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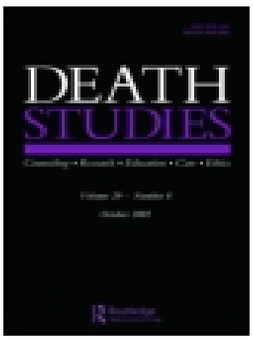

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REPORT

The role of pre-sleep arousal in the connection between insomnia and suicide risk

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ABSTRACT

Insomnia is a risk factor for suicidal thoughts and behaviors. The present study examined the role of pre-sleep arousal in this association. Seventy-eight adults (M_{age} = 24.28, 56% had recent history of suicidal thoughts and behaviors) attended two lab visits over four consecutive days. We tested if generally experienced self-reported pre-sleep arousal explained the association between self-report insomnia symptoms experienced over the past two weeks and past week-suicidal ideation. Results indicated full mediation for pre-sleep cognitive arousal, but not somatic arousal. Pre-sleep cognitive arousal could be a key variable linking insomnia symptoms to suicide risk.

Sleep disturbance is a key risk factor for suicidal thoughts and behaviors, and this is especially true for insomnia (Bernert et al., 2015; McCall & Black, 2013). Broadly, insomnia involves difficulties with sleep duration, continuity, and quality, which in turn contribute to daytime distress and impairment (American Psychiatric Association, 2013). Insomnia poses both long-term and imminent risk for suicide. More than a dozen population-based studies indicate that insomnia is associated with increased lifetime odds of experiencing suicidal thoughts and behaviors (see Pigeon et al., 2012). Moreover, experience sampling studies indicate that insomnia symptoms are predictive of next day suicidal ideation (e.g., Zuromski et al., 2017), and in psychological autopsy studies acute episodes of insomnia-related issues commonly precede suicide death (Goldstein et al., 2008; Goodwin & Marusic, 2008). Hence, insomnia is highly relevant to the emergence and maintenance of suicidal thoughts and behaviors, and research should clarify the mechanisms underlying this association.

One aspect of sleep functioning that has received less attention in the literature on the insomnia-suicide association is pre-sleep arousal, described as unwanted hyperarousal at bedtime that is counterproductive to initiating and maintaining sleep (Nicassio et al., 1985). There are two components of pre-sleep arousal. Cognitive pre-sleep arousal refers to the extent that an individual is mentally active or alert while attempting sleep, and thoughts are often distressing (e.g., rumination, worry). Somatic pre-sleep arousal refers to physiological sensations (e.g., rapid heart rate) at bedtime that disrupt the resting state necessary for sleep. Cognitive and somatic pre-sleep arousal are interactive, such that greater cognitive pre-sleep arousal increases somatic pre-sleep arousal, which can in turn perpetuate cognitive pre-sleep arousal. As a result, both domains are associated with insomnia (Perlis et al., 1997).

Pre-sleep arousal is evident in conditions that co-occur with insomnia and suicidal thoughts and behaviors, including depression (Karlson et al., 2010), post-traumatic stress disorder (Werner et al., 2020), and borderline personality disorder (Grove et al., 2017). Less research has examined pre-sleep arousal and suicide risk, but pre-sleep arousal may be relevant to those with concurrent insomnia and suicidal thoughts and behaviors. Indeed, rumination links subjective sleep quality to suicidality (Weis et al., 2015), and pre-sleep suicidal thoughts (e.g., defeat and entrapment) predict nightly sleep quality and next day increases in suicidal ideation (Littlewood et al., 2019). Moreover, acute agitation, which can be described as a state of heightened arousal and emotional turmoil, commonly precedes suicidal behavior (Rogers et al., 2016), and has been discussed as a possible

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contributing factor linking transient insomnia to imminent risk for suicide (Fisher et al., 2017). People with a history of suicidal thoughts and behaviors also generally tend to exhibit characteristics associated with pre-sleep arousal, such as rumination and worry (Rogers & Joiner, 2017) and physiological hyperarousal during sleep (Dolsen et al., 2017). However, more research is necessary to gain clarity on the role of both cognitive and somatic pre-sleep arousal in the association between insomnia and suicide risk.

The present study sought to provide a preliminary test to determine if and how pre-sleep arousal is an explaining factor underlying the insomnia-suicidal thoughts and behaviors link. As part of a larger laboratory study, this research involved 78 adults, more than half of whom reported a recent history of suicidal thoughts and behaviors. Participants completed several self-report questionnaires, and answered questions pertaining to insomnia symptoms over the past two weeks, the degree to which they generally experience both cognitive and somatic pre-sleep arousal, and the extent to which they experienced suicidal ideation over the past week. The central goal of this study was to test if insomnia symptoms predicted suicidal ideation and examine if both domains of pre-sleep arousal mediated this association. We hypothesized that insomnia symptoms would predict suicidal ideation, and that this association would be at least partially mediated by both cognitive and somatic pre-sleep arousal.

Method

Participants and procedure

Participants included 78 adults (66% Female) with a mean age of 24.28 ($SD = 6.53$) recruited from a large metropolitan city in the southwestern region of the United States. The sample was primarily Caucasian (81%). To ensure that the sample represented the full range of suicide risk, we intentionally recruited individuals from an array of settings likely to yield participants demonstrating low, moderate, and high baseline risk for suicide. The vast majority of higher risk participants were recruited from inpatient and outpatient psychiatric facilities, whereas lower to moderate risk individuals were primarily recruited from community venues and undergraduate psychology courses. A total of 44 individuals (56% of the sample) reported a recent history of suicidal thoughts and behaviors, and of these, 16 (20% of the sample) reported a recent suicide attempt. More information about the sample is in Table 1.

Table 1. Characteristics of the sample.

Variable	%
Sex	66% Female
Race	
White/Caucasian	81%
Black/African American	1%
American Indian	1%
Asian or Pacific Islander	7%
More than one race	6%
Other/Not reported	4%
Ethnicity	13% Hispanic
Sexual Orientation	
Heterosexual	73%
Homosexual	4%
Bisexual	16%
Other	4%
Prefer not to say or unsure	3%
Recruitment Site	
Inpatient	32%
Outpatient Clinic	24%
Community	18%
Undergraduate Research Pool	26%

Measures

Sleep measures

The *Insomnia Severity Index* (ISI; Bastien et al., 2001) is a 7-item scale measuring insomnia symptoms over the past two weeks. Items are Likert scaled. For example, one item ("How satisfied/dissatisfied are you with your current sleep pattern?") is on a scale ranging from 0 (Very satisfied) to 4 (Very Dissatisfied). Higher scores indicate greater symptom severity. Internal consistency for the present study was good ($\alpha = .87$).

The *Pre-Sleep Arousal Scale* (PSAS; Nicassio et al., 1985) is a 16-item measure that provides a total score, and scores for cognitive and somatic types of pre-sleep arousal. Respondents rate symptoms that can occur immediately prior to sleep. Higher scores indicate greater levels of pre-sleep arousal. Items are Likert scale ranging from 1 (not at all) to 5 (extremely), pertaining to cognitive pre-sleep arousal (e.g., "Worry about falling asleep") and somatic pre-sleep arousal (e.g., "Heart racing, pounding, or beating irregularly"). For the present study, internal consistency was good for the full scale ($\alpha = .93$) and its domains: cognitive ($\alpha = .93$) and somatic ($\alpha = .83$) cognitive pre-sleep arousal.

Suicidal ideation (past week)

Beck Scale for Suicide Ideation (BSSI; Beck et al., 1988) was used to measure past week suicidal ideation. BSSI has 21 item groups that are Likert scaled ranging from 0 to 2. For example, an item assessing wish to live ranges from 0 ("I have a moderate to strong wish to live") to 2 ("I have no wish to live"). The first 19 items indicate past week suicidal ideation, whereas the last two items indicate lifetime suicide

attempts. As such, we calculated total scores by summing up the first 19 items. Higher scores indicate more severe past week suicidal ideation. The BSSI displayed excellent internal consistency in the present study ($\alpha = .91$).

Depression and anxiety

The Mini International Neuropsychiatric Interview (MINI 6.0; Sheehan & Lecrubier, 2010) was used to assess if participants met diagnostic criteria for major depressive episode and generalized anxiety disorder. The interview is structured with "yes" or "no" questions (e.g., "Were you excessively anxious or worried about several routine things, over the past 6 months?"). Questions inquiring about diagnostic status correspond to the criteria and thresholds specified in the DSM-IV (American Psychiatric Association, 2013). In the present study, the major depressive episode and generalized anxiety disorder variables are binary coded (0 = no diagnosis, 1 = criteria met).

Procedure

Participants were invited to the research lab on two separate occasions, 4 days apart. They completed the ISI at Time 1, which inquired about insomnia symptoms over the past two weeks. Here, they also completed the PSAS to indicate general experiences of pre-sleep arousal. At this same visit, they also completed a brief diagnostic interview for DSM-IV diagnoses, including major depressive episode and generalized anxiety disorder. Participants returned to the lab at Time 2, where they completed the BSSI to indicate their experience of suicidal ideation over the past week. Although the participants completed the ISI and BSSI at two separate time points, there is overlap between participant report of past two-week insomnia symptoms at Time 1 (i.e., Day 1) and their report of past week suicidal ideation at Time 2 (i.e., Day 4). Thus, analyses in the current study are not meant to determine longitudinal mediation. Participants were compensated for their time. The study was approved by the University of Utah Institutional Review Board.

Analytic strategy

Hypothesized associations were first examined using zero-order correlations. To test the initial associations of insomnia and pre-sleep arousal with subsequent suicidal ideation, we conducted multiple regression analyses. To examine the mediating role of pre-sleep arousal, we conducted bootstrapping mediation analyses using the SPSS PROCESS Macro (Hayes, 2018). Here, 5000 samples were drawn and bootstrapping confidence intervals for point estimates were generated. Direct, indirect, and total effects were considered significant if bootstrapping confidence intervals did not include zero. We conducted two separate mediation analyses: the first used the PSAS total score as the mediating variable; the second was a multiple mediation analysis testing cognitive and somatic pre-sleep arousal as simultaneous mediating variables. In both models, insomnia was the predictor and suicidal ideation was the dependent variable. Given the degree to which depression and anxiety overlap with insomnia, arousal, and suicidal thoughts and behaviors (McCall & Black, 2013), we included the major depressive episode and generalized anxiety disorder diagnostic status as binary (i.e., diagnosis vs. non-diagnosis) covariates. Standardized beta weights are reported for effect sizes.

Results

Descriptive statistics, zero-order correlations, and initial regression analyses

Descriptive statistics and zero-order correlations are depicted in Table 2. We conducted a series of multiple regressions to establish associations between variables. First, pre-sleep arousal total score ($\beta = .57$, $t[76] = 6.15$, $p < .001$), cognitive pre-sleep arousal ($\beta = .61$, $t[76] = 6.78$, $p < .001$), and somatic pre-sleep arousal ($\beta = .41$, $t[76] = 3.93$, $p < .001$) were regressed onto insomnia symptoms, and the associations were significant. Next, suicidal ideation was regressed onto insomnia symptoms, pre-sleep arousal total score, both domains of pre-sleep arousal (cognitive and somatic) in separate analyses. Insomnia symptoms were positively associated with suicidal ideation ($\beta = .25$, $t[76] = 2.06$, $p = .04$). Pre-sleep arousal total score predicted suicidal ideation, ($\beta = .46$, $t[76] = 4.54$, $p < .001$), as did cognitive pre-sleep arousal ($\beta = .46$, $t[76] = 4.53$, $p < .001$) and somatic pre-sleep arousal ($\beta = .37$, $t[76] = 3.53$, $p = .001$). Next, we regressed suicidal ideation on insomnia symptoms and pre-sleep arousal total score simultaneously, and included major depressive episode and generalized anxiety disorder covariates, and pre-sleep arousal was significant ($\beta = .45$, $t[76] = 3.33$, $p = .001$), but insomnia symptoms were no longer significant ($\beta = -.03$, $t[76] = -.21$, $p = .83$). Neither major depressive episode ($\beta = -.04$, $t[76] = -.36$, $p = .71$) nor generalized anxiety disorder ($\beta = .09$, $t[76] = .75$, $p = .45$) were significant. In another model with both pre-sleep arousal domains included with insomnia

Table 2. Descriptive statistics and zero order correlations of study variables.

	1	2	3	4	5	6	7
1. ISI	–						
2. BSSI	.23*	–					
3. PSA-C	.61**	.46**	–				
4. PSA-S	.41**	.37**	.69**	–			
5. PSA Total	.57**	.46**	.95**	.88**	–		
6. MDE[a]	.36**	.08	.24*	.11	.21	–	
7. GAD[a]	.17	.22	.32**	.29*	.33**	.39**	–
Mean (SD)	11.82 (6.24)	5.83 (6.44)	22.58 (8.69)	13.76 (5.71)	36.33 (13.33)	.13	.25
Range	0–27	0–33	8–40	8–32	16–71	0–1	0–1
Skewness	.02 (.27)	1.79 (.72)	.13 (.27)	1.30 (.27)	.53 (.27)	2.29 (.27)	1.15 (.27)
Kurtosis	−.57 (.53)	3.82 (.54)	−.87 (.54)	1.37 (.54)	−.42 (.54)	3.33 (.53)	−.68 (.53)

Note. *$p < .05$, **$p < .01$. ISI: Insomnia Severity Index; BSSI: Beck Scale for Suicide Ideation, PSA-C: cognitive pre-sleep arousal; PSA-S: somatic pre-sleep arousal; PSA: pre-sleep arousal; MDE: major depressive episode; GAD: generalized anxiety disorder.
[a]A total of 20 participants met diagnostic criteria for GAD, and 10 participants met diagnostic criteria for MDE.

symptoms and covariates, only cognitive pre-sleep arousal significantly predicted suicidal ideation (β = .42, $t[76] = 2.43$, p = .02), whereas somatic pre-sleep arousal (β = .08, $t[76]$ = .56, p = .57), insomnia symptoms (β = −.05, $t[76]$ = −.40, p = .69), and major depressive episode (β = −.05, $t[76]$ = −.43, p = .67) and generalized anxiety disorder (β = .09, $t[76]$ = .74, p = .46) were not significant.

Mediation analyses

Model 1 (pre-sleep arousal total score as mediator)

The full model of insomnia symptoms to suicidal ideation was significant ($F[1,76] = 2.68$, $MSE = 39.35$, p = .05, R^2 = .10). Insomnia symptoms were positively related to pre-sleep arousal ($b = 1.27$, SE = .21, 95% CI [.86, 1.69]), and the path from pre-sleep arousal to suicidal ideation was positive and also significant (b = .22, SE = .07, 95% CI [.09, .35]). Insomnia symptoms had a significant total effect on suicidal ideation (b = .26, SE = .13, 95% CI [.0003, .50). There was a significant indirect effect of insomnia symptoms on suicidal ideation via pre-sleep arousal (b = .28, SE = .09, 95% CI [.11, .47]), but the direct effect was not significant, (b = −.03, SE = .14, 95% CI [−.32, .26]), indicating full mediation. See Figure 1 (Panel A).

Model 2 (multiple mediation with cognitive and somatic pre-sleep arousal)

The full model of insomnia symptoms to suicidal ideation was again significant ($F[1,76] = 2.64$, $MSE = 39.35$ p = .05, R^2 = .10). Insomnia symptoms were related to both cognitive (b = .87, SE = .13, 95% CI [.61, 1.14]) and somatic (b = .40, SE = .10, 95% CI [.20, .60]) pre-sleep arousal. The path from cognitive pre-sleep arousal to suicidal ideation was also significant (b = .31, SE = .15, 95% CI [.06, .57]), but not the somatic pre-sleep arousal to suicidal ideation path (b = .09, SE = .17, 95% CI [−.24, .43]). Insomnia symptoms had a significant total effect on suicidal ideation (b = .25, SE = .13, 95% CI [.00003, .5]). There was also a significant indirect effect for cognitive pre-sleep arousal on suicidal ideation (b = .27, SE = .16, 95% CI [.01, .63]), but not for somatic pre-sleep arousal (b = .04, SE = .08, 95% CI [−.11, .19]). The direct effect for insomnia symptoms on suicidal ideation was not significant (b = −.06, SE = .15, 95% CI [−.35, .24]), indicating full mediation for cognitive pre-sleep arousal. See Figure 1 (Panel B).

Discussion

The present research represents a preliminary investigation on the extent to which pre-sleep arousal, including its cognitive and somatic domains, contributes to the association of insomnia symptoms with risk for suicide. Pre-sleep arousal has long been considered to be a significant feature of the development and maintenance of psychophysiological insomnia in several clinical populations (e.g., Werner et al., 2020). What is less clear is the extent that pre-sleep arousal explains the association of insomnia symptoms with risk for suicide.

Consistent with hypotheses, insomnia symptoms were significantly associated with suicidal ideation reported, and pre-sleep arousal was also predictive of suicidal ideation. The former result confirms the well-documented finding that those who struggle with suicidal thoughts and behaviors also tend to struggle with sleep (see Bernert et al., 2015 for review). The latter result from the present study supports a small but growing body of research indicating an association between pre-sleep arousal and suicide risk. For example, cognitive pre-sleep arousal in the form of rumination relates to depression and suicidal ideation among pregnant women (Kalmbach et al., 2021) and suicide-specific rumination is generally associated with

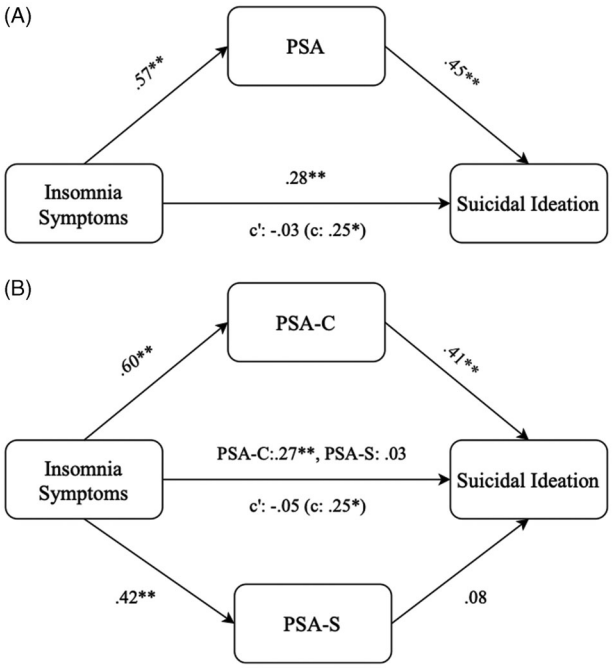

Figure 1. Mediation analyses examining the indirect association (ab) between insomnia symptoms and suicidal ideation via pre-sleep arousal. Standard regression weights are reported to demonstrate the effect of insomnia symptoms on pre-sleep arousal (a), effect of pre-sleep arousal on suicidal ideation (b), the direct effect of insomnia symptoms on suicidal ideation (c') and the total effect of the mediation model (c). Results suggest full mediation of pre-sleep arousal total score on the effect of insomnia symptoms on suicidal ideation (Panel A), but when the two domains are examined simultaneously, only cognitive pre-sleep arousal fully mediates the insomnia symptoms-suicidal ideation link (Panel B). *Note.* $^{*}p < .05$, $^{**}p < .01$. PSA: pre-sleep arousal; PSA-C: cognitive pre-sleep arousal; PSA-S: somatic pre-sleep arousal.

increased risk for suicidal thoughts and behaviors (Rogers & Joiner, 2017). Although less research has examined pre-sleep suicide rumination and its association with suicide risk, at least one study found that pre-sleep thoughts of defeat and entrapment prospectively predicts next-day in suicidal ideation (Littlewood et al., 2019). Moreover, psychophysiological hyperarousal during sleep may be a potential biomarker of suicide risk (Dolsen et al., 2017). Hence, overall, it is not surprising that cognitive and somatic pre-sleep arousal in our sample were predictive of suicidal thoughts and behaviors. Additional research should leverage advances in technology and conduct more ambulatory and ecological momentary assessment studies to generate a more nuanced understanding of pre-sleep arousal in everyday life among those at risk for suicide.

Our results further demonstrated that the association between insomnia and suicidal ideation was mediated by pre-sleep arousal, but this was only true for the cognitive type. Somatic pre-sleep arousal did not significantly mediate the insomnia-suicidal thoughts and behaviors association. These results are partially in line with our hypotheses, and with previous research studies as well. For instance, pre-sleep arousal is heightened in conditions that have been independently linked with suicide risk, including post-traumatic stress disorder (Werner et al., 2020) and personality pathology (Grove et al., 2017). Moreover, at least one cross-sectional study has demonstrated that rumination, a common feature of cognitive pre-sleep arousal, contributed to the association of suicidality with poor sleep quality among young adults (Weis et al., 2015). This study especially supports our findings indicating that cognitive pre-sleep arousal may be the aspect of pre-sleep arousal most important in suicidal thoughts and behaviors. However, other research has indicated that somatic pre-sleep arousal is not only a key marker of insomnia more broadly, but if directly targeted with biofeedback, can reduce depression symptoms among those with co-occurring major depressive disorder and insomnia (Lin et al., 2019). Hence, more clinical research utilizing multiple methods of assessment is necessary to further clarify the role of somatic pre-sleep arousal in individuals with co-occurring suicidal thoughts and behaviors and insomnia symptoms.

The present study had a number of limitations. The self-report measures introduce the risk of method bias in our results. The relatively small and nonrepresentative sample warrants caution regarding the generalizability of our results. The present study was slightly underpowered to detect indirect effects (see Schoemann et al., 2017). There was also overlap in timepoints between reported insomnia symptoms and suicidal ideation. This, coupled with the study's low sample size, precludes our ability to make conclusions about longitudinal mediation. Additional research is necessary to determine if the associations found in the present study remain significant above and beyond other factors related to insomnia, arousal, and suicide. Finally, we only measured suicidal ideation as our suicide outcome variable. Although suicidal ideation is highly predictive of suicidal behavior and death, the vast majority of those who think about suicide will not attempt suicide (May & Klonsky, 2016). Thus, the extent that pre-sleep arousal mediates the association between insomnia and suicidal behavior requires additional research. Overall, a multi-method prospective study investigating suicidal ideation *and* behavior with

a larger sample would improve our understanding of these issues.

The above notwithstanding, this line of research could have important clinical implications. For instance, if future research replicates and extends our findings, and cognitive pre-sleep arousal is indeed particularly relevant to those at high risk for suicide, then behavioral sleep interventions for these individuals might be more effective with a strong focus on cognitive pre-sleep arousal. Maximizing the effectiveness of insomnia treatments for at-risk individuals should be a priority in research and clinical settings, as cognitive behavioral therapy and other sleep interventions have been shown to reduce risk for suicide by way of improving sleep (Trockel et al., 2015). Future research should also further examine the content of cognitive pre-sleep arousal for those with co-occurring suicidal thoughts and behaviors. Those who frequently experience daytime suicidal thoughts may also have suicidal thoughts prior to bedtime (see Littlewood et al., 2019), and the middle of the night may be a particularly risky period for the emergence of suicidal thoughts and behaviors (Perlis et al., 2016). Future research should determine if targeting suicide-specific cognitive pre-sleep arousal in those with co-occurring insomnia and suicidal thoughts and behaviors is especially indicated.

Disclosure statement

All authors declare that they have no conflicts of interest.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, JLG, upon reasonable request.

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