares, or untreated sleep apnea. Even if sleep occurs without interruption, it may be of insufficient duration; current guidelines state that adolescents and young adults should get between 7 and 9 h of sleep (Hirshkowitz et al., 2015; Paruthi et al., 2016; Watson et al., 2015), and yet up to 40% of college students report sleeping less than 7 h (Becker et al., 2018; Peltzer & Pengpid, 2016). Unstable sleep schedules may also confer risk (Bernert, Hom, Iwata, & Joiner, 2017), and many young adults significantly shift their sleep timing between weekday

and weekend schedules, a phenomenon known as social jetlag, which is associated with depression and poorer mental health (Henderson, Brady, & Robertson, 2019; Wittmann, Dinich, Merrow, & Roenneberg, 2006).

The lack of specificity in quantifying sleep makes it difficult to investigate the causal mechanisms that link sleep and NSSI for three reasons. First, different sleep disorders affect different neurocognitive and psychological processes of relevance to NSSI. For example, NSSI is linked to emotional dysregulation and poor impulse control (Liu, Trout, Hernandez, Cheek, & Gerlus, 2017; Taylor et al., 2018; Wolff et al., 2019). Although nightmares are closely associated with emotional dysregulation (Rufino, Ward-Ciesielski, Webb, & Nadorff, 2020; Ward-Ciesielski, Winer, Drapeau, & Nadorff, 2018), insomnia is linked to impulsivity as well as thwarted belongingness, hyperarousal, and impaired decision-making (Chu, Hom, et al., 2017; Hom et al., 2017; Riemann et al., 2010; Shekleton et al., 2014; Van Someren, 2020; Wardle-Pinkston, Slavish, & Taylor, 2019). Insufficient sleep, fragmented sleep, circadian preference (or chronotype), and social jetlag also affect risk-taking, emotion regulation, conflict processing, and impulsivity (Berdynaj et al., 2016; Henderson et al., 2019; Lowe, Safati, & Hall, 2017; McGowan & Coogan, 2018; McGowan, Uzoni, Faltraco, Thome, & Coogan, 2020; Palmer & Alfano, 2017; Pilcher, Morris, Donnelly, & Feigl, 2015; Rumble et al., 2018; Schmidt et al., 2012; Wittmann et al., 2006), and thus may also contribute to risk for NSSI. Second, sleep disorders vary in prevalence across sociodemographic and clinical factors. Nightmares are a central component of post-traumatic stress disorder and other psychiatric disorders (Lemyre, Bastien, & Vallières, 2019) and tend to be more common among women (Schredl & Reinhard, 2011), while insomnia and short sleep vary by racial and ethnic identity (Grandner & Drummond, 2007; Grandner et al., 2015; Grandner et al., 2010; Jean-Louis et al., 2015; Whinnery, Jackson, Rattanaumpawan, & Grandner, 2014). Additionally, use of alcohol, cannabis, or other substances can confound the relationship between sleep and NSSI (Bresin & Mekawi, 2020; Fox et al., 2015; Sellers, Diaz-Valdes, Oliver, Simon, & O'Brien, 2021; Williams & Hasking, 2010). Finally, without specifically identifying the sleep disorder at issue, it is difficult to devise or deploy an appropriate intervention to resolve the sleep problem and thus reduce risk.

Multidimensional assessment of sleep and circadian rhythms is needed to identify which sleep features are associated with NSSI, independent of confounders such as mental illness or substance use, and whether such associations are mediated by impulsivity or suicidal cognitions such as thwarted belongingness (Van Orden et al., 2010). Therefore, the present study used multiple self-report measures of sleep and circadian rhythms in a large sample of college students to study the relationship between sleep and NSSI. Analyses compared 14 measures of sleep continuity, timing, stability, chronotype, insomnia symptoms, and nightmare symptoms to identify the sleep variables relevant to NSSI. Given the paucity of similar comparative studies, no *a priori* hypotheses were made about which variables would be significant. Sequential modeling then examined whether significant sleep classifiers were related to NSSI independent of, or in concert with, sociodemographic factors and substance use, severity of anxiety and depression symptoms, thwarted belongingness and perceived burdensomeness, and measures of impulsivity.

MATERIALS AND METHODS

Data Source

Data were collected between May 2020 to May 2021 from 885 students aged 18–25 at the University of Arizona as part of the Assessing Nocturnal Sleep/Wake Effects on Risk of Suicide (ANSWERS) Phase I Survey. Recruitment occurred either through participation in an undergraduate psychology course or in response to flyers and emails sent through departmental list-servs. Participants provided informed consent using an e-consent framework before completing the survey in their web browser. Prior to completing self-report measures of suicidality and NSSI, participants were instructed that, if they were suicidal or at-risk for suicide, they should call 911, the Suicide Prevention Hotline, the Crisis Response Center in Tucson, or the University of Arizona Counseling and Psych Services. No other risk assessment or follow-up was conducted. This study was approved by the University of Arizona IRB (Protocol #2005675654).

Measures

Non-Suicidal self-Injury

The primary outcomes were a history of non-suicidal self-injury (NSSI) within the last 3 months (recent NSSI) or in an individual's lifetime (lifetime NSSI). This was assessed using a self-report version of the Columbia Suicide Severity Ratings Scale (C-SSRS) (Posner et al., 2011), which asks about suicidal thoughts and behaviors, including NSSI. Specifically, participants were asked to respond yes or no to the question, "have you hurt yourself for reasons other than to die or without any intention of killing yourself (like to relieve stress, feel better, or get something else to happen)?" The internal consistency (Cronbach's alpha) of responses on the C-SSRS was 0.90.

Sleep Continuity

Sleep continuity for weekdays/workdays and weekends/non-workdays was assessed using the split week Self-Assessment of Sleep Survey (Dietch, Sethi, Slavish, & Taylor, 2019), which collects similar information to the consensus sleep diary (Carney et al., 2012) and the Munich Chronotype Questionnaire (Roenneberg, Wirz-Justice, & Merrow, 2003) for the past 2 weeks. For weekdays/workdays and weekends/non-workdays, participants report when they typically go to bed (TTB), when they intend to go to sleep (TTS), how long it takes to fall asleep (sleep onset latency, SOL), how many times they wake up at night (NWAK) and for how long (wake after sleep onset, WASO), their time of final awakening (TFA), when they got out of bed (TOB) and how long it took to get out of bed (early morning awakening, EMA), and how they rate their sleep quality (SQ: 1 = worst to 5 = best). These data were used to calculate time in bed (TIB: TOB − TTB), total wake time (TWT: SOL + WASO + EMA), total sleep time (TST: TIB − TWT), the percent of time spent in bed asleep (sleep efficiency, SE: TST/TIB), and SQ for weekdays/workdays and weekends/non-workdays.

Social Jetlag and Chronotype

Measures of sleep continuity can be used to calculate the midpoint of the sleep period for weekdays/workdays and weekends/non-workdays, thus creating a single variable that captures sleep timing. Taking the absolute and relative difference between these midpoints provides the absolute and relative social jetlag, representing the shift in time between the weekday and weekend sleep period (Roenneberg et al., 2003; Wittmann et al., 2006). Since weekday/workday sleep schedules are often constrained by employment or social obligations, the midpoint of sleep on weekdays/workdays can be "corrected" using the weekend/non-workday sleep schedules to obtain an individual's chronotype, or their preferred midpoint of sleep (Roenneberg et al., 2003). Using this approach, morning larks would have an earlier midpoint of sleep (e.g., 2AM) while night owls would have a later midpoint of sleep (e.g., 4AM).

Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) is a 19-item self-report questionnaire that provides a total score of sleep quality (0–21) for the past month based on 7 component scores for sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleep medications, and daytime dysfunction. The PSQI is included here for descriptive purposes but is not used in subsequent analyses because of more precise assessment by other measures. The internal consistency between PSQI component scores was 0.70.

Brief Inventory of Sleep Control

The Brief Inventory of Sleep Control (BRISC) (Grandner et al., 2020) is a 4-item self-report questionnaire of perceived sleep control for the past 2 weeks and is intended as a brief evaluation of dysfunctional beliefs about sleep in epidemiological contexts. Participants are asked how much control they have over (1) when they go to sleep, (2) when they wake up, (3) how much they sleep, and (4) how well they sleep, and can select "none at all" (0), "a little control" (1), "some control" (2), "a lot of control" (3), and "complete control" (4). Higher scores reflect greater perceived sleep control. The internal consistency of the BRISC was 0.75.

The Disturbing Dream and Nightmare Severity Index

The Disturbing Dream and Nightmare Severity Index (DDNSI) (Krakow, 2006) is a 5-item self-report questionnaire that assesses the number of nights in a week with nightmares (0–7), how many nightmares happen per week (0–14), how many times the nightmares wake the respondent up (0, "never" to 4, "always"), the severity of the nightmare problem (0, "no problem" to 6, "extremely severe"), and the intensity of the nightmares (0, "not intense" to 6, "extremely intense") in the past 2-weeks. The scores on each item are summed to a total score (0 to 37), with scores greater than 10 indicative of nightmare disorder (Krakow, 2006). The internal consistency of the DDNSI was 0.89.

The Insomnia Severity Index

The Insomnia Severity Index (ISI) (Bastien, Vallieres, & Morin, 2001) is a 7-item self-report measure of insomnia symptoms. Each symptom is scored 0–4, with greater scores reflecting greater symptom severity, and all items are summed to calculate a total score (0–28). The internal consistency of the ISI was 0.81.

Covariates

Severity of depressive symptoms was assessed using the Center for Epidemiological Studies Depression Scale (CESD) (Van Dam & Earleywine, 2011), a 20-item self-report questionnaire in which participants rank the frequency of particular feelings (0, "rarely or none of the time" to 3 "most or all of the time"). Items are summed to provide a total score ranging from 0 to 60, with greater scores reflecting greater depression severity. The internal consistency of the CESD was 0.91. The severity of anxiety symptoms was assessed using the Generalized Anxiety Disorder-7 Questionnaire (GAD-7) (Spitzer, Kroenke, Williams, & Lowe, 2006), in which participants rank the frequency of seven anxiety symptoms from 0 ("not at all") to 3 ("nearly every day"). Items are summed to provide a total score ranging from 0 to 21 with higher scores reflecting greater anxiety. The internal consistency of the GAD-7 was 0.92. Alcohol and cannabis use were assessed by asking respondents, "how often do you drink alcohol" or "how often do you use marijuana/cannabis," with respondents reporting "never," "once a month or less," "once a week or less," "a few times a week," "every day," or "multiple times a day." These were recoded to "Never," "Once a week or less," and "More than once a week." Participants additionally reported their age, sex, race, and ethnicity. Age is reported for completeness but was not included in analyses because age was limited by study design (18–25).

Mediators

Finally, trait impulsivity was assessed using the Short UPPS-P Impulsive Behavior Scale (SUPPS-P) (Cyders, Littlefield, Coffey, & Karyadi, 2014), a 20-item questionnaire that asks participants to rank whether they "agree strongly," "agree some," "disagree some," or "disagree strongly" with 20 statements. Responses are scored and grouped into five subscales of impulsive behavior: positive and negative urgency, lack of perseverance, lack of premeditation, and sensation seeking. The internal consistency of the SUPPS-P was 0.79. Perceived burdensomeness and thwarted belongingness, components of the ITPS (Van Orden et al., 2010), were measured using the Interpersonal Needs Questionnaire (INQ) (Van Orden, Cukrowicz, Witte, & Joiner, 2012). The INQ asks respondents to rate 15 statements from 1 (not at all true for me) to 7 (very true for me), such that the sum of the first 6 items measures perceived burdensomeness and the sum of the remaining items measures thwarted belongingness. The internal consistency of the INQ was 0.91.

Statistical Analyses

Simple comparisons were made using *t*-tests and Chi-squared tests. Statistical analyses compared lifetime NSSI to no NSSI and recent NSSI to lifetime NSSI. Primary outcomes were modeled using Poisson models with robust variance estimation to estimate

prevalence risks directly while accounting for model misspecification (Cameron & Trivedi, 2013; Chen, Shi, Qian, & Azen, 2014; Jean-Louis et al., 2020; Zou & Donner, 2013). The results of robust Poisson models are reported as prevalence risk ratios (PRR) instead of odds ratios, along with their 95% confidence intervals. Bidirectional stepwise selection filtered through all sleep variables (weekday and weekend TST, TWT, SE, SQ, chronotype, absolute and relative social jetlag, perceived sleep control, insomnia severity score, and nightmare disorder) using the Akaike Information Criterion to identify the best subset of sleep classifiers. This was done for both lifetime NSSI (yes/no) and recent NSSI (yes in the past 3 months/yes, but not in the past 3 months).

Following variable selection, significant sleep classifiers were entered together as predictors of recent and lifetime NSSI in robust Poisson models that were unadjusted (Model 1), adjusted for sex, race, ethnicity, CESD total score, GAD-7 score, alcohol and cannabis use (Model 2), adjusted for all 5 impulsivity subscales of the SUPPS-P (Model 3), and adjusted for perceived burdensomeness and thwarted belongingness from the INQ (Model 4). Significant mediator variables (identified from Models 3 and 4) were then included in bootstrap mediation models of the relationship between the sleep classifiers and recent/lifetime NSSI. All analyses were conducted in R version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria), and the code used for analysis is freely available at https://github.com/atubbs-sleep.

RESULTS

Sample Characteristics

The final sample of 885 respondents was 73.6% ($N = 651$) female, 77.7% ($N = 688$) White, and 30.1% ($N = 266$) Hispanic. A total of 233 out of 885 (26.3%) individuals endorsed a lifetime history of NSSI and 93 out of 885 (10.5%) engaged in NSSI within the past 3 months. When compared with individuals with no NSSI, those with lifetime NSSI were more often female (83% vs. 70% $p < 0.001$), had worse sleep quality (PSQI: 8.4 vs. 6.3, $p < 0.001$), and had more severe depression symptoms (CESD: 27.6 vs. 18.0, $p < 0.001$), and anxiety symptoms (GAD-7: 10.7 vs. 6.7, $p < 0.001$). Compared to those with only lifetime NSSI, individuals with recent NSSI had worse depression symptoms (CESD: 30.8 vs. 25.5, $p < 0.001$) and anxiety symptoms (GAD-7: 12.2 vs. 9.7, $p < 0.001$). There were no significant differences by age, race, ethnicity, alcohol use, or cannabis use. These data are presented in Table 1.

Variable Selection and Sequential Modeling

The unadjusted and adjusted associations between each sleep predictors and NSSI are presented in Table S1. All sleep variables were significantly associated with lifetime NSSI except relative and absolute social jetlag, but only weekday sleep efficiency, weekend total sleep time, weekend sleep efficiency, chronotype, BRISC score, and nightmare disorder remained significant after adjusting for covariates. Absolute social jetlag was the only sleep variable associated with recent NSSI in unadjusted and adjusted models.

Stepwise analyses confirmed that absolute social jetlag was the only significant sleep classifier of recent NSSI ($N = 93$) versus lifetime NSSI ($N = 233$). In the unadjusted

TABLE 1. Sample characteristics by lifetime and recent non-suicidal self-injury (NSSI).

	Lifetime NSSI					Recent NSSI				
Characteristic	No	Yes	*t* or χ	DF	*p*	Lifetime	3 months	*t* or χ	DF	*p*
N	652	233	–	–	–	140	93	–	–	–
Age	19.72 (1.41)	19.65 (1.56)	0.54	376.5	0.59	19.72 (1.60)	19.55 (1.50)	0.86	205.3	0.39
Sex										
Male	194 (30%)	40 (17%)	13.34	1	<0.001	24 (17%)	16 (17%)	<0.001	1	>0.999
Female	458 (70%)	193 (83%)				116 (83%)	77 (83%)			
Race										
White	509 (78%)	179 (77%)	8.48	4	0.075	106 (76%)	73 (78%)	7.72	4	0.102
Black	27 (4.1%)	11 (4.7%)				9 (6.4%)	2 (2.2%)			
Asian	75 (12%)	17 (7.3%)				12 (8.6%)	5 (5.4%)			
Native	9 (1.4%)	6 (2.6%)				5 (3.6%)	1 (1.1%)			
Multiracial	32 (4.9%)	20 (8.6%)				8 (5.7%)	12 (13%)			
Ethnicity										
Non-Hispanic	457 (70%)	162 (70%)	0.006	1	0.938	104 (74%)	58 (62%)	3.21	1	0.073
Hispanic	195 (30%)	71 (30%)				36 (26%)	35 (38%)			
PSQI Score (0–21)	6.3 (3.24)	8.4 (3.66)	−7.75	369.6	<0.001	8.0 (3.53)	8.9 (3.79)	−1.87	187.3	0.064
CESD Score (0–60)	18.0 (10.64)	27.6 (11.24)	−11.31	390.1	<0.001	25.5 (11.73)	30.8 (9.67)	−3.76	220.5	<0.001
GAD-7 Score (0–21)	6.7 (5.59)	10.7 (5.69)	−9.19	402.5	<0.001	9.7 (5.85)	12.2 (5.13)	−3.34	213.8	<0.001
Alcohol use										
Never	239 (37%)	90 (39%)	0.89	2	0.64	55 (39%)	35 (38%)	1.05	2	0.592
Once a week or less	280 (43%)	102 (44%)				58 (41%)	44 (47%)			
More than once a week	133 (20%)	41 (18%)				27 (19%)	14 (15%)			
Cannabis use										
Never	450 (69%)	144 (62%)	5.17	2	0.075	87 (62%)	57 (61%)	2.78	2	0.249
Once a week or less	124 (19%)	49 (21%)				33 (24%)	16 (17%)			
More than once a week	78 (12%)	40 (17%)				20 (14%)	20 (22%)			

Data presented as Mean (SD) or n (%). Tests: student's *t*-test or Pearson's Chi-squared test.
CESD: Center for Epidemiological Studies Depression Scale; PSQI: Pittsburgh Sleep Quality Index; GAD-7: Generalized Anxiety Disorder 7-item Questionnaire.

TABLE 2. Sequential modeling of significant sleep classifiers for recent and lifetime NSSI.

	Model 1			Model 2			Model 3			Model 4		
Sleep classifiers	PRR	95% CI	*p*	PRR	95% CI	*p*	PRR	95% CI	*p*	PRR	95% CI	*p*
Recent NSSI												
Absolute Social Jetlag (hours)	1.17	[1.07, 1.27]	0.001	1.12	[1.02, 1.23]	0.021	1.13	[1.03, 1.25]	0.011	1.12	[1.01, 1.23]	0.027
Lifetime NSSI												
Weekend Sleep Efficiency (%)	0.99	[0.98, 0.99]	<0.001	0.99	[0.99, 1.00]	0.021	0.99	[0.98, 1.00]	0.001	0.99	[0.99, 1.00]	0.032
Nightmare Disorder (DDNSI > 10)	1.66	[1.33, 2.07]	<0.001	1.25	[0.99, 1.56]	0.056	1.47	[1.17, 1.85]	0.001	1.37	[1.10, 1.72]	0.006
BRISC Score	0.73	[0.63, 0.83]	<0.001	0.89	[0.77, 1.02]	0.103	0.79	[0.68, 0.91]	0.001	0.80	[0.70, 0.92]	0.002

Model 1: Unadjusted. Model 2: Adjusted for sex, race, ethnicity, CESD score, GAD-7 score, and frequency of alcohol and cannabis use. Model 3: Adjusted for all 5 short UPPS-P subscales. Model 4: Adjusted for perceived burdensomeness and thwarted belongingness from the INQ.

analysis (Model 1), each additional hour of social jetlag increased the prevalence risk of NSSI by 17% (PRR: 1.17 [1.07, 1.27]). Adjusting for covariates (Model 2), measures of impulsivity (Model 3), and perceived burdensomeness/thwarted belongingness (Model 4) attenuated but did not eliminate this association. For lifetime NSSI ($N = 233$) versus no NSSI ($N = 559$), stepwise selection identified weekend sleep efficiency, BRISC score, and clinically significant nightmares as significant sleep classifiers. In unadjusted analyses (Model 1), each percent increase in weekend sleep efficiency reduced the prevalence risk of NSSI by 1% (PRR: 0.99 [0.98, 0.99]), and a 1-point increase in perceived sleep control reduced the prevalence risk of NSSI by 27% (PRR: 0.73 [0.63, 0.83]). Conversely, clinically significant nightmares increased the prevalence risk of NSSI by 66% (PRR 1.66 [1.33, 2.07]). Adjusting for covariates (Model 2) eliminated the associations for BRISC score and nightmares, but not for weekend sleep efficiency. Adjusting for measures of impulsivity (Model 3) and perceived burdensomeness/thwarted belongingness (Model 4) attenuated but did not eliminate these associations. These results are presented in Table 2.

Comparisons of the significant sleep classifiers by NSSI status are presented in Figure 1. Individuals with lifetime NSSI had significantly lower weekend sleep efficiency (Figure 1A: 74% vs. 80%, $p < 0.001$), lower BRISC scores (Figure 1B: 1.87 vs. 2.25, $p < 0.001$), and greater prevalence of clinically significant nightmares (Figure 1C: 33% vs. 16%, $p < 0.001$) than those with no NSSI. Additionally, those with recent NSSI had more absolute social jetlag than those with only lifetime NSSI (Figure 1D: 1.45 h vs. 1.1 h, $p = 0.023$).

Mediation Analyses

Only the negative urgency subscale of impulsivity was associated with recent NSSI (Model 3, $p < 0.001$), and negative urgency only partially mediated the relationship between absolute social jetlag and recent NSSI (direct effect: 12.0%, $p = 0.034$; indirect effect: 4.2%, $p = 0.032$). Additionally, only perceived burdensomeness was associated with recent NSSI (Model 4, $p = 0.001$), and perceived burdensomeness did not mediate the relationship between absolute social jetlag and recent NSSI (direct effect: 12.9%, $p = 0.03$; indirect effect: 3.3%, $p = 0.141$).

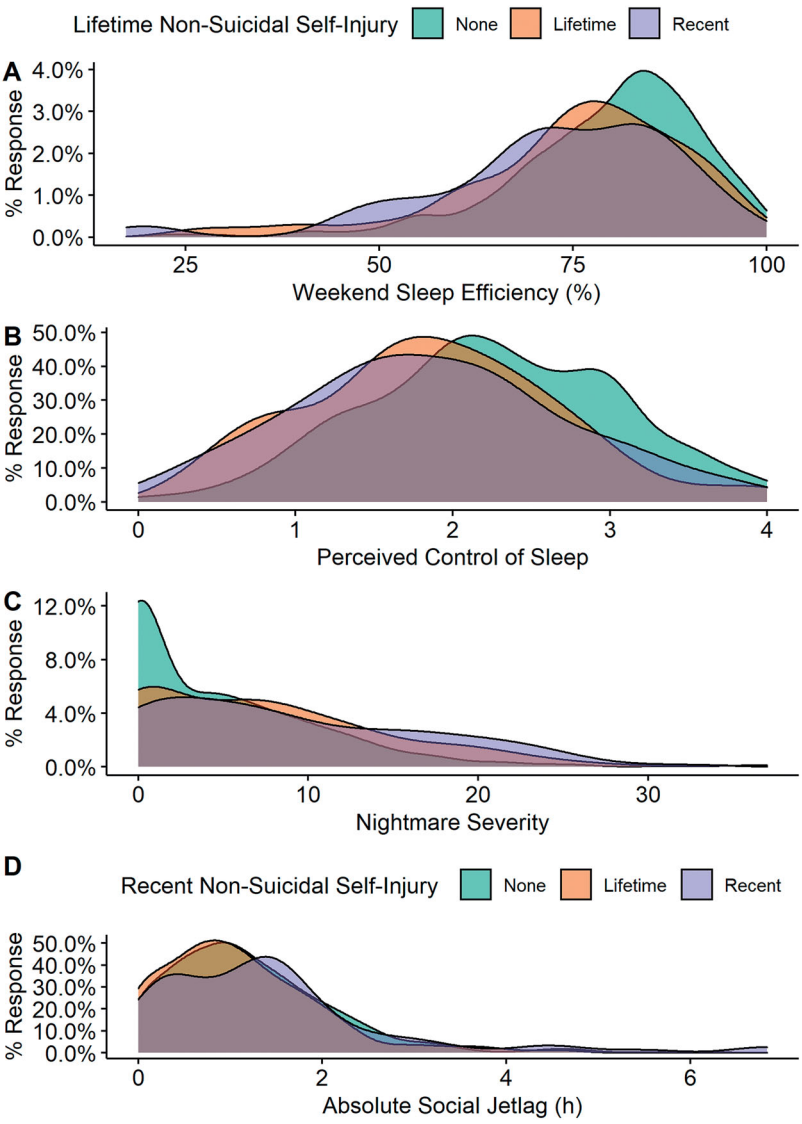

FIGURE 1. The distribution of non-suicidal self-injury across significant sleep classifiers. Those with lifetime non-suicidal self-injury tended to have 6% lower weekend sleep efficiency (A), less perceived control of sleep (B) and greater nightmare severity (C). Additionally, those with recent non-suicidal self-injury tended to have 21 min greater absolute social jetlag (D) than those without non-suicidal self-injury.

Lifetime NSSI was associated with the impulsivity scales negative urgency (Model 3, $p < 0.001$) and lack of premeditation (Model 3, $p = 0.01$), and both measures of impulsivity partially mediated the relationship between lifetime NSSI and weekend sleep efficiency, nightmares, and perceived sleep control (direct effect: 13.5%, $p < 0.001$; indirect effect of negative urgency: 2.9%, $p = 0.003$; indirect effect of lack of premeditation: 1.8%, $p = 0.011$). Only perceived burdensomeness was associated with lifetime NSSI (Model 4, $p = 0.001$), and perceived burdensomeness only partially mediated the

relationship between lifetime NSSI and weekend sleep efficiency, nightmares, and perceived sleep control (direct effect: 10.8%, $p = 0.002$; indirect effect: 7.3%, $p < 0.001$).

DISCUSSION

In the present study, 25.2% of students reported a lifetime history of NSSI, with 10.5% reporting NSSI within the last 3 months. College students who engaged in NSSI in the prior 3 months had a 21-min greater absolute difference between the weekday and weekend sleep period, compared to those with lifetime NSSI, and each hour increase in that difference increased the prevalence risk of NSSI by 17%. Those who had a lifetime history of NSSI had 6% worse sleep efficiency on weekends, lower perceived sleep control, and a two-fold greater prevalence of clinically significant nightmares than those without NSSI. In regression models, the prevalence risk of lifetime NSSI decreased with improved weekend sleep efficiency and higher perceived sleep control, whereas nightmare disorder increased the prevalence risk of lifetime NSSI by 66%. These results provide evidence of a complex relationship between sleep and NSSI among college students that is not fully captured by the most common sleep metrics.

It is notable that absolute social jetlag was the only significant sleep classifier of recent NSSI among the 14 variables investigated, even after adjusting for depression, anxiety, impulsivity, perceived burdensomeness, and thwarted belongingness. Prior studies, however, do indicate that weekday/weekend sleep discrepancies are relevant to NSSI. Kang and colleagues (Kang et al., 2014) reported that greater weekend recovery sleep was associated with NSSI, while Hysing and colleagues (Hysing, Sivertsen, Stormark, & O'Connor, 2015) reported that greater variation between weekday and weekend sleep duration, along with shorter sleep and worse sleep continuity, were associated with NSSI. Although more data are needed, unstable sleep schedules (e.g., oversleeping on weekends to catch-up from the week or delayed weekend sleep due to social activities) may have a greater impact on emotional regulation and risk for NSSI; the partial mediation between absolute social jetlag and recent NSSI by negative urgency supports this conclusion.

Absolute social jetlag was not associated with lifetime NSSI, however, so it is possible that the short-term risks of an unstable sleep schedule are eventually eclipsed by prolonged deficits in sleep continuity. The fact that weekend sleep efficiency was a significant classifier of lifetime NSSI lends support to this hypothesis, although the relative importance of weekend versus weekday sleep continuity is unclear. Perceived sleep control and nightmares were also significantly associated with lifetime NSSI, although not independent of sociodemographic and clinical covariates. This may reflect the close relationship between mental disorders (e.g., depression and anxiety) and nightmares (Lemyre et al., 2019), and the inherent vulnerability of subjective perceptions of sleep to negative affect (Biddle, Robillard, Hermens, Hickie, & Glozier, 2015). Speaking mechanistically, nightmares are closely associated with emotional dysregulation (Rufino et al., 2020; Ward-Ciesielski et al., 2018), and the partial mediation between sleep variables and lifetime NSSI by lack of premeditation and negative urgency suggests impulsivity is also at play.

Perceived burdensomeness and thwarted belongingness are components of the interpersonal theory of suicide (Joiner, 2005; Van Orden et al., 2010), and the close relationship between NSSI and suicidal thoughts and behaviors (Kiekens et al., 2018) supported their potential relevance to NSSI. The present study did not bear this out, however. Thwarted belongingness was not associated with recent or lifetime NSSI, and perceived burdensomeness was only a partial mediator of sleep problems and lifetime NSSI. These findings stand in contrast with prior findings that thwarted belongingness mediates the relationship between sleep problems and suicide risk (Chu et al., 2016; Chu, Hom, et al., 2017; Hom et al., 2017). Consequently, the relationship between sleep and NSSI may be distinct from the relationship between sleep and suicide risk. Future research should explore these differences, and whether sleep plays a mediating role in the relationship between NSSI and suicide risk, as it appears to do for suicidal cognitions (Grove et al., 2020).

The strengths of this study are that it used multiple, validated measures of sleep in a large, racially and ethnically diverse sample (22% nonwhite, 30% Hispanic) of college students as part of a robust analysis of multiple dimensions of sleep health. Additionally, a reasonably large subset of respondents reported NSSI in the sample (25% lifetime, 10.5% within 3 months), and although this is higher than previous reports (Kiekens et al., 2021; Swannell et al., 2014) which may reflect a misclassification effect of the NSSI assessment (e.g., a single-item included as part of a validated assessment of suicidal thoughts and behaviors) (Robinson & Wilson, 2020), it may also be the result of conducting the study during the stress of the COVID-19 pandemic. The study has several limitations, however, including that the data are cross-sectional and thus preclude causal claims (even in mediation analyses), that the time periods covered by these measures did not precisely match (many sleep measures reviewed the past 2 weeks or month while NSSI was measured over the past 3 months or lifetime), and that all measures were subjectively collected and vulnerable to recall and reporting bias. The majority of the sample was female (74%), and although females are more likely to engage in NSSI than males (Fox et al., 2015), the skewed sample means inferences about males may be more limited. Additionally, apart from assessing anxiety and depression, the limited investigation of mental health conditions relevant to NSSI and sleep (e.g., borderline personality disorder) could limit these results. Longitudinal studies with repeated measures of sex-balanced samples will go a long way to improve these methodological weaknesses, and these results provide a useful guide to identifying the sleep variables of greatest interest for such studies.

CONCLUSION

NSSI is a clinically significant behavior that increases the risk of subsequent suicidal thoughts and behaviors, particularly among college students. Sleep is known to affect suicide risk, but few studies have explored the link between sleep and risk of NSSI. This study found that greater differences between weekend and weekday sleep schedules are linked to short-term risk of NSSI, whereas weekend sleep efficiency, nightmare disorder, and perceived sleep control are linked to a lifetime history of NSSI. This indicates that the sleep variables of greatest relevance for NSSI risk in college students may not be the

standard sleep continuity variables (e.g., insomnia, sleep duration), and that future studies should use a broader range of measures to examine sleep as an NSSI risk factor.

ACKNOWLEDGEMENTS

FXF acknowledges support from the Velux Stiftung (Proj. No. 1360).

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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