Actigraphy-Measured Sleep/Wake Characteristics Associated With Suicidal Ideation in Older Adults Who Have Depression and High Suicide Risk

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Abstract

Objective: The aim of this study was to identify sleep/wake characteristics associated with suicidal ideation (SI) severity among older adults who are at risk for suicide.

Methods: This 6-week observational study examined associations between weekly actigraphy-derived sleep/wake measures and SI severity (Beck Scale for Suicidal Ideation [SSI]). The sample (n = 30; 83% female; average age = 62 years), enrolled April 2021 through March 2023, self-reported a physician diagnosis of *DSM-5* major depressive disorder with an episode in the last 6 months and also had either recent active SI or a past suicide attempt. Weekly sleep/wake measures included sleep duration, fragmentation, and 2 rhythm variables (interdaily stability and relative amplitude). Primary analyses used age- and sex-adjusted repeated-measure linear mixed models, 1 model per sleep/wake variable, to assess associations between weekly sleep/wake and SI reported at week's end. We examined if associations of sleep/wake factors with SI were independent of depression severity (Patient Health Questionnaire-8 scores).

Results: Longer sleep duration, greater interdaily stability, and higher relative amplitude were associated with lower SI (eg, for each standard deviation higher interdaily stability, SSI scores were an estimated 1.4 points lower [$P = .005$]). After adjusting for depression severity, both sleep/wake rhythm variables remained significantly associated with SI, whereas the association between sleep duration and SI severity was attenuated by >80%.

Conclusion: In this sample, sleep/wake rhythm disruption (but not sleep duration or fragmentation) related to SI independent of depression severity. Targeting disruptions in sleep/wake rhythms may be an important avenue for future trials of sleep medicine approaches to reduce SI in older adults.

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Depression and suicidal ideation (SI) in older adults are major clinical and public health problems. Depression is associated with worse chronic disease outcomes[1–5] and is a world leading cause of disability.[6,7] Both depression symptoms and SI are associated with the risk of making a suicide attempt.[8–10] The number of older adults is expected to double globally by 2050 (World Health Organization), and in the United States, a third of all completed suicides occur in adults who are 55 years of age and older (Centers for Disease Control and Prevention).

Sleep/wake disturbances may increase the risk of suicide in older adults by exacerbating depression symptoms and SI. Prior reviews [11–17] and meta-analyses [18–21] have linked various sleep/wake characteristics with measures of suicidality, including poor sleep quality,[22,23] insomnia,[24,25] hypersomnia,[26] sleep duration,[27] nighttime wakefulness,[28,29] and sleep/wake rhythm disruption.[30–33] However, as suggested in recent reviews,[17,20,21] the field has yet to establish which objective, actigraphy-based, sleep/wake measures are most relevant to suicidality in key at-risk groups. Actigraphy measures are objective and relatively easy to obtain, and the sleep/wake behaviors measured by actigraphy are potentially modifiable. As such, actigraphy could potentially be useful to monitor sleep-wake risk factors for suicide and to identify sleep/wake targets for suicide prevention efforts.

Prior studies examining relationships between objective actigraphy-derived sleep/wake characteristics and measures of suicidality have been conducted in

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Clinical Points

- Actigraphy-derived measures of 24-hour sleep/wake disruption have been linked with suicidal ideation in younger and middle aged adults. But little information exists on which objectively measured sleep/wake factors are associated with suicidal ideation in older adults who are at high risk for suicide.
- Actigraphy-derived sleep/wake measures that are associated with suicidal ideation in older adults at high risk could be developed into an objective risk factor measure and also may provide a novel treatment target.
- Measures of sleep/wake rhythm disruption were independently associated with higher level of suicidal ideation in this sample of high-risk older adults. Disrupted 24-hour sleep/wake rhythms may signal that suicide risk is high. Future trials are needed to establish whether treating disrupted sleep/wake rhythms reduces suicide risk.

young[30,34,35] and middle-aged[31–33,36,37] individuals. Aronen et al[34] found that children with depression and SI had lower actigraphy-assessed activity levels compared with both children who had depression and no SI and with children without depression. In young adults with a past suicide attempt and recent SI, Bernert et al[30] found that actigraphy measures of irregular sleep-wake rhythms correlated more strongly with weekly SI than measures of sleep duration. Consistent with studies on nighttime wakefulness and suicidality in adults,[28,29] Kivelä et al[35] found in young adults that actigraphy-measured sleep fragmentation was related to higher next day SI.

In actigraphy studies of suicidality in middle-aged adults, Verkes et al[31] reported that sleep/wake rhythm loss was associated with SI. Benard et al[36] found that earlier activity onset was associated with having made a prior suicide attempt. Indic et al[32] reported that weakened sleep/wake rhythm amplitude was associated with passive death wish. Rumble et al[37] reported that lower activity amplitude was associated with worse SI. Salvatore et al[33] reported that measures of sleep/wake rhythm loss were associated with passive SI. Collectively, prior studies found that actigraphy measures of 24-hour sleep/wake disruption relate to measures of suicidality in younger and middle-aged adults.

The overarching goal of this study was to generate information on which sleep/wake characteristics were most strongly related to SI severity in older adults with depression and high suicide risk. Prior evidence suggests that, in older adults, regular 24-hour sleep/wake rhythms may be particularly important to mood. Above and beyond sleep measures, prospective observational studies have shown that 24-hour sleep/wake rhythm measures are related to a worse course of depression symptoms over time.[38,39] A recent study found that, when compared with than measures of sleep, irregular sleep/wake rhythms were more strongly related to depression in older adults.[40]

The primary aim of this study was to compare effect sizes of associations between actigraphy sleep/wake measures and SI severity in older adults who had elevated suicide risk by virtue of having an MDD diagnosis plus a past suicide attempt and/or current active SI. We conducted a 6-week prospective observational study. Analyses examined how weekly actigraphy sleep/wake variables related to SI severity assessed at each week's end. Sleep/wake measures included sleep duration, sleep fragmentation, and commonly used measures of sleep/wake rhythm stability (interdaily stability) and strength (relative amplitude). Secondarily, we evaluated if any relationships between sleep/wake factors and SI are attributable to worse depression, and we also evaluated (*a*) if there were also associations between these sleep/wake factors and depression severity and (*b*) if any associations between sleep/wake factors and SI were attenuated when adding depression severity as a covariate.

METHODS

Design

This was a longitudinal observational study with the primary repeated measures being sleep-wake patterns (via actigraphy) and mood/SI (via self-report). The protocol was approved by the University of Pittsburgh Institutional Review Board (identifier: STUDY20010226). All participants provided written informed consent prior to beginning study procedures. Assessment time points included a baseline study visit, 5 telephone assessments 1 week apart, and a follow-up study visit approximately 6 weeks after baseline. In the 6 weeks between the baseline visit and the follow-up visit, participants were asked to wear the actigraph device at all times except when bathing or during watersports. This timeframe was chosen to balance feasibility (eg, participant burden wearing the device/completing weekly calls) while allowing time to observe potential fluctuations in sleep/wake and SI measures. Participants received monetary compensation for completing the study protocol.

Recruitment and Eligibility Criteria

To identify participants, we used 3 approaches: (1) we reviewed medical records of relevant Western Psychiatric Hospital units and asked patient care team members to determine if potentially eligible participants were interested; (2) study team members from prior studies asked current/prior participants if they were interested; and (3) we posted fliers in community organizations and libraries. From these sources, we identified and screened 124 individuals for eligibility. After we explained the study purposes and procedures, we obtained verbal

consent to complete a screener interview determining eligibility.

Inclusion criteria were as follows: (*a*) age 45+ years old; (*b*) diagnosis from a physician of *DSM-5* major depressive disorder without psychotic features; (*c*) self-reported episode of depression lasting 2 weeks or more in the last 6 months; (*d*) either a current active, moderate-to-strong, SI (assessed using item 4 from the Beck Scale for Suicidal Ideation [SSI]) or any past suicide attempt; and (*e*) being willing and able to complete the study procedures. Exclusion criteria were as follows: (*a*) undergoing active behavioral treatment for insomnia; (*b*) active transcranial magnetic stimulation treatment; (*c*) having probable dementia; (*d*) active, moderate-to-severe, substance use disorder within the last 6 months; and (*e*) a diagnosis from a physician of *DSM-5* bipolar disorder. Of the 124 participants screened, 70 screened ineligible, 22 refused, and 32 consented/enrolled in the study. One participant did not complete the protocol due to being rehospitalized for suicide risk at the baseline study visit. The actigraphy device completely failed for 1 participant, rendering an analytic sample of 30 individuals.

Depression and Suicidal Ideation Measures

The primary outcome, SI, was measured as the total Beck SSI score (potential range: 0–38).[41] Depression symptom severity was assessed with the Patient Health Questionnaire-9 (PHQ-9).[42] To measure depression severity exclusive of SI severity, we utilized PHQ-8 scores in this analysis (ie, we exclude the SI item from the depression severity total score; range: 0–24). As these mental health measures were repeated on a weekly basis, we modified the scales so that the timeframe reflected the prior week. Based on our aims, the main analysis focused on the 6 SI/depression measures taken at the end of each actigraphy recording week (ie, from the 5 weekly calls and 1 follow-up). To describe the sample, we also report baseline levels of SI severity and the percentage of participants who had a prior suicide attempt (Table 1). Data completeness for these mental health measures was very high (179/180 expected measures were completed).

Given that the sample is at high risk for suicide, a detailed participant safety protocol was in place. The study psychiatrist overseeing the safety protocol was immediately contacted whenever there was escalation of SI toward suicidal behaviors defined as the incidence of (1) active suicide planning; (2) self-injurious behavior/suicide attempt; or (3) hospitalization for suicide-related mental health treatment. Of the 30 individuals in the analytic sample, 7 met at least 1 of these criteria during the 6-week study period. We analyzed these escalations to suicidal behavior during the 6-week study period, hereafter referred to as "escalation," as an additional exploratory outcome.

Table 1.
Initial Sample Characteristics (n = 30)

Characteristic	Value
Age, mean (SD), y	62 (8)
Female sex, n (%)	25 (83)
White race, n (%)	25 (83)
Prior suicide attempt, n (%)	21 (70)
Baseline Scale for Suicidal Ideation total score, mean (SD)	9 (7)
Baseline Scale for Suicidal Ideation ≥3, n (%)	23 (77)
Patient Health Questionnaire (9-item) total score, mean (SD)	15 (7)
Patient Health Questionnaire (8-item) total score, mean (SD)	13 (6)
Insomnia Severity Index total score, mean (SD)	14 (6)
Interdaily stability, mean (SD)[a]	0.17 (0.08)
Relative amplitude, mean (SD)[a]	0.77 (0.15)
Sleep duration in hours, mean (SD)[a]	6.8 (1.4)
Minutes awake after sleep onset, mean (SD)[a]	54 (26)

[a]Objective actigraphy sleep/wake measures shown in this table are from the first recording week (between the baseline visit and first weekly call).

Sleep/Wake Measures

At baseline, but not on a weekly basis, we measured self-reported insomnia symptom severity as total scores on the Insomnia Severity Index (ISI).[43]

Participants wore Philips Spectrum Plus (Philips Respironics, Bend, Oregon, US) actigraphy device on their nondominant wrist. Data were recorded in 30-second epochs. We extracted weekly values of the sleep/wake measures as described below. Each week included up to 7 days ending on the day that the weekly SI/depression measures were taken. For 24-hour sleep/wake measures, weekly data were considered adequate if there were at least 3 continuous days of valid wear. Consistent with National Sleep Research Resource data processing standards (see Dean et al[44] and associated website), valid wear days were defined as those with no more than 4 hours of nonwear time or any nonwear time during the main sleep period. Of the 179 weekly mental health measures, 146 (81%) had actigraphy data that passed quality control standards and produced usable measures on all sleep/wake measures.

For each week, we selected 4 main objective sleep/wake measures a priori: (1) interdaily stability, calculated using custom R code, measuring the consistency of circadian sleep-wake activity rhythms across days (with lower values indicating less stable, more irregular, daily rhythms); and (2) relative amplitude, measuring the standardized peak-trough difference of 24-hour activity rhythms, with lower values indicating weaker or dampened rhythms; (3) weekly sleep duration, assessed by first manually verifying/editing the resting intervals using any observed event markers, light data, and activity data (similar to[45] except without diary); then applying an automated sleep scoring algorithm in Philips Actiware Software (Version 6) using a medium sensitivity threshold of 40 activity counts per epoch; and (4) sleep fragmentation measured as the number of minutes (within the main sleep period) awake after sleep onset (wake after sleep onset [WASO]). We calculated

interdaily stability following previously published technical definitions[46,47] and specifically using the entire time series (ie, not subsampling to hourly activity levels).

Statistical Analyses

To compare association effect sizes including insomnia severity, which was measured at baseline (not weekly), we used linear regression to compute age/sex adjusted effect sizes for the associations of baseline/initial sleep/wake measures with baseline SI severity. The main analysis used separate repeated-measure linear mixed effects models to evaluate associations of each objective sleep/wake measure with weekly SI severity as the outcome variable. These models were implemented using the *lme* function in R Software (R Foundation for Statistical Computing, Vienna, Austria). We used a first-order autoregressive correlation matrix to account for repeated measures within subjects. Each model included fixed effects for 1 of the sleep/wake variables, time (expressed as study week), as well as the covariates age and sex. Missing data were excluded (not imputed; see tables for numbers of observations). To standardize and facilitate effect size comparisons, independent variables were rescaled to a mean of zero and standard deviation of 1 prior to analysis. To address our secondary aims, we (*a*) repeated the above-described mixed models except using depression severity (PHQ-8 scores) as the outcome and then (*b*) repeated the mixed models above modeling SI as the outcome but now including depression severity as an additional covariate.

Finally, we compared initial sleep/wake variables between participants with and without escalation during the study period. Due to the low absolute number of cases with escalation (7 of 30 total participants), we considered these analyses post hoc and exploratory. As such, we focused on Cohen *d* effect sizes and present 95% CIs rather than measures of statistical significance.

RESULTS

Sample Characteristics

Participants were an average of 62 years old, and 83% were female (Table 1). At baseline, 77% (n = 23) of participants had SI severity in the clinically significant range (SSI scores ≥3[48]), and 70% (n = 21) had made a prior suicide attempt (n = 21). Depression severity was moderate on average (ie, PHQ-9 scores ≥10[49]), and on average, the sample had mild-to-moderate insomnia symptoms (ISI scores ~14[50]).

Correlations of Baseline Sleep/Wake and Mental Health Measures

Higher levels of interdaily stability and relative amplitude were associated with lower levels of baseline SI, and these relationships were independent of depression severity (Table 2). Effect sizes for the associations of these sleep/wake rhythm variables with SI were similar in exploratory analyses conducted in subgroups with/without a past attempt (Supplementary Table 1). For each standard deviation better sleep/wake rhythm measure, SI severity was 2–3 points lower on average. When examining only baseline data, we found no statistically significant associations of insomnia severity, sleep duration, or WASO with SI severity.

Table 2.
Associations Between Initial Sleep/Wake Factors and Baseline Suicidal Ideation Severity (n=30)[a]

	Not adjusting for depression severity		Adjusting for depression severity	
	β (SE)	*P* value	β (SE)	*P* value
Insomnia Severity Index total score	2.0 (1.1)	.09	−0.33 (1.5)	.83
Interdaily stability[b]	−2.5 (1.0)	.02	−2.0 (0.9)	.04
Relative amplitude[b]	−3.2 (0.9)	.002	−2.6 (0.9)	.009
Sleep duration[b]	0.1 (1.1)	.94	0.33 (1.0)	.74
Wake after sleep onset[b]	1.7 (1.1)	.14	1.2 (1.0)	.22

[a]All regression coefficients were derived from separate linear regression models adjusted for age and sex.
[b]Objective actigraphy sleep/wake measures shown in this table are from the first recording week (between the baseline visit and first weekly call).

Associations of Repeated Sleep/Wake and Mental Health Measures

When weekly data were examined, greater interdaily stability, higher relative amplitude, and longer total sleep time were all associated with lower depression severity (Supplementary Table 2). There was no association of WASO with depression severity.

There were robust statistical associations between the measures of 24-hour sleep/wake rhythms (interdaily stability and relative amplitude) with weekly SI levels (left columns in Table 3). There was also a statistically significant association of longer total sleep time with lower SI severity. Again, there was no association of WASO with SI levels.

Given these findings, we constructed 2 more models including the same covariates as prior models plus (1) interdaily stability and sleep duration or (2) relative amplitude and sleep duration. In both models, the sleep/wake rhythm variables remained highly statistically associated SI, whereas the association of sleep duration with SI was attenuated and no longer statistically significant. We do not report results from a model including both rhythm variables as they are highly colinear (Pearson rho = 0.8; see Supplementary Table 3).

Associations of Sleep/Wake Factors With Repeated Suicidal Ideation Measures Adjusting for Depression Severity

After adjusting for depression severity, the association of sleep duration with SI severity was

Table 3.

Associations Between Sleep/Wake Measures With Weekly Suicidal Ideation Severity Measured With the SSI (n = 30)[a]

	Not adjusting for depression severity		Adjusting for depression severity	
	β (SE)	*P* value	β (SE)	*P* value
Interdaily stability	−1.4 (0.5)	.005	−0.9 (0.4)	.048
Relative amplitude	−1.5 (0.4)	.0004	−0.9 (0.4)	.02
Sleep duration	−1.2 (0.6)	.04	−0.2 (0.4)	.58
Wake after sleep onset	−0.2 (0.5)	.69	−0.2 (0.4)	.60

[a]All regression coefficients were derived from separate repeated-measure mixed effects models adjusted for age, sex, and week in study. Sleep/wake measures reflect the week prior to the suicidal ideation measure. The number of observations range from 146 to 149 due to differences in missingness across the sleep/wake variable.

attenuated by 83% and was no longer statistically significant (right columns in Table 3). Associations between these 24-hour sleep/wake rhythm measures and SI severity were attenuated by 36%–40% and retained statistical significance after adjusting for depression severity.

To illustrate the relative loss of sleep/wake rhythms observed in some participants, we show weeks of actigraphy data from participants with/without sleep/wake rhythm disruption and high SI severity (Figure 1).

Exploratory Analysis of Suicidal Escalation

Cohen *d* effect sizes for the association between sleep/wake variables and escalation were small-to-medium (Table 4). The exception was that relative amplitude had a large effect size. Participants who experienced escalation during the study period tended to have lower relative amplitude at baseline (indicating weak 24-hour rhythms).

DISCUSSION

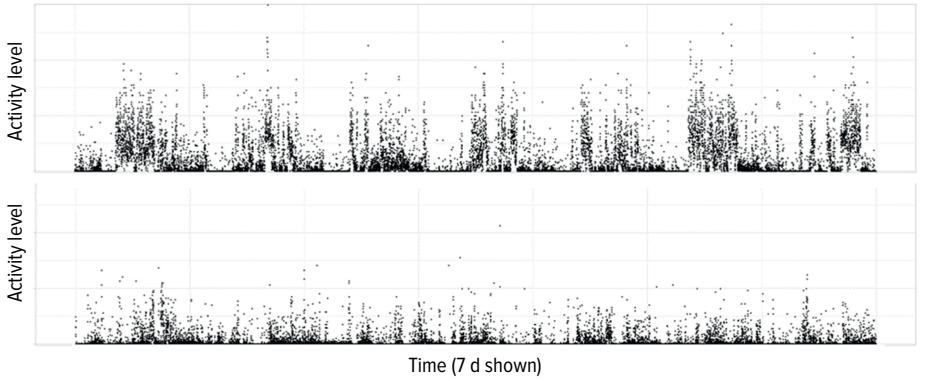
Our findings add to existing observational evidence highlighting associations between sleep/wake rhythm disruption with both depression[40,51–53] and suicidality (as reviewed in Rumble et al[17]). The present work adds to prior literature by demonstrating robust associations of sleep/wake rhythm disruption measures with SI that are independent of depression severity, specifically in older adults who have depression and high suicide risk. We also found evidence in this sample that longer sleep duration was associated with lower SI severity, but that this relationship was attenuated and no longer statistically significant after adjusting for either sleep/wake rhythm measure or depression severity. Altogether, these findings suggest that (*a*) relationships between short sleep duration and worse SI may be due to depression and (*b*) sleep/wake rhythm disruption may be a uniquely important target for future clinical trials that aim to reduce both depression and SI.

Future clinical trials will be necessary to move beyond observing links between sleep/wake factors and suicidality measures (as done here), toward establishing whether interventions for sleep/wake disruption help to reduce SI and ultimately prevent suicide. Prior studies intervening on sleep to influence mood outcomes have mostly focused on treating insomnia using Cognitive Behavioral Therapy for Insomnia (CBT-I). Two pre-/post-studies found that SI levels decrease following CBT-I.[54,55] One small controlled trial of CBT-I in people with insomnia plus SI observed large treatment effects on depression but only small effects on SI.[56] One large-scale trial treating insomnia pharmacologically found mixed evidence for effects on SI (ie, treatment effects on 1 of 2 SI outcome measures).[57] The novel findings presented here suggest that sleep/circadian interventions which target rhythm disruption (rather focusing on insomnia alone) may be promising candidates for future trials that aim to reduce SI in older adults.

Strengths of our study include selecting a sample of older adults who are known to be at high risk for suicide; comparing standardized effect sizes relating self-reported insomnia severity, nighttime sleep, and rhythm variables with SI; using repeated, objective, standard, actigraphy measures in the main analysis; and a robust modeling strategy leveraging the available continuously measured, standard, psychopathology severity measures.

Several limitations to this study should also be noted. This was an observational study subject to unmeasured confounding, and we are unable to determine whether/what causal relationships exist between sleep/wake rhythm disruption, depression, and SI. Due to the sample being small and selected, our findings may not necessarily generalize to groups that are not well represented here, including men, younger adults, and the "oldest-old." The small sample also precludes inferences disentangling the roles of current and prior sleep/wake factors, mental health symptoms, medical comorbidity, and medication usage as they relate to the course of SI. There is the risk of false-negative findings due to the small sample size. The lack of diary measures could have increased measurement error in our WASO calculation, and, combined with the small sample size, the lack of association between WASO and SI in this older adult sample should be taken with caution and confirmed in future studies; there may also be relationships between WASO and SI that occur on different time scales (such as day-to-day). When examining the relationship between baseline sleep/wake factors and categorically defined escalation, all 95% CIs overlapped with zero. This indicates that, in analyzing this clinically meaningful secondary outcome, we could not assign statistical

Figure 1.
Example Weeks of Actigraphy Data From 2 Participants[a]



[a]The top participant had relatively higher sleep/wake rhythm stability and strength measures and had lower suicidal ideation severity on average throughout the study (average Scale for Suicidal Ideation [SSI] score = 1). In contrast, the bottom participant had relatively lower sleep/wake rhythm stability and strength and higher suicidal ideation severity (average SSI score = 18).

Table 4.
Effect Sizes of Associations Between Baseline Sleep/Wake Factors and Suicidal Escalation During the Study Period[a]

	Cohen *d* (95% CI)
Insomnia Severity Index total score	0.3 (−0.7 to 1.2)
Interdaily stability[b]	−0.5 (−1.4 to 0.4)
Relative amplitude[b]	−0.8 (−1.8 to 0.1)
Sleep duration[b]	−0.5 (−1.4 to 0.4)
Wake after sleep onset[b]	0.5 (−0.3 to 1.4)

[a]Positive values indicate that the sleep/wake variable was higher in the people with escalation. Negative values indicate that the sleep/wake variable was lower in people with escalation.
[b]Objective actigraphy sleep/wake measures shown in this table are from the first recording week (between the baseline visit and first weekly call).

significance to medium/large effect size point estimates. Small subgroup sample sizes prevent definitive conclusions regarding potential differences in the sleep-wake factors that are associated with urgent/imminent suicide risk (eg, severe active ideation/planning) vs sleep-wake characteristics that may be associated with more historical suicide risk markers (eg, having made a past attempt).

Our study is also unable to clarify which mechanism(s) link sleep/wake rhythm disruption with SI. Prior studies implicate immune system dysregulation[58,59] as well as cognitive and affective factors[60] as possible mechanisms underlying suicidality. It is possible that disrupted sleep/wake rhythms are associated with SI in older adults via these pathways. In older adults, sleep/wake rhythms have also been related to heighten pro-inflammatory markers[61] and cognitive impairment.[62] Effects of sleep/wake rhythm disruption on affective function are also plausible, especially given controlled experiments which demonstrate that disrupting normal 24-hour rhythms can influence mood; ie, simulated shift work (an extreme 12-hour shift in timing) worsens mood/well-being,[63] and sleeping at atypical circadian phases reduces positive affect and increases hostility.[64] Future studies will be needed to determine why sleep-wake rhythm disruption occurs, how it relates to suicidality, and on what timescale these factors interrelate (including possible day-to-day changes).

In conclusion, this report demonstrates that measures of sleep/wake rhythm disruption are associated with SI independent of depression severity among older adults who are at high risk for suicide. These findings raise questions regarding what mechanisms underlies these associations. Furthermore, these findings raise the question of whether interventions addressing sleep/wake rhythm disruption will reduce SI in older adults at high suicide risk. For example, preliminary evidence from a sample of older adults indicates that the Transdiagnostic Intervention for Sleep and Circadian Disruption[65] may improve rhythm stability and increase rates of sustained depression symptom responses.[66] This approach aims to stabilize rhythms behaviorally through a combination of sleep/wake scheduling, increasing daytime functioning, and improving nighttime sleep. However, large-scale clinical trials are needed to (*a*) confirm the efficacy of such approaches in older adults who have depression and high suicide risk (eg, efficacy for improving mood, reducing SI, and preventing suicide); (*b*) determine if changes in the sleep/wake rhythm targets identified here mediate the clinical efficacy of such approaches; (*c*) characterize the underlying mechanisms; and (*d*) determine for whom these approaches work.

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Supplementary Material

Article Title: Actigraphy-Measured Sleep/Wake Characteristics Associated With Suicidal Ideation in Older Adults Who Have Depression and High Suicide Risk

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LIST OF SUPPLEMENTARY MATERIAL FOR THE ARTICLE

DISCLAIMER

Supplementary Table 1. Associations between initial sleep/wake factors and baseline suicidal ideation severity in the overall sample and subgroups with and without a prior suicide attempt

	Overall sample (n=30)		**Subgroup with a prior suicide attempt (n=21)**		**Subgroup without a prior suicide attempt (n=9)**	
	β (standard error)	p-value	β (standard error)	p-value	β (standard error)	p-value
Insomnia Severity Index total score	-0.3 (1.5)	0.83	2.1 (1.8)	0.26	-4.7 (4.0)	0.31
Inter-daily stability[a]	-2.0 (0.9)	0.04	-1.9 (1.1)	0.09	-2.7 (2.4)	0.04
Relative amplitude[a]	-2.6 (0.9)	0.009	-2.8 (1.0)	0.02	-2.1 (2.3)	0.42
Sleep duration[a]	0.3 (1.0)	0.74	0.4 (1.2)	0.73	0.7 (2.9)	0.83
Wake after sleep onset[a]	1.2 (1.0)	0.22	2.0 (1.2)	0.10	-2.4 (2.0)	0.30

All regression coefficients were derived from separate linear regression models adjusted for age, sex, and depression severity. [a]Objective actigraphy sleep/wake measures shown in this table are from the first recording week (between the baseline visit and first weekly call)

Supplementary Table 2. Associations between sleep/wake measures with weekly depression severity measured with the PHQ-8

	β (standard error)	p-value
Inter-daily stability	-1.0 (0.5)	0.03
Relative amplitude	-1.0 (0.4)	0.009
Sleep duration	-1.2 (0.5)	0.02
Wake after sleep onset	-0.2 (0.4)	0.21

Regression coefficients were derived from separate mixed effects models adjusted for age, sex, and week in study. Sleep/wake measures reflect the week prior to the depression severity measure. The number of observations range from 146-149 due to differences in sleep/wake variable missingness.

Supplementary Table 3. Partial, age/sex adjusted, Pearson correlations between the initial sleep/wake variables

	Insomnia Severity Index total score		Inter-daily stability		Relative amplitude		Sleep duration		Wake after sleep onset	
	Pearson r	p-value	Pearson r	p-value	Pearson r	p-value	Pearson r	p-value	Pearson r	p-value
Insomnia Severity Index	1.00		-0.21	0.28	-0.40	0.03	-0.24	0.22	0.33	0.09
Inter-daily stability	-0.21	0.28	1.00		**0.80**	**<.0001**	-0.04	0.83	-0.33	0.09
Relative amplitude	-0.40	0.03	**0.80**	**<.0001**	1.00		0.24	0.23	**-0.55**	**0.003**
Sleep duration	-0.24	0.22	-0.04	0.83	0.24	0.23	1.00		-0.36	0.06
Wake after sleep onset	0.33	0.09	-0.33	0.09	-0.55	**0.003**	-0.36	0.06	1.00	