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Special Issue Article

Sleep problems predict next-day suicidal thinking among adolescents: A multimodal real-time monitoring study following discharge from acute psychiatric care

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Abstract

Suicidal thoughts and behaviors (STBs) are major public health concerns among adolescents, and research is needed to identify how risk is conferred over the short term (hours and days). Sleep problems may be associated with elevated risk for STBs, but less is known about this link in youth over short time periods. The current study utilized a multimodal real-time monitoring approach to examine the association between sleep problems (via daily sleep diary and actigraphy) and next-day suicidal thinking in 48 adolescents with a history of STBs during the month following discharge from acute psychiatric care. Results indicated that specific indices of sleep problems assessed via sleep diary (i.e., greater sleep onset latency, nightmares, ruminative thoughts before sleep) predicted next-day suicidal thinking. These effects were significant even when daily sadness and baseline depression were included in the models. Moreover, several associations between daily-level sleep problems and next-day suicidal thinking were moderated by person-level measures of the construct. In contrast, sleep indices assessed objectively (via actigraphy) were either not related to suicidal thinking or were related in the opposite direction from hypothesized. Together, these findings provide some support for sleep problems as a short-term risk factor for suicidal thinking in high-risk adolescents.

Keywords: actigraphy, adolescents, ecological momentary assessment, sleep, suicide ideation

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Suicidal thoughts (i.e., thoughts of killing oneself; Silverman, Berman, Sanddal, O'Carroll, & Joiner, 2007) and behaviors (i.e., non-fatal self-directed injury with at least some intent to die; Silverman et al., 2007) are major public health concerns among youth. Suicidal thoughts and behaviors (STBs) typically begin during adolescence and rates increase markedly during this developmental period (Glenn et al., 2017b; Nock et al., 2008, 2013). In the most recent (2019) data from the Centers for Disease Control and Prevention's (CDC) Youth Risk Behavior Survey, 18.8% of high school students reported thinking about suicide in the past year and 8.9% attempted suicide at least once (Ivey-Stephenson et al., 2020). These high rates of non-fatal STBs among youth are alarming because they cause significant impairment in academic and social domains (Copeland, Goldston, & Costello, 2017; Foley, Goldston, Costello, & Angold, 2006), and increase risk for suicide (Ribeiro et al., 2016) – now the second leading cause of death among youth (CDC, 2018).

In an effort to better understand and predict who may be most at risk for taking their own life, decades of research have focused on identifying potential risk factors for suicide across the life span (Franklin et al., 2017). This research has helped to identify groups that may be at elevated risk over the long term (e.g., specific sociodemographic groups and those with certain psychiatric disorders and comorbidities; Franklin et al., 2017). However, this research base has provided less information about factors that predict risk over shorter time periods, such as hours, days, and weeks. The field's limited understanding of short-term risk is due to *what* has been measured and *how* it has been measured (Glenn & Nock, 2014). *What* has been measured are primarily distal (from suicide outcomes), time-invariant (do not fluctuate over time), and non-modifiable risk factors (e.g., sociodemographic factors), which may indicate *who* is at risk but not *when* an individual is most at risk. Moreover, many studies have focused on specific psychiatric disorders as risk factors, but the role of specific disorders may be less useful given the high rates of psychiatric comorbidity found among individuals with STBs (Beautrais et al., 1996; Hawton, Houston, Haw, Townsend, & Harriss, 2003; Kessler, Chiu, Demler, & Walters, 2005; Rudd,

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Dahm, & Rajab, 1993; Wunderlich, Bronisch, & Wittchen, 1998), and because these heterogenous diagnostic categories tell us less about the psychological processes that put individuals at risk for suicide over the short term (Glenn, Kleiman, et al., 2018; Glenn, Cha, Kleiman, & Nock, 2017a). *How* these factors have been measured has been limited by largely retrospective designs or long follow-up periods in longitudinal studies (i.e., years to decades; Franklin et al., 2017). Taken together, to identify short-term risk factors for STBs, the field needs intensive prospective research over short time periods that examines transdiagnostic, time-varying, and modifiable risk factors (Glenn & Nock, 2014). This research has key implications for downstream suicide prevention approaches by indicating which factors may be proximally related, and treatment targetable, to decrease suicide risk.

To date, this type of research has been limited because it is methodologically challenging. Given that STB outcomes are relatively infrequent (i.e., low base rate) in most samples, a key methodological approach is to focus on high-risk populations (i.e., those at elevated risk for engaging in suicidal behavior) during high-risk periods when both fluctuations in time-varying risk factors and STBs are likely to co-occur, such as the high-risk period following discharge from acute psychiatric care (Chung et al., 2017). Temporally sensitive methods, such as real-time monitoring (Russell & Gajos, 2020; Trull & Ebner-Priemer, 2013), have the ability to elucidate the short-term associations between time-varying risk factors and STBs (Kleiman, Glenn, & Liu, 2019). The current study fills a significant research gap by examining a specific transdiagnostic, time-varying, and modifiable risk factor–sleep problems.

Sleep problems as a short-term risk factor for suicidal thoughts and behaviors

Sleep problems (broad term used here to refer to a range of sleep difficulties, including insomnia symptoms, nightmares, and poor sleep quality) may be one promising short-term risk factor for STBs in youth. Converging research has demonstrated a link between a range of sleep problems and STBs in cross-sectional and long-term follow-up (longitudinal) research with adults (Bernert, Kim, Iwata, & Perlis, 2015; Harris, Huang, Linthicum, Bryen, & Ribeiro, 2020; Littlewood, Kyle, Pratt, Peters, & Gooding, 2017; Liu et al., 2020; Pigeon, Pinquart, & Conner, 2012b; Porras-Segovia et al., 2019; Russell et al., 2019) and youth (Chiu, Lee, Chen, Lai, & Tu, 2018; Fernandes, Zuckerman, Miranda, & Baroni, 2021; Goldstein & Franzen, 2020; Kearns et al., 2020; Liu et al., 2019a; Liu et al., 2020). The link between sleep problems and STBs is notable for three major reasons.

First, sleep problems are transdiagnostic symptoms (Harvey, Murray, Chandler, & Soehner, 2011) reported among a variety of disorders linked to STBs, including mood, anxiety, and posttraumatic stress disorders (Borges et al., 2010; Nock et al., 2008, 2013). Of note, sleep problems have been uniquely linked to STBs above and beyond depression and anxiety (Bernert, Hom, Iwata, & Joiner, 2017; Bishop, Ashrafioun, & Pigeon, 2018; Littlewood et al., 2019; Pigeon et al., 2012b; Pigeon, Britton, Ilgen, Chapman, & Conner, 2012a), suggesting that they may help explain the relationship between these disorders and suicide risk. In fact, this transdiagnostic link was observed in one cohort of US Veterans (Britton, McKinney, Bishop, Pigeon, & Hirsch, 2019).

Second, sleep problems are promising because they hold particular importance for youth. Notably, sleep patterns change significantly, and become more irregular, during adolescence (Carskadon, 1990; Carskadon, Acebo, & Jenni, 2004; Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). For instance, compared to children, adolescents prefer to go to bed later (delay in sleep onset) while, at the same time, they are required to wake up earlier for school (Carskadon et al., 2004). As a result, most adolescents do not get the recommended 8–10 hr of sleep per night (Hirshkowitz et al., 2015), despite having an increased biological need for sleep (Carskadon et al., 2004). Not surprisingly, many adolescents report feeling fatigued during the day (Fisher, 2013; Fredriksen, Rhodes, Reddy, & Way, 2004; Ohayon, Roberts, Zulley, Smirne, & Priest, 2000). Further, insomnia symptoms, reported in 25%–40% of youth (Chung, Kan, & Yeung, 2014; Ohayon et al., 2000), are associated with significant impairment in academic performance (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010), interpersonal relationships (Roberts, Roberts, & Duong, 2008), and overall health (Dahl & Lewin, 2002; Roberts et al., 2008). Alarmingly, even a decrease of 1 hr of sleep has been linked to increased suicide ideation in adolescents (Winsler, Deutsch, Vorona, Payne, & Szklo-Coxe, 2015). Taken together, the significant changes in sleep patterns during adolescence, and the impairment from even small amounts of sleep deprivation, suggest that sleep problems may be particularly pernicious for youth (Fernandes et al., 2021; Kearns et al., 2020).

Third, sleep problems are promising risk factors because they are time-varying (i.e., fluctuating between days; Bernert et al., 2017; Littlewood et al., 2019) and exhibit a unidirectional relationship with STBs, as opposed to STBs predicting sleep problems (Hochard, Heym, & Townsend, 2015; Littlewood et al., 2019; Ribeiro et al., 2012; Zuromski, Cero, & Witte, 2017). Finally, sleep problems are modifiable and amenable to treatment through empirically supported interventions, such as cognitive behavioral therapy for insomnia (CBT-I; Blake, Sheeber, Youssef, Raniti, & Allen, 2017a; Ma, Shi, & Deng, 2018; Werner-Seidler, Johnston, & Christensen, 2018) and imagery rehearsal therapy (IRT) for nightmares (Krakow, 2011; Krakow & Zadra, 2006).

Relevance to developmental psychopathology and the RDoC framework

The examination of sleep problems as a risk factor for STBs among youth is consistent with developmental perspectives and dimensional frameworks for studying psychopathology. First, this approach is in line with the developmental psychopathology (DP) perspective. The DP perspective focuses on pathophysiology (beyond psychiatric disorders) with an emphasis on dimensional processes assessed utilizing a multimethod approach (Cicchetti, 1993; Rutter & Sroufe, 2000). Moreover, the DP perspective highlights the significance of sensitive periods during development and using knowledge of normative development to inform selection of important processes during a particular stage (Casey, Oliveri, & Insel, 2014). Consistent with this perspective, sleep problems are transdiagnostic symptoms, of particular relevance during adolescence, that can be assessed using a variety of methods (e.g., self-report of sleep quality, behavioral assessment of sleep–wake patterns using actigraphy).

Second, this approach to studying risk for STBs is consistent with the National Institute of Mental Health's proposed framework to transform understanding of psychopathology – the Research Domain Criteria (RDoC) initiative (Glenn et al., 2017a; Glenn, Kleiman, et al., 2018). The RDoC framework aims to identify transdiagnostic dimensions (that are more fine-grained than the disorders and heterogenous constructs typically

examined in psychopathology research) across multiple units of analysis (from genes to self-report; Cuthbert, 2014; Insel et al., 2010; Sanislow et al., 2010). Within the RDoC framework, the construct of sleep–wakefulness is categorized within the Arousal and Regulatory Systems domain, and refers to "endogenous, recurring, behavioral states that reflect coordinated changes in the dynamic functional organization of the brain and that optimize physiology, behavior, and health" (National Institute of Mental Health, 2012). Although sleep can be examined across multiple units of analysis, behavior (e.g., sleep timing and variability) and self-report (e.g., perceived sleep quality) may be the most useful units for examining sleep's relationship to fluctuations in STBs observed in an individuals' naturalistic environment (Glenn et al., 2017a; Millner, Robinaugh, & Nock, 2020). It is important to note that there are several ways that the DP perspective can inform the RDoC initiative (Drabick, 2009; Franklin, Jamieson, Glenn, & Nock, 2015; Garber & Bradshaw, 2020). Although RDoC is relatively new to the field (i.e., past decade; Insel et al., 2010; Sanislow et al., 2010), the DP perspective, for decades, has been utilizing a multimethod and (in part) dimensional approach to understand the complex development of psychopathology across the life span (Cicchetti, 1993; Rutter & Sroufe, 2000). Development was not initially incorporated into the two-dimensional (2D) RDoC framework (i.e., domain/construct × unit of analysis); however, it was later conceptualized as another plane in the matrix, such that domains/constructs measured across different units of analysis could be examined at developmental periods relevant to the construct or clinical outcome (Badcock & Hugdahl, 2014; Glenn et al., 2017a; Woody & Gibb, 2015). As described above, adolescence is a particularly critical period for the onset and escalation of STBs, as well as for significant changes in sleep patterns.

Limitations of prior research on sleep problems and suicidal thoughts and behaviors

Although prior evidence is promising, there are three major limitations of previous research on the link between sleep problems and STBs. First, there is limited research in adolescents (Kearns et al., 2020; Liu et al., 2020). This is a notable gap given the importance of sleep for youth (as previously described). Second, prior research on the sleep–STB link, particularly among youth, has been limited by the methods used to assess sleep problems (Kearns et al., 2020). Prior studies have relied primarily on brief self-report measures (and in many cases, single-item measures) that fail to assess the multidimensional nature of sleep problems (Kearns et al., 2020; Lallukka, Dregan, & Armstrong, 2011; Lewandowski, Toliver-Sokol, & Palermo, 2011). Thus, research with these measures may not accurately assess the link between sleep problems and STBs and, given the decreased specificity, may be limited in their treatment utility. Alternatively, there are a range of measures and methods that can more comprehensively assess the nature of sleep disturbance (Van Meter & Anderson, 2020). In terms of subjective (self-report) assessment tools, there are well-validated self-report scales that better assess the multidimensional nature of sleep problems over intervals of 2–4 weeks (e.g., seven-item Insomnia Severity Index [ISI; Bastien, Vallières, & Morin, 2001] and 19-item Pittsburgh Sleep Quality Index [PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989]). In addition, daily self-report sleep diaries assess details about a single (the prior) night's quality and quantity of sleep, allowing for the computation of specific sleep parameters (e.g., sleep efficiency – the percentage of time asleep out of the total window of time in bed) for a single night of sleep that can then be examined over time (Buysse, Ancoli-lsrael, Edinger, Lichstein, & Morin, 2006; Carney et al., 2012; Perlis et al., 2010). Moreover, given the known limitations of subjective assessments of sleep patterns (Carskadon et al., 1976; Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008; McCall & McCall, 2012), objective measurement of sleep patterns is important to consider. A common and flexible option for objective assessment of sleep patterns is actigraphy, which is the measurement of sleep–wake patterns via motor activity using a sensor, an actigraph, worn on the wrist or ankle. Actigraphy has been validated against polysomnography (PSG; i.e., lab-based sleep study; Marino et al., 2013; McCall & McCall, 2012; Sadeh, Hauri, Kripke, & Lavie, 1995), is widely considered to be the diagnostic gold-standard in sleep research (combined with daily sleep diaries; Kushida et al., 2001), and has strong reliability and validity for measuring activity during sleep across the life span (Kushida et al., 2001; Meltzer, Montgomery-Downs, Insana, & Walsh, 2012; Sadeh, 2011). Actigraphy may be preferable to PSG because it is low cost, non-invasive, and allows for longitudinal assessment in the naturalistic environment. However, only a few studies to date have used actigraphy to examine the association between sleep problems and STBs: three studies in adults (Benard et al., 2019; Bernert et al., 2017; Littlewood et al., 2019) and one in youth (Meir, Alfano, Lau, Hill, & Palmer, 2019). In addition, only two of these studies have leveraged the temporal resolution of actigraphy to examine the relation between sleep parameters and suicide ideation over the short term (Bernert et al., 2017; Littlewood et al., 2019) – an issue we turn to next.

Third, prior research has been limited in its temporal resolution, or the timing between the assessment of sleep problems and STBs. Longitudinal research, which is necessary to establish sleep problems as a risk factor for STBs (Kraemer et al., 1997), has been limited in youth compared to adults (Kearns et al., 2020; Liu et al., 2020). Collectively, eight longitudinal studies with adolescents have demonstrated that a range of sleep problems and daytime sleepiness prospectively predict greater STBs in youth (Asarnow et al., 2020; Liu et al., 2019b; Meir et al., 2019; Nrugham, Larsson, & Sund, 2008; Wong & Brower, 2012; Wong, Brower, & Zucker, 2011) or when adolescents are followed into adulthood (Mars et al., 2019; Roane & Taylor, 2008). However, this prior research is limited by few studies in clinical samples (however, see Meir et al., 2019, which included children [7–11 years old] with clinical and subclinical anxiety symptoms, and Asarnow et al., 2020, which included adolescents [12–18 years old] with current suicide ideation and history of suicide attempt or nonsuicidal self-injury), brief (in some cases, single-item) assessments (however, see Asarnow et al., 2020; Meir et al., 2019), and long follow-up periods (the shortest is 6 months, but most are one year or more). Long follow-up periods in youth create a notable gap because they cannot identify how sleep problems impact suicide risk over the short term (needed to establish sleep problems as a proximal risk factor for STBs; Kraemer et al., 1997).

Only two studies, both in adults, have examined how sleep problems predict suicide ideation over the short-term – over the subsequent days and weeks (Bernert et al., 2017; Littlewood et al., 2019). In a sample of 50 college students (18–23 years old) with a prior suicide attempt and/or recent suicide ideation, sleep disturbance was measured with wrist actigraphy (verified with daily sleep diaries) for seven days, and past-week suicide ideation was measured with the Beck Scale for Suicide Ideation (Beck

& Steer, 1991) at baseline, 7-day follow-up, and 21-day follow-up (Bernert et al., 2017). Greater variability in sleep timing (i.e., standard deviation of sleep onsets [when the sleep period started] and sleep offsets [when the sleep period ended]) predicted changes in suicide ideation from baseline to 7-day follow-up and from 7- to 21-day follow-up, even when controlling for depression symptoms (Bernert et al., 2017). Most notably, a recent study leveraged the temporal resolution of ecological momentary assessment (EMA; i.e., repeated assessment of thoughts, feelings, and behaviors in an individual's natural environment; Shiffman, Stone, & Hufford, 2008) to measure suicide ideation in combination with daily sleep diaries and actigraphy. In 51 adults (18–65 years old) with recent suicide ideation or attempts, the link between sleep disturbance (actigraphy and daily sleep diaries) and suicide ideation (using six daily prompts via EMA) was examined intensely for seven days (Littlewood et al., 2019). Less total sleep time (assessed via actigraphy and daily sleep diaries) and poorer sleep quality (assessed via daily sleep diaries) predicted greater suicide ideation the following day, even after controlling for depression and anxiety symptoms. Of note, greater suicide ideation did not predict poorer sleep the following night, further supporting the temporal precedence of sleep problems in predicting subsequent increases in suicide ideation (Ribeiro et al., 2012; Zuromski et al., 2017). Taken together, these real-time monitoring studies indicate that, in adults, sleep problems (e.g., greater sleep variability, less total sleep time, poorer sleep quality) exhibit a unique and unidirectional association with increased suicide ideation over the short term. However, this fine-grained approach has not yet been used to examine the association between sleep problems and STBs in youth.

Current study

Using an intensive real-time monitoring design, the goal of the current study was to examine the association between sleep problems (assessed via daily sleep diaries and continuous wrist actigraphy) and suicidal thinking (multiple prompts daily via EMA) over the short term in a high-risk sample of adolescents. Specifically, this study focused on adolescents who were recently hospitalized for suicide risk and were intensely monitored for 28 days following their discharge from acute psychiatric care. Consistent with prior real-time monitoring studies in adults (Bernert et al., 2017; Littlewood et al., 2019), we hypothesized that daily-level sleep problems (multiple sleep parameters were assessed using daily sleep diaries and wrist actigraphy) would predict greater suicidal thinking the next day. In addition to within-person sleep problems, we also examined how baseline (person-level) sleep problems predicted greater suicidal thinking over the same time period.

Further, we explored how important clinical constructs linked to both sleep problems and suicidal thinking – depression and rumination – related to greater suicidal thinking over the 28-day follow-up period. Depression is closely linked to both sleep problems (Baglioni et al., 2011; Buysse et al., 2008; Pigeon & Perlis, 2007; Roberts & Duong, 2013) and suicidal thinking (Avenevoli, Swendsen, He, Burstein, & Merikangas, 2015; Beck, Steer, Beck, & Newman, 1993; Birmaher et al., 1996; Wilkinson, Kelvin, Roberts, Dubicka, & Goodyer, 2011). Moreover, given prior research indicating the unique association between sleep problems and suicide risk controlling for depression (Bernert et al., 2017; Pigeon et al., 2012b), we included depression in our models. We examined person-level depression symptoms at baseline and daily-level sadness ratings (as a within-person measure of a related affect state). In addition, ruminative thinking has been related to both sleep problems (Harvey, 2005; Harvey, Tang, & Browning, 2005) and suicidal thinking (Miranda & Nolen-Hoeksema, 2007; Morrison & O'Connor, 2008; O'Connor & Noyce, 2008; Rogers & Joiner, 2017) and was included in two forms. Ruminative thoughts before sleep were assessed in the daily sleep diary as one potential mechanism of sleep disruption, and person-level rumination was assessed at baseline. Finally, for significant within-person predictors (i.e., EMA and actigraphy), we examined the interaction between daily-level (within-person) and person-level (baseline) predictors of these constructs. That is, we explored how different baseline levels of these constructs may moderate how these factors predict suicidal thinking at the daily level. These analyses were exploratory and therefore we did not have specific hypotheses.

Method

Participants

Adolescents, 12–18 years old, were eligible for the study if they had recently received acute psychiatric care (i.e., psychiatric emergency department, inpatient unit, or partial hospitalization) for suicide risk (i.e., suicide ideation with intent and/or plan, suicide attempt) and were being discharged to outpatient care. Youth were excluded if they were: unable to provide informed consent (e.g., extreme cognitive impairment, current mania or psychosis), unwilling to complete the study procedures (i.e., unwilling to wear wrist actigraphy device or complete smartphone-based EMA surveys), or a safety concern (i.e., imminent risk for suicide or other-directed violence). Of note, adolescents without a smartphone were loaned an Android (Tracfone) with a pre-paid data plan. The full sample included 53 adolescents and their parents (see for additional details about the full sample in Glenn et al., 2021). For the current study, the first five adolescents were excluded because they did not receive the same EMA questions assessing suicide risk as the rest of the sample (i.e., the question about ability to keep themselves safe was added after the first five participants). Table 1 displays the major demographics for the 48 adolescents (age: $M = 14.96$ years; gender identity: 64.6% female; race: 77.1% White) and their parents included in this study. Prior to enrollment in the study, eight adolescents (16.7%) were discharged directly from the psychiatric emergency department, 19 (39.6%) from inpatient care, and 21 (43.8%) from partial hospitalization (*Note*. Prior to partial, most adolescents [71.4%] were admitted to the psychiatric emergency department or inpatient unit). In addition, 10 adolescents (18.9%) were treated on a medical unit for their suicide attempt before transitioning to psychiatric care.

Procedure

Adolescents were enrolled in the study within two weeks of discharge from acute psychiatric care. Each adolescent had at least one parent or legal guardian (referred to collectively as *Parents*) participate in the study (even 18-year-olds for consistency across the sample). Informed consent was obtained prior to study initiation: adolescent assent and parental permission for 12-to-17-year-olds and adolescent consent and parental consent (for their own participation) for 18-year-olds. All study procedures were approved by the University of Rochester's Institutional Review Board. The study included three main phases: (a) baseline, (b) 28-day monitoring period, and (c) a

Table 1. Major demographics and history of suicidal thoughts and behaviors in the sample

	Adolescents (*n*=48)	Parents (*n*=48)
Age (years): *M* (*SD*)	14.96 (1.60)	44.5 (8.25)
Gender identity: % (*n*/*N*)		
Female	64.6% (31/48)	89.6% (43/48)
Male	16.7% (8/48)	10.4% (5/48)
Nonbinary[a]	18.8% (9/48)	-
Race and ethnicity: % (*n*/*N*)		
White	77.1% (37/48)	89.6% (43/48)
Black/African American	8.3% (4/48)	6.3% (3/48)
American Indian/Alaskan Native	2.1% (1/48)	-
Multi-racial	10.4% (5/48)	-
Other/Do not wish to answer	-	4.2% (2/48)
Hispanic/Latinx[b]	12.5% (6/48)	10.4% (5/48)
Sexual orientation: % (*n*/*N*)		
Heterosexual	41.7% (20/48)	89.6% (43/48)
Gay or Lesbian	6.3% (3/48)	-
Bisexual	31.3% (15/48)	8.3% (4/48)
Pansexual	6.3% (3/48)	-
Asexual	4.2% (2/48)	2.1% (1/48)
Unsure	10.4% (5/48)	-
Annual household income: % (*n*/*N*)		
<$29,000	-	4.2% (2/48)
$30,000–$69,000	-	31.3% (15/48)
$70,000–$99,000	-	35.4% (17/48)
>$100,000	-	18.8% (9/48)
Prefer not to report	-	10.4% (5/48)
Employment status: % (*n*/*N*)		
Full-time/self-employed	-	64.6% (31/48)
Stay-at-home parent/retired	-	12.5% (6/48)
Part-time employed	-	10.4% (5/48)
Full- or part-time student	-	8.3% (4/48)[c]
Unemployed/on disability	-	6.3% (3/48)
Major psychiatric disorders[d]: % (*n*/*N*)		
Anxiety disorder	93.5% (43/46)	-
Attention-deficit hyperactivity disorder	27.9% (12/43)	-
Bipolar disorder	6.5% (3/46)	-
Disruptive behavior disorder	25.0% (11/44)	-
Eating disorder	20.9% (9/43)	-
Major depressive disorder	82.6% (38/46)	-
Obsessive compulsive disorder	9.3% (4/43)	-
Posttraumatic stress disorder	20.0% (9/45)	-
Psychotic symptoms	7.0% (3/43)	-
Substance use disorder	8.7% (4/46)	-

(*Continued*)

Table 1. (*Continued.*)

	Adolescents (*n*=48)	Parents (*n*=48)
Self-injurious thoughts and behaviors (lifetime):		
Active suicide ideation	100% (48/48)	
Suicide attempt: % (*n*/*N*)	85.4% (41/48)	-
Multiple lifetime attempts[e]:	61.0% (25/41)	-
NSSI: % (*n*/*N*)	81.3% (39/48)	-
Number of lifetime NSSI methods[f]: *M* (*SD*)	2.11 (0.89)	-
Sleep problems, depression, and rumination: (*M*, *SD*)		
Insomnia (ISI total score; *n* = 47):	13.72 (5.22)	-
Sleep quality (PSQI total score; *n* = 44):	11.09 (3.93)	-
Nightmares (DDNSI total score; *n* = 46):	10.35 (9.04)	-
Depression (BDI-Y T score; *n* = 44):	69.78 (15.20)	-
Rumination (RRS Brooding scale; *n* = 46):	14.87 (3.95)	-

BDI-Y = Beck Depression Inventory for Youth; DDNSI = Disturbing Dreams and Nightmares Severity Index; ISI = Insomnia Severity Index; NSSI = nonsuicidal self-injury; PSQI = Pittsburgh Sleep Quality Index; RRS = Rumination Responses Scale.
[a]Nonbinary includes adolescents identifying as transgender, nonbinary, or agender.
[b]Four adolescents preferred not to report their ethnicity.
[c]One parent reported that they were both employed full time and a full-time student.
[d]Current diagnoses were determined by integration of the adolescent and parent reports (obtained separately). Anxiety disorder includes any of the following current disorders: panic disorder, agoraphobia, social anxiety disorder, specific phobia, or generalized anxiety disorder; Attention-deficit hyperactivity disorder includes any of the following current subtypes: inattentive only, hyperactive/impulsive only, or combined; Bipolar disorder includes current bipolar I or II disorder; Disruptive behavior disorder includes current conduct disorder or oppositional defiant disorder; Eating disorder includes current anorexia nervosa or bulimia nervosa; Substance use disorder includes current alcohol use disorder or substance (drug) use disorder. Given time constraints, not all disorder modules were administered to all participants resulting in missing data.
[e]Out of the sample of lifetime suicide attempters, the percentage who reported more than one suicide attempt in their lifetime.
[f]Average number of lifetime NSSI methods among adolescents reporting lifetime NSSI.

final phone follow-up (not relevant for the current study so not described here).

Baseline

Adolescents and their parents completed a baseline assessment in the principal investigator's (PI's) research laboratory within approximately two weeks of the adolescent's discharge from acute psychiatric care ($M = 8.75$ days, $SD = 3.86$, Range = 0–15). The baseline consisted of interviews to assess history of STBs and major psychiatric disorders (see Measures), a battery of self-report questions to assess baseline sleep problems, depression, and rumination (see Measures), an orientation to the smartphone-based EMA application and the wrist actigraphy device, and concluded with a risk assessment and review of the adolescent's most recent safety plan (developed during acute psychiatric care or with their current outpatient provider).

28-day monitoring period

Following the baseline assessment, adolescents completed 28 consecutive days of EMA (including sleep diaries) and continuous wrist actigraphy was measured.

EMA. Participants completed a range of EMA surveys (those relevant for the current study are described here): (a) Interval-contingent/fixed surveys were completed each morning (ICAM), within 2 hr of waking up. Adolescents answered questions about the previous night's quantity and quality of sleep (see Measures). The median ICAM completion time was 1 min 36 s ($SD = 4$ min 2 s). (b) Signal-contingent/random surveys (SC) were completed multiple, 3–6, times each day (but not during week-day school hours), within 30 min of receiving the SC survey prompt. SC surveys asked about current suicidal thinking and sadness (see Measures). The median SC completion time was 3 min 25 s ($SD = 4$ min 58 s). The timing of all surveys was determined based on each adolescent's waketime and bedtime to increase survey adherence and validity of data (i.e., ICAM with sleep diary was completed within a short time after waking up). All EMA surveys were completed on participants' smartphones (personal or loaned) using HIPAA-compliant EMA software designed specifically for mobile EMA research (www.metricwire.com).

Given the high-risk sample, adolescents' EMA survey responses were monitored multiple times daily to assess their risk and ensure their safety. Appropriate steps were taken to keep youth safe during this assessment study (additional details about the risk and safety monitoring procedures reported in Glenn et al., 2021).

Actigraphy. Wrist actigraphy was measured in the current study with the Actiwatch Spectrum Plus–a lightweight (31 g with band), unobtrusive wristwatch-like device (size: 48 mm × 37 mm × 15 mm) containing a miniaturized solid-state three-axis MEMS-type accelerometer that detects and locally stores motor information (sampling rate: 32 Hz). These watches share many features in common with widely used commercial devices, such as the Fitbit. In the current study, the Actiwatch was worn consistently throughout the 28-day monitoring period on the adolescent's nondominant wrist, except for during activities when it would be submerged in water (i.e., showering, bathing, swimming) or potentially damaged (e.g., contact sports). These Actiwatches hold a charge for up to 60 days and therefore did not need to be charged during the study period (increasing adherence). Actiwatches capture raw data that are stored locally on the device and retrieved when the watch is connected to the Actiware software (e.g., on a lab computer). See Measures section for

the sleep parameters assessed with the Actiwatch. At the end of the study period, Actiwatches were returned to the PI's lab by mail, drop off, or meeting at a public place to return the device.

Compensation

Adolescents and parents were compensated $25/hr for the baseline assessment (max $75). For the 28-day monitoring period, adolescents were compensated with a $25 Amazon gift card for each week they completed at least 75% of the EMA surveys. In addition, they received a $15 Amazon gift card for returning the Actiwatch at the end of the study period.

Measures

Sleep problems

Baseline self-report measures. Sleep problems were measured at baseline from the adolescent using several well-validated self-report scales.

Sleep disturbance and quality in the past month were measured with the 19-item Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989. The PSQI provides seven component scores assessing subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, daytime dysfunction, and global sleep quality. The seven component scores are summed to a global PSQI score, which ranges 0–21 with higher scores indicating poorer sleep quality. Scores 5 or greater indicate poor sleep quality. The PSQI has been consistently used to assess sleep problems in adolescents (Bei et al., 2013; Blake et al., 2017b; Harvey et al., 2018). In the current sample, reliability of the seven components of the PSQI was low (Cronbach's $\alpha = .625$), but acceptable when examining individual PSQI items (Cronbach's $\alpha = .746$).

The presence and severity of insomnia was assessed using the Insomnia Severity Index (ISI; Bastien et al., 2001. The ISI is a seven-item self-report scale that measures the type, severity, and impact of insomnia. ISI scores range 0–28: 0–14 = *no insomnia or sub-clinical insomnia*, 15–21 = *moderate insomnia*, and 22–28 = *severe insomnia*. The ISI has been widely used to assess insomnia in adolescents (Clarke et al., 2015; Conroy et al., 2019; Palermo, Beals-Erickson, Bromberg, Law, & Chen, 2017). The ISI demonstrated acceptable reliability in the current sample (Cronbach's $\alpha = .766$).

Nightmares were measured using the Disturbing Dreams and Nightmare Severity Index (DDNSI; Krakow et al., 2002). The DDNSI is a five-item self-report measure that assesses the number of nightmares a week (up to 14), the number of nights in which nightmares occur, the intensity and severity of nightmares (each rated 0–6), and nighttime awakenings due to nightmares (rated 0–4). Scores >10 are consistent with nightmare disorder. The DDNSI has been used to assess nightmares in young people (Bernert et al., 2017; Russell, Rasmussen, & Hunter, 2018). The DDNSI demonstrated acceptable reliability in the current sample (Cronbach's $\alpha = .778$).

28-day monitoring period. ***Daily sleep diary.*** Each morning (ICAM survey), adolescents completed a sleep diary, assessing the previous night's sleep quality and quantity, using the core items of the Consensus Sleep Diary (Carney et al., 2012). Sleep diary questions were used to compute the following sleep parameters on a daily basis (see Table 2 for sleep parameter definitions): (a) sleep onset latency (SOL), (b) wake after sleep onset (WASO), (c) total sleep time (TST), (d) sleep efficiency (SE), and (e) sleep quality (SQ). In addition, sleep timing variability (i.e., sleep onset variability and sleep offset variability) was an average over the 28-day monitoring period. Further, adolescents reported the presence of nightmares the prior night using an item adapted from the DDNSI (Krakow et al., 2002). Finally, ruminative thoughts while trying to fall asleep were assessed with items adapted from the Ruminative Responses Scale (RRS) – brooding subscale (Treynor et al., 2003); see Rumination section for additional information). The specific sleep diary questions and sleep parameters derived from the responses are reported in Table 2. Participants completed an average of 16.04 sleep diaries each ($SD = 8.06$, Range = 3–28).

Actigraphy. Continuous actigraphy data was collected for 28 days following the baseline assessment. The Actiwatch captured data to compute the following sleep parameters (see Table 2 for sleep parameter definitions): SOL, WASO, TST, and SE. In addition, sleep timing variability (i.e., sleep onset variability and sleep offset variability) was an average over the 28-day monitoring period. Participants wore the actigraph an average of 23.41 nights ($SD = 9.38$, Range = 3–39[1]).

Suicidal thoughts and behaviors (STBs)

Baseline interview. The Columbia-Suicide Severity Rating Scale (C-SSRS; Posner et al., 2011), which has been validated in adolescents (Brent et al., 2009; Gipson, Agarwala, Opperman, Horwitz, & King, 2015), was utilized to assess lifetime and recent suicide ideation, plans, and attempts. Nonsuicidal self-injury (NSSI: deliberate self-inflicted injury with no intent to die) presence and frequency were assessed with a supplemental form based on the validated Self-Injurious Thoughts and Behaviors Interview (SITBI; Nock, Holmberg, Photos, & Michel, 2007), which has been widely used in adolescents (Auerbach, Millner, Stewart, & Esposito, 2015; Barrocas, Hankin, Young, & Abela, 2012; Nock, Prinstein, & Sterba, 2009; van Alphen et al., 2017). The prevalence of adolescents' lifetime self-injurious thoughts and behaviors are presented in Table 1.

28-day monitoring period via EMA. Daily suicidal thoughts were assessed 3–6 times daily using signal-contingent (SC) EMA prompts. Four suicidal thinking items were adapted from prior EMA studies with adolescents (Nock et al., 2009) and adults (Kleiman et al., 2017). Questions asked about current (at that moment) suicide desire, suicide intent, desire for life, and inability to keep oneself safe (see Table 2). These four items were summed to create a suicidal thinking composite score at each time point to reflect the multi-faceted nature of suicidal thinking and to enhance model parsimony (including one main suicidal thinking variable in each model). Higher scores on this composite variable indicated greater suicidal thinking.

Over the course of the study, participants completed an average of 62.36 SC surveys ($SD = 31.03$, Range = 6–116). Surveys are reported as raw numbers instead of percentages because the number of total prompts varied across participants depending on the number of days enrolled in the study and number of daily prompts based on availability. Only three SCs were required each day for total adherence (details of adherence and enrollment in study were reported in our prior manuscript: Glenn et al., 2021).

[1]Some participants wore the actigraph beyond the 28-day monitoring period while we were coordinating return of the device. Only data for the main 28-day monitoring period were included in analyses (corresponding to the time period for which suicidal thinking via EMA was collected). The full range is reported here for future studies that may be interested in adherence with this wearable device.

Table 2. Items utilized during 28-monitoring period to assess sleep (via sleep diary and actigraphy) and suicidal thinking

Primary sleep parameters[a]					
Sleep parameter (and abbreviation)	Sleep parameter definition	Sleep diary questions	Origin of sleep diary questions	Sleep diary calculations *(if applicable)*	Assessed via actigraphy?
–	–	What time did you get into bed last night? This may not be the time that you began "trying" to fall asleep.	Consensus Sleep Diary (Carney et al., 2012)	–	–
–	–	What time did you begin trying to go to sleep?	Consensus Sleep Diary (Carney et al., 2012)	(TIB_1 see below)	–
Sleep onset latency (SOL)	How many minutes it takes to fall asleep, starting from the moment of intention to fall asleep	How long did it take you to fall asleep? *(in minutes)*	Consensus Sleep Diary (Carney et al., 2012)	–	Yes
Terminal wakefulness (TWAK)	Amount of awake time between final awakening and the time of getting out of bed (final arising)	When did you wake up for the final time this morning?	Consensus Sleep Diary (Carney et al., 2012)	–	–
		What time did you get out of bed for the day this morning?	Consensus Sleep Diary (Carney et al., 2012)	(TIB_2 see below)	–
Time in bed (TIB)	Starting from the moment of intention to fall asleep and concluding with the final arising	*(Calculated from other items, see above)*	–	$TIB_2 - TIB_1$	–
Number of awakenings	Number of awakenings, excluding the final awakening before the final arising	How many times did you wake up last night? *(Do not count the final time you woke up before getting out of bed.)*	Consensus Sleep Diary (Carney et al., 2012)	–	Yes
Wake after sleep onset (WASO)	Total amount of time awake during the night (excluding SOL and TWAK)	In total, how much time did you spend awake in the middle of the night? *(in minutes)*	Consensus Sleep Diary (Carney et al., 2012)	–	Yes
Total sleep time (TST)	Actual time slept	*(Calculated from other items-see above)*	–	TIB – SOL – WASO – TWAK	Yes
Sleep efficiency (SE)	Percent of time in bed spent asleep	*(Calculations from other items)*	–	(TST/TIB) * 100%	Yes
Sleep quality (SQ)	Subjective sleep quality	How would you rate the quality of your sleep last night? *Scale: 1 = Very poor, 2 = Poor, 3 = Fair, 4 = Good, 5 = Very good*	–	–	–

Additional sleep variables					
Sleep variable assessed	Sleep variable definition	Sleep diary questions	Origin of sleep variable	Sleep diary calculations *(if applicable)*	Assessed via actigraphy?
Sleep onset variability	Variability in sleep onset timing	What time did you begin trying to go to sleep?	Bei et al., 2016; Bernert et al., 2017	*SD* of daily sleep onsets [i.e., time when sleep was initiated]	Yes
Sleep offset variability	Variability in sleep offset timing	When did you wake up for the final time this morning?	Bei et al., 2016; Bernert et al., 2017	*SD* of daily sleep offsets [i.e., time of final wakening]	Yes
Nightmares – presence	Presence of nightmares	Did you have any nightmares or distressing dreams last night? Yes/No	Disturbing Dreams and Nightmares Scale (DDNSI; Krakow et al., 2002)	–	–

(*Continued*)

Table 2. (*Continued.*)

Additional sleep variables					
Sleep variable assessed	Sleep variable definition	Sleep diary questions	Origin of sleep variable	Sleep diary calculations *(if applicable)*	Assessed via actigraphy?
Rumination before sleep	Ruminative thoughts/ brooding while trying to fall asleep	Sometimes when people are going to sleep, they think about things that have happened to them. Please indicate the extent to which you had each of the following thoughts before falling asleep last night: *Scale: 0 = Not at all, 1 = Somewhat, 2 = Quite a bit, 3 = Very much* Prior to sleep last night, I thought… "What am I doing to deserve this?" "Why do I always react this way?" …about a recent situation, wishing it had gone better. "Why do I have problems other people don't have?" "Why can't I handle things better?"	Five-item Brief Ruminative Responses Scale (RRS) – brooding subscale from the full 22-item scale (Treynor, Gonzalez, & Nolen-Hoeksema, 2003)	Sum of the 5 RRS items	–

Suicidal thinking items		
Variable	Question	Scale
Suicide desire	"How intense is your desire to kill yourself right now?"	0 = *Absent/no desire*, 1 = *Present, but not at all intense* to 5 = *Extremely intense*
Suicide intent	"How strong is your intent to kill yourself right now?"	0 = *Absent/no intent*, 1 = *Present but not at all strong* to 5 = *Extremely strong*
Desire for life	"How strong is your desire to live right now?"	1 = *Very strong* to 5 = *Very weak*
Inability to keep self safe	"How able are you to keep yourself safe right now?"	1 = *I definitely CAN keep myself safe* to 5 = *I definitely CANNOT keep myself safe*

[a]Standard acronyms and definitions of sleep parameters adapted from Buysse et al. (2006).

Rumination, depression, and daily sadness

Baseline self-report measures. ***Rumination.*** Because we examined rumination before sleep in the daily sleep diary, we also included trait-level rumination (assessed at baseline) with the RRS – brooding subscale; Treynor et al., 2003). The RRS assesses ruminative thinking and behavioral responses to negative mood. The RRS brooding subscale assesses "mood pondering" (e.g., You think "Why do I always react this way?") on a four-item scale from 1 = *Almost never* to 4 = *Almost always*. The RRS has demonstrated excellent reliability and validity in prior research (Butler & Nolen-Hoeksema, 1994; Nolen-Hoeksema & Morrow, 1991) and has been used in hundreds of prior studies to assess rumination in adolescents and adults (see review: Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). The current study used the brief (10-item) RRS scale, which has been validated in prior research (Erdur-Baker & Bugay, 2010) and is psychometrically equivalent in women and men (Whisman et al., 2020). The RRS brooding subscale demonstrated acceptable reliability in the current sample (Cronbach's $\alpha = .800$).

Depression. Depression symptoms were assessed with the Beck Depression Inventory for Youth (BDI-Y; Beck, 2005), which has demonstrated good psychometric properties in high-risk samples of adolescents (Stapleton, Sander, & Stark, 2007). The BDI-Y contains 20 sets of statements assessing symptoms of depression, scored from 0 = *Never* to 3 = *Always*, with higher scores indicating greater depression severity.[2] Raw total scores are T-scored based on sex and age. The current study assessed gender identity, but not sex assigned at birth. For adolescents who identified as transgender or nonbinary, the average of T-scores for females and males at that age was utilized. The BDI-Y demonstrated acceptable reliability in the current sample (Cronbach's $\alpha = .943$).

28-day monitoring period. ***Daily sadness.*** When possible, we included complementary person-level (baseline) and daily-level measures. Given the important role of person-level depression, we also included daily sadness, which was assessed 3–6 times daily in the SC survey. The sadness affect item was adapted from the Positive and Negative Affect Schedule (PANAS) short

[2]The suicide ideation item is not included in the BDI-Y total score so there was no item overlap between the BDI-Y and the EMA suicidal thinking items.

form (Mackinnon et al., 1999), utilized in previous EMA studies with suicidal populations (Kleiman et al., 2017; Nock et al., 2009). Momentary sadness was rated on a 5-point scale: 0 = *Very slightly/not at all* to 4 = *Extremely*.

Additional background and clinical information

Baseline self-report and interviews. Sociodemographic information (age, gender identity, race, ethnicity, sexual orientation, and socioeconomic status) was assessed from the adolescent and parent separately at baseline. Major psychiatric disorders were assessed from the adolescent and parent (separately) using the Mini International Neuropsychiatric Interview for Children and Adolescents (MINI-Kid; Duncan et al., 2020), a brief diagnostic interview. Current diagnoses were determined by integration of adolescents and parents reports to characterize the sample (see Table 1). At the baseline assessment, 45 adolescents (93.8% of the sample) reported taking at least one psychiatric medication, and 37 (77.1%) reported taking some type of medication that could be utilized for sleep: 34 reported prescription medications used for sleep (most common: off-label use of the antihistamine Hydroxyzine;[3] 66.7% of the total sample, 86.5% of the sample on any medication that could impact sleep) and six over-the-counter medications (5 melatonin; 1 Benadryl).[4] Notably, no adolescents were receiving any pharmacotherapy that is recommended by insomnia clinical guidelines (Sateia, Buysse, Krystal, Neubauer, & Heald, 2017).

Data preparation

Sleep data

Sleep data (i.e., sleep diaries and actigraphy) were inspected and cleaned prior to analysis. A brief overview is provided below but also see Supplementary Material. Sleep data were available from the two streams on some overlapping days, but on a significant number of different days. To maximize available data, sleep diary and actigraphy data were included in separate models.

Daily sleep diary. Daily sleep diaries were manually reviewed for outliers and inconsistent responses prior to analysis. Sleep parameters were scored consistent with established guidelines (Buysse et al., 2006). We adjusted the 24-hr window for EMA self-reports of sleep onset and offset times from mid-day to mid-day instead of midnight to midnight, as doing so allowed us to avoid issues with artificially high standard deviations for participants who went to bed just after midnight some nights and just before midnight on other nights.

Actigraphy. De-identified, raw actigraphy data were downloaded to a secure computer by the research team at the end of the study period. Prior to analysis, actigraphy data were examined: (a) manually to verify adherence and detect potential outliers (e.g., extremely long sleep intervals) and (b) using the Philips Actiware software that automatically generates sleep–wake statistics needed for our analyses.

Daily suicidal thinking and sadness (EMA reports)

Although these variables were assessed multiple times each day, we aggregated all EMA data to the day level, given that our main predictors – sleep problems – were assessed at the day level. For suicidal thinking, we included the maximum report of suicidal thinking in any given day (i.e., highest suicidal thinking composite score each day), consistent with research focused on *worst-point* models of suicide risk (i.e., suicidal thinking at its worst point may be the best indicator of risk for suicidal behavior; Beck, Brown, Steer, Dahlsgaard, & Grisham, 1999). For sadness, we included the average report of sadness each day (mean affect intensity) as one indicator of daily sadness (Larsen & Diener, 1987).

Missing data

For baseline moderators (BDI-Y, DDNSI, and RRS), listwise deletion was utilized when some or all of the scale items were missing. For EMA, data were missing at the survey level (i.e., a survey was not completed) rather than at the item level (i.e., all items were completed in a single survey). If a morning survey (i.e., sleep diary) was missing, that day's data were not included in the model (because the predictor was missing for that day). If a random survey was missing (i.e., suicidal thinking), other random surveys that day were included in the model. If all random surveys were missing (i.e., no assessment of suicidal thinking – the DV), that day's data were not included in the model. We did not use imputation because we had no cases where it would be useful, as the configuration of our missing data involved a completely missing survey rather than a missing item from an otherwise complete survey.

Data analysis

The main analyses examined how daily sleep problems predicted next-day worst-point suicidal thinking. Sleep problem predictors from daily diaries and actigraphy (see Table 2) were included in separate models. Given the large number of potentially related predictors and lack of specific hypotheses about individual predictors, we utilized multilevel least absolute shrinkage and selection operator (LASSO) regression. Multilevel LASSO regression is a type of linear regression-based machine learning that applies to the regression coefficients a regularization penalty that penalizes predictors (i.e., brings regression weights closer to zero) whose influence on the model is overly large. It can also shrink to zero any predictors that do not significantly contribute to the model, making it distinct from other regression approaches. Because it can be used for both reduction of large coefficients and removal of noninformative predictors (i.e., feature selection), this approach is useful, in cases like the present study, where there are a large number of predictors, lack of specific hypotheses about individual predictors, and potentially high levels of multicollinearity (Tibshirani, 1996).

Because we had repeated-measures EMA data, we used an implementation of LASSO in the *glmmLasso* R package (Groll, 2017) that allowed for such data. To determine the optimal penalization parameter, lambda (λ), we compared the Bayesian information criterion (BIC) of models across a range of possible lambda values (0–100, incremented by 5), and for each model chose the lambda that produced the lowest BIC. Although it is

[3]We do not know unequivocally that Hydroxyzine was used for sleep as it can also be used for anxiety, or its intended use – allergies.

[4]Of the 37 participants who reported, at baseline, utilizing a medication that could have had an impact on sleep, only 24 (65%) reported using these medications during the EMA phase. This raises concerns about the accuracy of daily reporting of sleep medications. Because we cannot be certain that sleep medications were not taken on the days they were not reported, we did not include sleep medications in the models for this study.

difficult to determine power for machine learning models, several rules of thumb exist, generally converging on the idea that 5–10 datapoints per feature are needed (Hua, Xiong, Lowey, Suh, & Dougherty, 2005). Using this rule of thumb, our sample of almost 3,000 datapoints was sufficient for models with up to 300 features, far fewer than the 21 main effects included in this paper.

We conducted separate sets of models for the sleep diary (EMA) predictors and actigraphy predictors. In addition to daily-level (within-person) predictors, we also included person-level variables assessing sleep timing variability (i.e., *SD* of sleep onsets and offsets), baseline sleep problems (ISI, PSQI, DDNSI), baseline depression (BDI-Y), and baseline rumination (RRS-brooding). We person-mean centered all repeated-measures data using the *EMAtools* R package (Kleiman, 2017) and grand-mean centered BDI-Y, DDNSI, and RRS scores, as they were used in interaction effects. All models had random intercepts and used worst-point suicidal thinking in any given day for the outcome variable.

For the EMA models, we included three different steps. The first model included EMA (daily-level) variables only (sleep from the prior night: SOL, WASO, TST, SE, SQ, nightmares, rumination before sleep; and average sadness during the day). The second model added relevant person-level variables (PSQI, ISI, DDNSI, BDI-Y, RRS-brooding; sleep timing variability: *SD* of sleep onsets and offsets). Finally, the third model added interactions between significant daily-level variables and person-level variables that assessed the same construct (i.e., daily rumination × baseline rumination [RRS]; daily nightmares × baseline nightmares [DDNSI]; daily sadness × baseline depression [BDI-Y]). When interactions were significant, we plotted them using the *sjPlot* R package (Lüdecke, 2021). We calculated simple slopes using data from a traditional multilevel model and the *interactions* R package (Long, 2019).

We utilized a similar approach for the actigraphy data. The first model included daily sleep problems assessed via actigraphy (i.e., SOL, WASO, TST, and SE). The second model added relevant person-level variables (PSQI, ISI, DDNSI, BDI-Y, RRS-brooding; sleep timing variability: *SD* of sleep onsets and offsets). Because there were no theoretically relevant combinations of actigraphy and baseline sleep variables, we did not test any interactions in this set of models.

Results

Daily-level (EMA) sleep models

Table 3 shows the results of the LASSO models with the EMA variables (i.e., sleep diary variables and daily sadness). In the first model (shown in the leftmost columns), the following sleep indices were related to greater (more severe) suicidal thinking the next day: greater SOL, greater SQ (opposite from the hypothesized direction), presence of nightmares, and more rumination before sleep. In addition, higher daily average sadness was related to greater suicidal thinking during the day. Because variables were entered simultaneously, the previously mentioned sleep variables were significant when daily sadness was included in the model. SE was the only variable that shrank to zero (i.e., no meaningful contribution). In the second model (shown in the middle column of Table 3), person-level variables were added to the model. The same EMA variables from the prior model were still associated with greater suicidal thinking. In addition, in this model, lower TST (hypothesized direction) and greater SE (opposite from the hypothesized direction) were positively associated with suicidal thinking. Among the new person-level predictors added to the model, only baseline depression (BDI-Y) was a significant predictor of greater suicidal thinking. The third model added interaction effects between significant EMA variables and the associated baseline measure of the construct: daily nightmares × baseline nightmares (DDNSI), daily rumination before sleep × baseline rumination (RRS-brooding), and daily sadness × baseline depression severity (BDI-Y). In this model, the same daily-level (EMA) and person-level variables were significant. All three interactions were significant and are plotted in Figure 1 and probed below.

Results of the simple slopes probe for the daily nightmares × baseline nightmares (DDNSI) interaction show that the relationship between nightmares and next-day suicidal thinking was significant and positive at all levels of DDNSI. The relationship was stronger among those with lower baseline nightmares/DDNSI scores ($-1SD$, $b = 1.30$, $t = 5.08$, $p < .001$) than those with mean-level ($b = 1.00$, $t = 6.56$, $p < .001$) or higher ($+1SD$, $b = 0.70$, $t = 4.37$, $p < .001$) DDNSI scores. Results of the simple slopes probe from the daily rumination × trait (baseline) rumination (RRS) interaction show that the relationship between daily rumination before sleep and next-day suicidal thinking was only significant for those at low ($-1SD$; $b = 0.10$, $t = 3.07$, $p < .001$) baseline rumination levels (RRS scores). The relationship was not significant at mean ($b = 0.03$, $t = 1.93$, $p = .05$) or high ($+1SD$, $b = -0.03$, $t = -1.21$, $p = .22$) rumination levels. Results of the simple slopes probe for the daily sadness × baseline depression (BDI-Y) interaction show that the relationship between sadness and next-day suicidal thinking was significant and positive at all levels of BDI-Y, but was stronger among those with higher baseline BDI-Y scores ($+1SD$, $b = 1.28$, $t = 15.55$, $p < .001$) than those with mean ($b = 0.94$, $t = 16.14$, $p < .001$) or lower ($-1SD$, $b = 0.59$, $t = 6.52$, $p < .001$) depression levels.

Daily-level (actigraphy) sleep models

Table 4 shows the results of the LASSO models involving the actigraphy data predicting next-day suicidal thinking. In the first model (actigraphy only; left columns), less WASO (opposite from hypothesized direction) was the only variable associated with more severe suicidal thinking the next day. In the second model, which added the baseline/person-level variables (shown in the right column), less WASO, and higher baseline depression (BDI-Y scores) were associated with greater next-day suicidal thinking. SOL, SE, and TST shrank to zero in this model.

Discussion

The current study found some support for sleep problems predicting short-term increases in suicidal thinking among suicidal adolescents during the 28 days following discharge from acute psychiatric care. There are five major findings of this research. First, specific sleep problems assessed via daily sleep diary (e.g., longer time to fall asleep, presence of nightmares, ruminative thoughts before sleep) were related to greater next-day suicidal thinking. Second, these sleep diary predictors held when controlling for baseline depression and daily-level sadness. Third, most sleep parameters assessed via actigraphy were not predictive of suicidal thinking, and those that did, were not in the expected direction (i.e., less time awake during the night). Fourth, person-level sleep problems (i.e., assessed at baseline) were not uniquely predictive of suicidal thinking during the 28-day monitoring period, over and above daily-level predictors. Fifth, and finally,

Table 3. Results of LASSO regression models using daily-level (ecological momentary assessment, EMA) and person-level (baseline) self-report data to predict next-day worst-point suicidal thinking

	Daily-level only				Daily-level + Person-level				Daily-level + Person-level + Interactions			
	B	*SE*	*Z*	*p*	*B*	*SE*	*Z*	*p*	*B*	*SE*	*Z*	*p*
(Intercept)	3.595	0.380	9.466	<.001	4.318	0.341	12.671	<.001	4.349	0.342	12.706	<.001
Daily sleep diary variables (EMA)												
Sleep onset latency	0.001	0.001	2.300	.021	0.003	0.001	2.970	.003	0.003	0.001	3.057	.002
Wake after sleep onset	0.001	0.001	1.470	.142	0.000	N/A	N/A	N/A	0.000	N/A	N/A	N/A
Total sleep time	0.000	0.000	−1.689	.091	−0.001	0.000	−2.603	.009	−0.001	0.000	−2.584	.010
Sleep efficiency	0.000	N/A	N/A	N/A	0.008	0.004	2.114	.034	0.009	0.004	2.258	.024
Sleep quality	0.121	0.031	3.941	<.001	0.155	0.035	4.411	<.001	0.190	0.035	5.372	<.001
Nightmares (presence)	0.595	0.070	8.513	<.001	0.836	0.078	10.653	<.001	1.016	0.088	11.570	<.001
Rumination before												
sleep	0.028	0.009	3.065	.002	0.031	0.010	3.187	.001	0.032	0.010	3.106	.002
Daily emotion variable (EMA)												
Daily sadness	1.006	0.031	32.129	<.001	0.924	0.034	27.112	<.001	0.895	0.034	26.085	<.001
Summary sleep variables over total period (EMA)												
SD sleep onsets					−10.693	9.367	−1.142	.254	−10.524	9.409	−1.119	.263
SD sleep offsets					4.189	15.164	0.276	.782	4.118	15.229	0.270	.787
Baseline sleep problems, depression, rumination												
PSQI total score					−0.120	0.131	−0.915	.360	−0.124	0.131	−0.946	.344
ISI					0.060	0.090	0.665	.506	0.061	0.091	0.672	.501
DDNSI					−0.007	0.040	−0.180	.857	−0.001	0.040	−0.025	.980
BDI-Y					0.115	0.026	4.430	<.001	0.115	0.026	4.426	<.001
RRS Brooding					−0.021	0.096	−0.216	.829	−0.023	0.097	−0.236	.814
Interactions between daily-level and person-level variables												
Daily rumination * RRS Brooding									−0.018	0.003	−5.097	<.001
Daily nightmares * DDNSI									−0.036	0.010	−3.522	<.001
Daily sadness * BDI-Y									0.023	0.003	9.079	<.001
Model summary metrics												
	Daily-level Only				Daily-level + Person-level				Daily-level + Person-level + Interactions			
BIC	−43259.4				−37065.85				−37159.68			
Optimal λ	35				80				80			

BDI-Y = Beck Depression Inventory for Youth; BIC = Bayesian information criterion; DDNSI = Disturbing Dreams and Nightmare Severity Index; ISI = Insomnia Severity Index; LASSO = multilevel least absolute shrinkage and selection operator; N/A = not applicable because magnitude shrank to zero; PSQI = Pittsburgh Sleep Quality Index; RRS = Ruminative Response Scale.

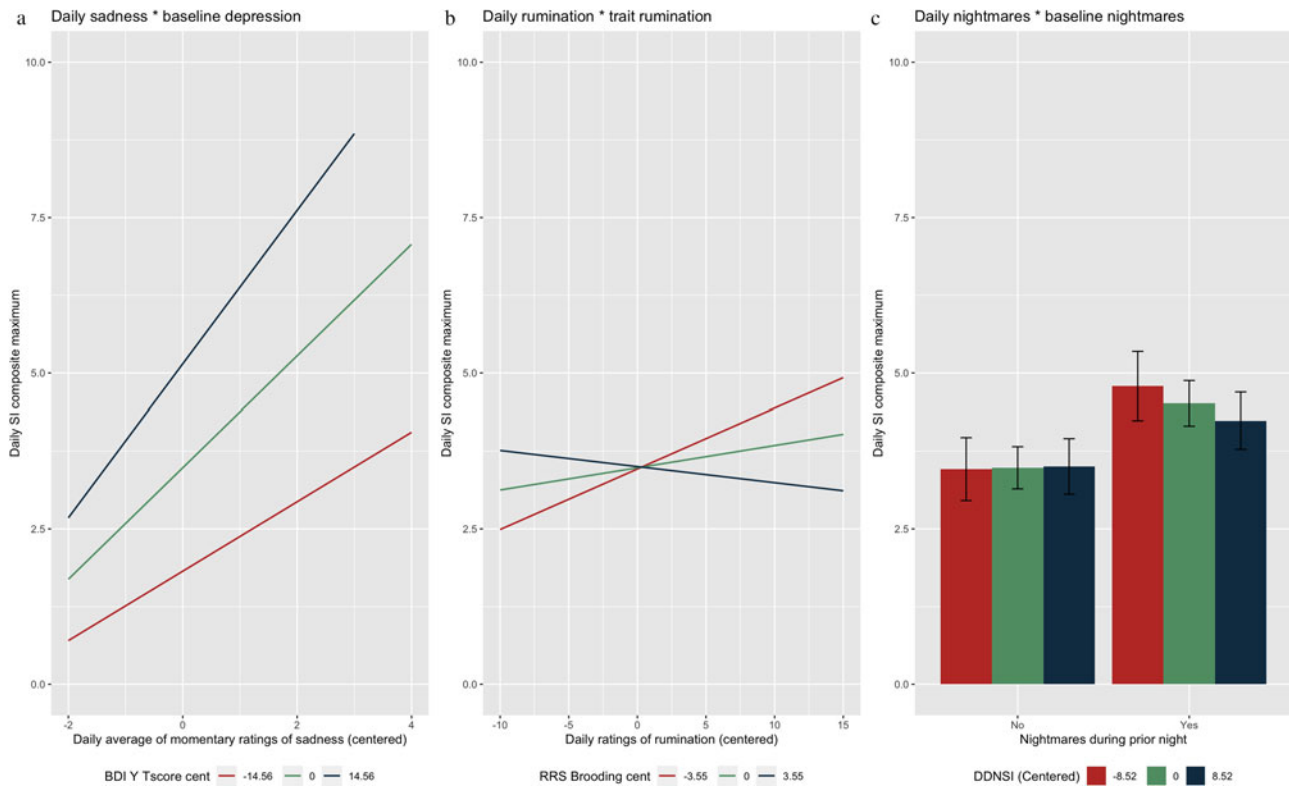

Figure 1. Significant interactions between daily-level (ecological momentary assessment, EMA) and person-level (baseline) variables predicting next-day worst-point suicidal thinking. BDI-Y = Beck Depression Inventory for Youth; DDNSI = Disturbing Dreams and Nightmares Severity Index; RRS = Ruminative Response Scale; SI = suicidal thinking. (a) Significant interaction between daily sadness and baseline depression (BDI-Y). BDI-Y scores are plotted at the mean, 1*SD* above the mean, and 1*SD* below the mean. Those with greater depression severity at baseline exhibited a stronger association between daily sadness and next-day worst-point suicidal thinking. (b) Significant interaction between rumination before sleep (daily-level) and baseline rumination (RRS brooding). RRS scores are plotted at the mean, 1*SD* above the mean, and 1*SD* below the mean. Those with lower rumination scores at baseline exhibited a stronger association between daily rumination before sleep and next-day worst-point suicidal thinking. (c) Significant interaction between daily nightmares and baseline nightmares (DDNSI). DDNSI scores are plotted at the mean, 1*SD* above the mean, and 1*SD* below the mean. Error bars represent standard error of the mean. Those with lower nightmares scores at baseline exhibited a stronger association between daily nightmares and next-day worst-point suicidal thinking.

associations between daily-level sleep problems and suicidal thinking were moderated by person-level (baseline) measures of similar constructs (e.g., baseline nightmares moderated the association between daily-level nightmares and next-day suicidal thinking). Each finding will be discussed in turn.

A range of sleep problems assessed through daily sleep diaries were related to greater next-day suicidal thinking. Three sleep problems were related to suicidal thinking in the hypothesized direction across all models. First, greater sleep onset latency (i.e., taking more time to fall asleep) significantly predicted greater next-day suicidal thinking. Although this specific sleep parameter was not a significant predictor in prior short-term (days and weeks) longitudinal research (Bernert et al., 2017; Littlewood et al., 2019), difficulty falling asleep is consistent with initial insomnia (i.e., early insomnia or sleep-onset insomnia), and different types of insomnia have been linked with STBs in previous research (Harris et al., 2020; Kearns et al., 2020; Liu et al., 2020). Second, the finding that ruminative thoughts before sleep was related to next-day suicidal thinking may suggest what is occurring when sleep onset is delayed. Although prior studies have not examined ruminative thoughts before sleep specifically, the connection between rumination and STBs has been found in long-term longitudinal research (Glenn, Kleiman, et al., 2018), as well as EMA research linking rumination to engagement in nonsuicidal self-injury (Selby, Franklin, Carson-Wong, & Rizvi, 2013; Zaki, Coifman, Rafaeli, Berenson, & Downey, 2013). Third, and finally, the association between nightmares and next-day suicidal thinking is consistent with prior research (Liu et al., 2020; Russell et al., 2019; Titus et al., 2018), including short-term longitudinal research (Bernert et al., 2017) and one prior daily diary study linking nightmares to (nonsuicidal and suicidal) self-harm (Hochard et al., 2015). In addition to these three indices of sleep problems, less TST also was related to next-day suicidal thinking in some, but not all, models. Shorter sleep duration has been related to greater risk for STBs in youth (Chiu et al., 2018; Mars et al., 2019), and a real-time monitoring study with adults found associations between less TST and suicide ideation at the daily level (Littlewood et al., 2019). Finally, two sleep parameters predicted suicidal thinking in the direction opposite from hypothesized. Specifically, *better* sleep quality and *greater* sleep efficiency (in some models) were also related to next-day suicidal thinking. Prior research in adults has found that *poorer* perceived sleep quality predicts next-day suicidal thinking (Littlewood et al., 2019). It is possible that this overall evaluation of sleep quality may be less useful in youth, as compared to more specific questions about sleep patterns (e.g., presence of nightmares). Supporting this hypothesis, the trait measure of sleep quality (i.e., PSQI) exhibited lower reliability in this high-risk adolescent sample compared to prior studies. Further, sleep efficiency was not a significant predictor of suicidal thinking in prior

Table 4. Results of LASSO regression models using daily-level (actigraphy) data and person-level (baseline) self-report data to predict next-day worst-point suicidal thinking

	Daily-level only				Daily-level + Person-level			
	B	*SE*	*Z*	*p*	*B*	*SE*	*Z*	*p*
(Intercept)	3.715	0.377	9.845	.000	−3.779	0.331	−11.417	<.001
Daily sleep variables (actigraphy)								
Sleep onset latency	−0.002	0.001	−1.873	.061	0.000	N/A	N/A	N/A
Wake after sleep onset	−0.007	0.002	−2.741	.006	−0.010	0.002	−4.780	<.001
Total sleep time	−0.001	0.000	−1.682	.093	0.000	N/A	N/A	N/A
Sleep efficiency	0.007	0.006	1.205	.228	0.000	N/A	N/A	N/A
Summary sleep variables over total period (actigraphy)								
SD sleep onsets					1.973	2.896	0.681	.496
SD sleep offsets					−9.906	8.061	−1.229	.219
Baseline sleep problems, depression, rumination								
PSQI					−0.074	0.129	−0.579	.563
ISI					0.092	0.089	1.033	.302
DDNSI					0.007	0.039	0.177	.860
BDI-Y					0.103	0.027	3.758	<.001
RRS brooding					−0.002	0.104	−0.019	.985
Model summary metrics								
	Daily-level Only				Daily-level + Person-level			
BIC	−17353.65				−15139.62			
Optimal λ	65				55			

BDI-Y = Beck Depression Inventory for Youth; DDNSI = Disturbing Dreams and Nightmare Severity Index; ISI = Insomnia Severity Index; LASSO = multilevel least absolute shrinkage and selection operator; N/A = not applicable because magnitude shrank to zero; PSQI = Pittsburgh Sleep Quality Index; RRS = Ruminative Response Scale.

research with adults (Bernert et al., 2017; Littlewood et al., 2019). As a parameter assessed from sleep diaries, sleep efficiency is calculated from a number of estimates of total time in bed and time slept (see Table 2), which may make it less reliable, particularly in younger and higher risk populations. Integrating across the other significant findings, adolescents could have had efficient, but shorter duration, sleep in which nightmares were present.

Notably, all of these sleep patterns (assessed via sleep diary) were related to next-day suicidal thinking, even when controlling for baseline depression symptom severity and daily-level sadness. This is consistent with prior research indicating that sleep problems are uniquely linked to suicide risk, beyond the role of depression (Bernert et al., 2017; Bishop et al., 2018; Littlewood et al., 2019; Pigeon et al., 2012a; Pigeon et al., 2012b).

In contrast to the findings with sleep diaries, most sleep problems assessed via actigraphy were not related to next-day suicidal thinking. The only actigraphic parameter that was related to suicidal thinking at the day-level was not in the hypothesized direction. Specifically, less wake after sleep onset (i.e., less waking up in the middle of the night) was related to greater next-day suicidal thinking in some, but not all, models. Using daily sleep diaries, this sleep parameter was not significantly related to suicidal thinking. Notably, most of the significant sleep diary variables could not be assessed using actigraphy (i.e., nightmares and ruminative thoughts before sleep). It is possible that adolescents woke up less on a given night, but still experienced nightmares or disturbing dreams (that did not wake them), which may have negatively impacted them the next day. The discrepancy between subjective and objective measures of sleep problems is consistent with prior research indicating that subjective sleep indicators may be more strongly related to clinical outcomes than objective sleep indicators (Edinger et al., 2000). Moreover, these findings underscore the importance of assessment across multiple units of analysis that may be best suited to measure these constructs (Cuthbert, 2014).

This study also incorporated person-level sleep problems (general sleep quality, insomnia, nightmares) assessed at baseline. When included in models with daily-level (within-person) sleep problems, person-level sleep problems were not predictive of suicidal thinking during the 28-day monitoring period. This study adds to the mixed findings in adults: some studies have found that sleep problems predict suicide ideation at the day level (Littlewood et al., 2019), whereas others have found this effect only at the person level (Kaurin, Hisler, Dombrovski, Hallquist, & Wright, 2020). The current study suggests that certain indices of sleep problems at the within-person level (assessed via sleep diary) relate to greater suicidal thinking in high-risk adolescents. However, person-level (baseline) sleep problems were significant moderators (discussed next).

Finally, this study found that several of the associations between daily-level sleep problems (assessed via sleep diary) and suicidal thinking were moderated by person-level (baseline) measures of the related construct. First, the association between daily-level nightmares and next-day suicidal thinking was moderated by baseline reports of nightmares, such that those with lower

nightmare scores at baseline (indicating lower frequency, intensity, and severity of nightmares) exhibited a stronger association between daily (sleep diary) nightmares and suicidal thinking at the day level. This may mean that nightmares are most disruptive for those who do not experience them on a regular basis (e.g., given the significant autonomic arousal experienced with nightmares; Paul, Alpers, Reinhard, & Schredl, 2019). Of note, daily nightmares were significantly related to next-day suicidal thinking at all baseline nightmare levels, indicating the robust role of nightmares as a sleep problem and potential treatment target (Titus et al., 2018). In addition, the relationship between ruminative thoughts before sleep (assessed via sleep diary) and next-day suicidal thinking was moderated by baseline rumination, such that only those with lower rumination at baseline exhibited a significant association between rumination and suicidal thinking at the day level. Similar to the nightmare interaction, this may mean that ruminative thoughts before sleep are the most impairing for those who do not typically ruminate. This interaction pattern is consistent with some prior research examining the impact of rumination on physical recovery (Key, Campbell, Bacon, & Gerin, 2008). However, not all interactions followed this pattern. The association between daily-level sadness and next-day suicidal thinking was moderated by baseline depression symptom severity such that those with higher depression symptoms exhibited a stronger association between sadness and suicide thinking at the day level. This suggests that daily increases in sadness may be most related to suicide risk for those with greater baseline depression severity, consistent with some prior research (i.e., examining the interaction between daily negative affect and baseline depression on quality of life; Barge-Schaapveld, Nicolson, Berkhof, & Marten, 1999). It is important to note that because all interactions were included simultaneously, they each exhibited a unique effect on next-day worst-point suicidal thinking. Future research is needed in larger samples to further explore the significant interactions between person-level and daily-level risk factors.

Taken together, this study provides further evidence to support bringing a developmental perspective to the RDoC framework. Specifically, these findings indicate that sleep problems, which are transdiagnostic symptoms, are important predictors of suicidal thinking during a critical stage of development – adolescence. In addition, they indicate the sleep constructs/parameters that may be the most helpful to assess during this developmental stage. Future research is needed to explore how sleep problems dynamically impact suicidal thinking from childhood through young adulthood, as well as how the environment (fourth plane in the matrix; Woody & Gibb, 2015) may impact these associations.

Limitations and future directions

Although this study provides unique information about the association between sleep problems and suicide risk in youth, limitations of the current project suggest important areas for future research. First, there were some limitations of the sample. The current study's sample was relatively small. Although well powered for within-person analyses (based on the repeated-measures design), the study was less powered for between-person analyses. In addition, the sample was predominantly female and White, which limits generalizability to diverse youth. Given high rates of STBs among transgender and nonbinary youth (The Trevor Project, 2020) and increasing suicide rates among youth of color (Centers for Disease Control and Prevention, 2018; Lindsey, Sheftall, Xiao, & Joe, 2019), it is imperative that future research increase recruitment of youth from diverse and underrepresented groups (Cha et al., 2018). Moreover, we were unable to examine how sleep problems relate to suicidal behavior because the sample was small and suicidal behavior is much lower in prevalence compared to suicide ideation (Ivey-Stephenson et al., 2020). Future research would benefit from replication in larger and more diverse samples that allow examination of individual differences and how sleep problems relate to short-term risk for suicidal behavior.

Second, there were a few assessment limitations. At baseline, the severity of sleep problems was assessed with self-report measures, rather than diagnostic tools (to assess sleep disorders). Future studies may benefit from examining how within-person effects are moderated by between-person differences in sleep problems. In addition, the psychometric properties of actigraphy are less well established in high-risk adolescents, such as the current sample. Although actigraphy demonstrates good convergence with gold-standard sleep measures (i.e., PSG; Kushida et al., 2001; Sadeh, 2011) and having an objective measure of sleep is preferred to reliance on self-report only (Lunsford-Avery, LeBourgeois, Gupta, & Mittal, 2015), the accuracy of actigraphy declines with reductions in sleep quality and quantity (Kushida et al., 2001; Martin & Hakim, 2011). Evaluating the reliability of actigraphic assessment in high-risk adolescents is an important step before research moves forward in this area. Finally, the current study was unable to examine the role of daily sleep medications on suicidal thinking, which will be important to examine in future studies.

Third, there were some limitations of the data analytic plan that suggest important future directions. This study examined one main empirically informed outcome of suicidal thinking (i.e., worst-point suicide ideation; Beck et al., 1999). Future studies would benefit from examining other indices of suicide ideation severity (e.g., duration). In addition, the current study's sample was sufficiently large for our machine learning approach to identify the most robust sleep indices, but larger samples are needed for gold-standard "out-of-sample" cross-validation (Jacobucci, Littlefield, Millner, Kleiman, & Steinley, 2021). Finally, this study examined one potential temporal association between sleep problems and suicidal thinking. However, there may be other associations that are useful to explore, such as the accumulation of sleep problems over several days or how sleep problems predict suicide risk several days later (as opposed to just one day later).

Beyond understanding the temporal association between sleep problems and suicidal thinking, there are several other important future directions. Additional research is needed to understand the mechanisms linking sleep problems to increased suicide risk. Prior research has suggested potential affective (Baum et al., 2014; Ben-Zeev, Young, & Depp, 2012), cognitive (De Bruin, van Run, Staaks, & Meijer, 2017; Keilp et al., 2001), and inflammatory mechanisms (Black & Miller, 2015; Irwin & Piber, 2018) that may mediate this association (Kearns et al., 2020; Liu et al., 2020). Moreover, it will be important to test the presence and strength of sleep problems as a causal risk factor and to what extent these may differ if the sleep problem is due to a specific sleep disorder (e.g., insomnia, obstructive sleep apnea). To determine whether sleep problems are a causal risk factor (Kraemer et al., 1997), research is needed to examine how modifying sleep problems reduce suicidal thoughts and behaviors among adolescents. There are a number of evidence-based psychosocial treatments for reducing sleep problems in youth, including CBT-I when the sleep problem is insomnia (Blake et al., 2017a; Ma et al., 2018; Werner-Seidler

et al., 2018), and IRT when the sleep probem is nightmares (Krakow, 2011; Simard & Nielsen, 2009). In addition to their impact on insomnia severity, sleep treatments, like CBT-I, have been found to also reduce mental health symptoms related to STBs (e.g., anxiety, depression) in youth (Blake et al., 2017a). STBs have not been examined as an outcome in sleep trials among youth, but growing research with adults indicates that improving sleep reduces STBs (Bishop, Walsh, Ashrafioun, Lavigne, & Pigeon, 2020; Christensen et al., 2016; Ellis, Rufino, & Nadorff, 2019; Manber et al., 2011; Pigeon, Funderburk, Cross, Bishop, & Crean, 2019; Trockel, Karlin, Taylor, Brown, & Manber, 2015). Considerably more research in youth is needed across all aspects of the sleep–suicide relationship.

Summary

This study found some support for the role of sleep problems as a short-term risk factor for suicidal thinking among high-risk youth. Findings indicate that some sleep problems (e.g., greater sleep onset latency, nightmares, and ruminative thoughts before sleep assessed via sleep diary) predicted worst-point suicidal thinking among high-risk adolescents following discharge from acute psychiatric care. It will be important for future research to replicate findings in larger samples, examine mechanisms in the sleep–suicide link, and test treatments that intervene on sleep problems and their mechanisms to decrease suicide risk among youth.

Supplementary Material. The supplementary material for this article can be found at https://doi.org/10.1017/S0954579421000699

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