Loneliness and sleep in everyday life: Using ecological momentary assessment to characterize the shape of daily loneliness experience

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A B S T R A C T

Background: Loneliness has been linked to an increased risk of sleep problems. Past research has largely relied on trait loneliness or daily recall loneliness when evaluating associations with sleep. Objective: The present study extended this work by evaluating the patterns of loneliness throughout the day, including a daily average of all reports, a maximum value, and daily variation. These loneliness patterns predicted daily subjective and objective sleep measures to evaluate whether they provide unique insight to this relationship. Methods: Undergraduate students (n = 71; 77% female; age 18-28) completed 2 weeks of electronic surveys 4 times a day to assess loneliness. Each morning participants completed a diary of their prior night’s sleep quality, as well as wore actigraphy devices to objectively assess sleep parameters. A total of 778 momentary surveys and 565 days of actigraphy-assessed sleep data were collected. Multilevel models tested whether within-person daily aggregates of loneliness were associated with within-person daily sleep outcome variables. Results: Subjective sleep duration, quality, and fatigue were significantly predicted by daily average loneliness. Subjective sleep latency, quality, and fatigue were significantly predicted by daily max loneliness. Only fatigue was significantly predicted by daily loneliness variability. No objective sleep measures were significantly predicted by daily loneliness measures. Conclusions: Patterns of daily loneliness focusing on central tendency (average) or intensity (max) were more consistently associated with subjective (but not objective) assessments of sleep than variability.

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Introduction

Loneliness is a mismatch between a person’s desired and actual social connections,1 and has been linked to physical and mental health problems,2 including increased risk of sleep problems.3-5 A recent meta-analysis evaluated 110 samples from cross-sectional and longitudinal research on loneliness and sleep and found a significant association between loneliness and insomnia, nightmares, poor sleep efficiency, and poor sleep quality.6 When studying loneliness and sleep it is typical to use trait assessments or end-of-day reports, assuming those who report more loneliness are also those prone to worse sleep. Yet, the shape of how loneliness is experienced across a day may be critical for informing interventions on when and how to target loneliness to improve sleep. For example, one’s subjective experience is likely to be quite different if a person vacillates between extreme lonely and nonlonely moments compared to having a relatively stable level of loneliness throughout the day. Thus, the purpose of this paper is to examine the association between loneliness measured repeatedly throughout the day and sleep that night. We consider three different operationalizations of daily loneliness – average levels across assessments, maximum daily scores, and variability across assessments, testing associations with various dimensions of subjectively and objectively measured sleep.

Measuring loneliness

The evidence we have for the relationship between loneliness and sleep comes almost entirely from trait assessments of loneliness, most
commonly using the UCLA Loneliness Scale. This approach classifies one as a lonely person or someone prone to loneliness based on a one-time retrospective assessment. As a (complementary) alternative to a trait perspective, loneliness can be viewed as a situational, or momentary, reaction within an individual’s immediate environment, and thus varies from one moment to day to the next. Indeed, research indicates high moment-to-moment variability across a day in how lonely one reports feeling, and there are factors outside of social relationships that may influence loneliness. For example, studies have found different levels of loneliness on weekdays vs. weekend days, and whether one appraises their social company as intimate vs. non-intimate, and positive vs. negative. This research indicates several ways in which loneliness can change from moment to moment over the course of a day, yet it remains unclear how these patterns of loneliness across a day are related to sleep.

Measuring loneliness across the day

While the majority of past research has utilized trait loneliness, some have evaluated loneliness using daily diaries in which participants reported on their perceptions of their day right before going to bed. Findings showed daily loneliness predicted greater daytime dysfunction regardless of the participant’s self-reported sleep duration, and participants who reported higher loneliness for a given day compared to their weekly average showed higher wake after sleep onset the subsequent night. Although end-of-day diaries measure how loneliness changes from 1 day to the next, they still do not capture momentary changes of loneliness across the day and they have the potential for higher rates of recall bias and less compliance than in-the-moment reports. Ecological momentary assessment (EMA) is a survey methodology that allows researchers to assess perceptions of loneliness across the day as a person moves from one environment or social interaction to another. How to aggregate this data to allow comparisons across different levels (in this case, moment-to-moment loneliness compared to day-to-day sleep) is an issue that EMA researchers often struggle with.

One common approach is to average momentary loneliness scores across the day to reveal the central tendency for how much loneliness was experienced that day. This method is most similar to prior work utilizing daily diaries. Focusing on central tendency, however, does not reveal whether the patterning of loneliness experiences matters. The same day average could be observed, for example, from a day in which all moments were relatively invariant and moderate in magnitude or from a day that vacillated between extreme highs and lows at each assessment. Thus, a second approach for aggregation is to consider the variability in momentary loneliness over a day, such as through the standard deviation. A low standard deviation means that the person’s loneliness values for the day tended to be close to their average loneliness, while a high standard deviation indicates high vacillations across the day.

Focusing on central tendency or variation, however, assumes all loneliness levels are important. It might simply be that the most severe events are what people remember and are impacted by. Thus, a third approach is to identify the maximum value for that day (and ignore all other scores). A max loneliness moment may negatively impact sleep given the relationship between loneliness and physiological and psychological reactivity, such as increased blood pressure and rumination. More extreme lonely events might require the mobilization of more psychosocial resources than less severe lonely episodes and be more disruptive to sleep routines regardless of what else ensues in the day. As such, this impact may be lost when max loneliness moments are averaged with low loneliness moments throughout the day. Although these measures may overlap on some days, they also offer the possibly of not just considering days as interchangeable or only variable in a single way (e.g., average levels, which daily diary typically approximates). Given the wide range of differences between the aggregation methods, as well as the potential advantages and disadvantages associated with each approach, the present study includes all three aggregation methods to better examine their relations with sleep outcomes.

Dimensions of sleep

Sleep is a multifaceted construct, consisting of several dimensions that can be assessed with different measurement methods, including subjective measurements (i.e., self-report) or objective measurements via electronic devices, such as a Fitbit worn on the wrist. In this paper, for subjective measures we assess sleep latency (how long one lays in bed before falling asleep), sleep duration (total minutes of sleep at night), sleep quality (satisfaction with sleep), and fatigue (feeling of tiredness after sleep and/or the ability to maintain wakefulness). For objective measures we assessed sleep duration and sleep efficiency (the percentage of time spent sleeping relative to time not sleeping but spent in bed and dedicated to sleep). It is important to evaluate different measures of sleep because past research has shown that they are distinct from one another in that one may change while another remains the same. For example, in a study with a trait assessment of loneliness, Cacioppo et al. found that young adults with higher trait loneliness scores were more likely to show poorer subjective sleep quality, duration, and greater daytime dysfunction than nonlonely participants. However, loneliness was not associated with subjective sleep efficiency, sleep disturbances, or use of sleep medications for young adults. Kurina et al. assessed subjective sleep quality and daytime sleepiness, as well as objective sleep duration and sleep fragmentation, and only found a significant relationship between loneliness and sleep fragmentation. Taken together, these prior studies suggest that different dimensions of sleep demonstrate distinct associations with loneliness, and the specific relationships remain unclear. Additionally, evaluating subjective and objective sleep measures is prudent because some research shows clinically significant subjective sleep problems even when objective measures show no significant sleep problems.

The present study

The present study used EMA methods to investigate the within-person relationships between daily loneliness and sleep measures that night. Young adults were instructed to complete short surveys several times a day on their smartphone devices for a 2-week period, assessing their loneliness throughout the day as well as daily subjective sleep measures. A novel contribution to this paper was the operationalizing of daily loneliness as a daily average, a daily max value, and a daily variability level, computed by aggregating EMA loneliness data in different ways. Further, we tested relationships on multiple dimensions of subjectively and objectively measured sleep. Given prior work using trait loneliness and daily diaries has found mixed results, and this was the first study to compare different aggregation methods for loneliness across the day, we did not have a priori hypotheses for each aggregation method being associated with specific sleep dimensions. Overall, we hypothesized that higher levels of loneliness throughout the day would be associated with poor sleep, and we explored how aggregation methods differentially related to sleep outcomes. While not the primary focus of the current study, we also explored between-person relationships for each aggregation method.

There is renewed interest in understanding loneliness, particularly as rates of loneliness increase. We focus on emerging adults because loneliness is a rising concern in emerging adults, particularly during this era of Covid-19 protocols and subsequent changes to daily life. Furthermore, poor sleep is common among college students and often increases over time. Given that sleep has been linked to significant mental and physical health problems,
it is critical to identify factors that relate to poor sleep outcomes to create early intervention. Additionally, past literature lacks Hispanic/Latino representation,6 which the present study aims to rectify. This is integral given that Hispanic/Latino subjects show significantly worse sleep outcomes relative to white samples.29,30

Methods

Participants

Seventy-one undergraduate students from a public university in California participated in the present study. The majority of participants were female (77%), while 21% were male, and 2% reported another gender identity. The age ranged from 18-28 years old (M = 20.6, SD = 2.00). Forty-nine (69%) participants identified as Hispanic/Latino. Thirty-four percent of participants reported growing up with guardians with a high school degree or less. Inclusion criteria included being at least 18 years old and speaking English.

Procedure

All procedures were in accordance with the ethical practices standard in research with human subjects, were approved by the local Institutional Review Board, and completed in January through March. Notably, the protocol was not completed during spring break or the final examination period. Participants were recruited through the university’s SONA online subject pool system. Participants attended an initial lab visit providing informed consent and baseline measures including demographic information through Qualtrics, an online survey platform (Qualtrics, Provo, UT). Next, they downloaded the RealLifeExp app (LifeData Corp, Marion, IN) on their smartphones or were provided an iPod (Apple, Cupertino, CA) with the app preinstalled to complete the EMA questionnaires. Participants were instructed how to respond to the EMA questions measuring loneliness, sleep duration, sleep quality, fatigue, and sleep latency, among other measures, and took a practice survey to see all of the question wording and answer choices. Each participant was fitted with a Fitbit monitor and instructed on how to properly wear and adjust the device to ensure a proper signal during the study.

Over 14 days, participants completed the EMA surveys keeping their phone/iPod on them at all waking hours. Push notifications alerted participants when it was time to complete the EMA questionnaires at random times within each of the following blocks of time: 9:00-11:30 AM, 12:00-2:30 PM, 3:00-5:30 PM, and 6:00-8:30 PM. Participants had 60 minutes to complete the EMA once prompted, with a reminder after 30 minutes. Additionally, participants completed a morning EMA survey as soon as they woke up each day to report on their sleep. Course credit was given for the initial lab visit, a $25 Amazon gift card after the 2-week EMA period, and a bonus $10 Amazon gift card if they completed at least 85% of the EMA surveys. With 71 participants completing 4 surveys a day for 14 days, there were 3976 potential surveys and 994 days of data possible. On average, participants completed 39 surveys (SD = 12.67), ranging from 3 to 55. For sleep measures, assessed in the morning, there were 994 surveys and days of data possible. For EMA sleep observations and days of data with loneliness, we observed 704 and 778 days, respectively. Anyone with two or less EMA reports in a day (about 5%) were excluded from analyses due to this not being enough data for reliable mean or standard deviation.

During the 2-week period, participants wore a Fitbit Charge 2 device (Fitbit Inc, San Francisco, CA) on their nondominant hand that measured sleep efficiency and sleep duration. The Fitbit Charge 2 is a commercially available accelerometer-based activity tracker and wrist-worn heart rate monitor that has been validated in measuring sleep and heart rate.31,32 Objective measures of sleep were extracted and processed using Fitabase (SmallSteps Labs LLC, San Francisco, CA). Of the 994 possible days (71 participants X 14 days) of Fitbit data, we observed 565 days of data.

Measures

Loneliness

Similar to prior research,7,33,34 each survey asked participants “Right now, how lonely do you feel” on a 7-point Likert scale from 0 (not at all) to 6 (extremely). Loneliness was then operationalized in three separate ways: (1) For average daily loneliness, each person’s loneliness scores across the day were averaged. (2) For daily max loneliness scores, the peak score from each day was used. (3) For daily loneliness variability, we created a standard deviation of the loneliness scores for that day. Before computing the aggregated values, each momentary score had the person’s mean across all days subtracted from it, thus producing momentary person-mean-centered scores. Across all days, average loneliness was highly correlated with max loneliness (r = 0.80, p < .001) and daily standard deviation (r = 0.82, p < .001), and max loneliness and daily standard deviation had a small correlation (r = 0.37, p < .001).

Sleep latency

Self-report sleep (latency, duration, quality, fatigue) items were adapted from items of the Pittsburgh Sleep Diary to measure different dimensions of sleep on a day-to-day basis and have been found to relate to sleep dimensions assessed via polysomnography.35 For sleep latency, during the morning survey completed upon awakening, participants were asked “How long did it take you to fall asleep last night?,” indicated in hours and minutes. Anyone who took more than 120 minutes to fall asleep (about 8%) were excluded for that day from analyses as outliers.36 As these values were more than four times the mean of values when they were removed. Correlations among all sleep outcome variables are presented in Table 1.

Sleep duration

During the morning survey, participants were asked “How long did you sleep?” in hours and minutes. Anyone who reported more than 12 hours (2 data points) were excluded for that day from

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Average sleep latency (subjective)</td>
<td>22.4</td>
<td>23.2</td>
<td>− .12</td>
<td>− .05</td>
<td>.01</td>
<td>− .02</td>
<td>− .06</td>
<td></td>
</tr>
<tr>
<td>2. Average sleep duration (subjective)</td>
<td>399.5</td>
<td>116.5</td>
<td>− .006</td>
<td>.37</td>
<td>− .33</td>
<td>.52</td>
<td>.07</td>
<td></td>
</tr>
<tr>
<td>3. Average sleep quality (subjective)</td>
<td>3.5</td>
<td>1.5</td>
<td>− .21</td>
<td>.30</td>
<td>− .49</td>
<td>.33</td>
<td>.003</td>
<td></td>
</tr>
<tr>
<td>4. Average fatigue (subjective)</td>
<td>3.5</td>
<td>1.6</td>
<td>.10</td>
<td>− .24</td>
<td>− .51</td>
<td>− .36</td>
<td>− .000</td>
<td></td>
</tr>
<tr>
<td>5. Average sleep duration (objective)</td>
<td>420.4</td>
<td>117.9</td>
<td>− .01</td>
<td>.54</td>
<td>.22</td>
<td>− .23</td>
<td>− .004</td>
<td></td>
</tr>
<tr>
<td>6. Average sleep efficiency (objective)</td>
<td>88.5</td>
<td>3.9</td>
<td>− .12</td>
<td>.001</td>
<td>− .04</td>
<td>.02</td>
<td>− .09</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: M, mean; SD, standard deviation.

Coefficients in bold significant at p < .001. Means, standard deviations, and coefficients below the midline are between-person correlations, while those above the midline use person-centered values to provide within-person correlations.

* Significant at p < .05.
analyses as outliers, as they were more than two standard deviations above the mean.

**Sleep quality**
During the morning survey, participants were asked “How well did you sleep?” on a 7-point Likert scale from 0 (not at all) to 6 (extremely).

**Fatigue**
During the morning survey, participants were asked “How tired do you feel?” on a 7-point Likert scale from 0 (not at all) to 6 (extremely).

**Objective sleep duration**
Calculated as the total number of minutes in bed that coded as being asleep. Any reports of 12 hours or more (one data point) were excluded for that day from analyses, as they were more than two standard deviations above the mean.

**Objective sleep efficiency**
Calculated as total minutes asleep divided by total time in bed, multiplied by 100.

**Other covariates**
Race, ethnicity, age, gender, and caffeine, nicotine, and alcohol use were all measured to account for possible covariates, as indicated by past research suggesting they may be related to sleep.\(^6,29,30,37\) The baseline questionnaire asked participants to select their race from the following options: Black/African American, Native American (North or South America), Asian, Native Hawaiian/Pacific Islander, White, or more than one (please specify). Participants selected their ethnicity as either Hispanic/Latino or Non-Hispanic/Non-Latino. They also reported their age and selected their gender from the following options: male, female, transgender, other (please specify), and declined to answer. The EMA surveys asked participants if they had any caffeine, nicotine, or alcohol in the last 30 minutes, which we used to capture general daily load by creating a daily person-centered mean for each variable to use in our models.

### Table 2
Unstandardized beta coefficients (standard errors) of loneliness as a day average predicting sleep dimensions

<table>
<thead>
<tr>
<th></th>
<th>Subjective</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Latency</td>
<td>Duration</td>
<td>Quality</td>
<td>Fatigue</td>
<td>Fitbit</td>
<td>Efficiency</td>
</tr>
<tr>
<td><strong>Random effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1407.32 (725.85)</td>
<td>3364.42 (922.11)</td>
<td>0.96 (0.23)</td>
<td>0.91 (0.23)</td>
<td>2286.21 (1058.62)</td>
<td>5.69 (1.84)</td>
</tr>
<tr>
<td>Residual</td>
<td>17633 (1146.68)</td>
<td>11400 (705.66)</td>
<td>1.61 (0.10)</td>
<td>1.79 (0.11)</td>
<td>12287 (928.56)</td>
<td>11.09 (0.83)</td>
</tr>
<tr>
<td><strong>Fixed effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>−26.04 (112.42)</td>
<td>462.40 (134.60)</td>
<td>4.25* (2.14)</td>
<td>3.88 (2.10)</td>
<td>440.62 (137.83)</td>
<td>81.28 (5.85)</td>
</tr>
<tr>
<td>Age</td>
<td>4.64 (4.88)</td>
<td>−2.89 (5.86)</td>
<td>−0.03 (0.09)</td>
<td>−0.03 (0.09)</td>
<td>−1.53 (6.08)</td>
<td>0.29 (0.26)</td>
</tr>
<tr>
<td>Gender</td>
<td>−2.36 (24.47)</td>
<td>14.10 (28.71)</td>
<td>−0.16 (0.45)</td>
<td>0.52 (0.45)</td>
<td>19.08 (28.33)</td>
<td>0.01 (1.20)</td>
</tr>
<tr>
<td>Race</td>
<td>0.95 (17.04)</td>
<td>−46.02 (20.27)</td>
<td>−0.25 (0.32)</td>
<td>−0.30 (0.32)</td>
<td>−53.05 (21.52)</td>
<td>−0.55 (0.93)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>−18.36 (17.32)</td>
<td>−12.70 (20.68)</td>
<td>0.35 (0.33)</td>
<td>−0.51 (0.32)</td>
<td>−9.91 (19.82)</td>
<td>0.89 (0.86)</td>
</tr>
<tr>
<td>Caffeine</td>
<td>−31.39 (38.91)</td>
<td>−57.84* (29.75)</td>
<td>−0.34 (0.35)</td>
<td>0.79 (0.37)</td>
<td>−87.42 (37.10)</td>
<td>2.77 (1.12)</td>
</tr>
<tr>
<td>Nicotine</td>
<td>−41.40 (112.71)</td>
<td>11.54 (88.76)</td>
<td>0.40 (1.06)</td>
<td>0.64 (1.10)</td>
<td>−97.26 (114.74)</td>
<td>−5.32 (3.47)</td>
</tr>
<tr>
<td>Alcohol</td>
<td>207.01 (128.99)</td>
<td>−76.75 (99.23)</td>
<td>0.71 (1.18)</td>
<td>−0.35 (1.24)</td>
<td>−164.58 (113.98)</td>
<td>1.22 (3.43)</td>
</tr>
<tr>
<td>Study day</td>
<td>−2.29 (1.59)</td>
<td>1.08 (1.23)</td>
<td>−0.004 (0.01)</td>
<td>0.02 (0.02)</td>
<td>−0.50 (1.54)</td>
<td>0.06 (0.05)</td>
</tr>
<tr>
<td>Weekend</td>
<td>7.92 (12.91)</td>
<td>22.44 (10.05)</td>
<td>0.31 (0.12)</td>
<td>−0.26 (0.13)</td>
<td>19.24 (12.26)</td>
<td>0.70 (0.37)</td>
</tr>
<tr>
<td>Loneliness average (between-person)</td>
<td>10.13 (7.31)</td>
<td>7.47 (8.67)</td>
<td>−0.11 (0.14)</td>
<td>0.05 (0.14)</td>
<td>4.41 (8.19)</td>
<td>0.52 (0.36)</td>
</tr>
<tr>
<td>Loneliness average (within-person)</td>
<td>7.54 (6.69)</td>
<td>−11.82 (5.22)</td>
<td>−0.19 (0.06)</td>
<td>0.22 (0.07)</td>
<td>−11.54 (6.51)</td>
<td>0.38* (0.20)</td>
</tr>
</tbody>
</table>

| **Model effects**    | Pseudo r²  |                |                |                |          |          |
|                      | 0.03       | 0.07           | 0.04           | 0.07          | 0.07     | 0.07     |

*Note. Coefficients in bold significant at p < .05. Weekend: weekday = 0, weekend day = 1. Race: White = 0, non-White = 1. Ethnicity: non-Hispanic/non-Latino = 0, Hispanic/Latino = 1. Gender: male = 0, non-male = 1. Coefficients with * indicate near significance at p < .06.*

### Analytic plan
The data have a two-level structure with days (level 1) nested within individuals (level 2), thus multilevel analyses were performed using the PROC MIXED command in SAS 9.3. In general, multilevel analyses are recommended when examining EMA data to account for missing data.\(^38\) Three groups of multilevel models tested whether within-person levels of loneliness were associated with within-person sleep outcome variables. The first set of models used daily average loneliness as a predictor, the second set used daily loneliness variability, and the final set used daily maximum loneliness. In addition, given the focus on trait loneliness and between-person analyses in prior research, each model also included a between-person analysis to evaluate in relation to existing studies. Each operationalization of loneliness was specified to predict the sleep measures: subjective latency, duration, quality, fatigue, and objective duration and efficiency.

Models controlled for temporal factors, including what day of the study it was for the participant (ranging from 1 to 14), and whether it was a weekday (coded as 0) or weekend day (coded as 1), race in terms of White (coded as 0) or non-White (coded as 1), ethnicity in terms of non-Hispanic/non-Latino (coded as 0) or Hispanic/Latino (coded as 1), age, gender in terms of male (coded as 0) or non-male (coded as 1), and daily caffeine, nicotine, or alcohol use. A random intercept was included to account for the possibility that participants had different levels of sleep measures. We also explored the use of random slopes in each model but found that they were either not significant or there was not enough data to utilize random slopes, and thus, were not included in the final models. We tested each outcome in a separate model to identify the unique relationship between loneliness and sleep. To calculate the model’s effect size, a pseudo \(R^2\) was calculated by first estimating a predicted value for each moment and then correlating that prediction with the observed value.\(^39\) Each model’s pseudo \(R^2\) are reported in Tables 2-4.

### Results
Descriptive statistics are presented in Table 1. Across the study, participants reported an average of 6 hours and 40 minutes of sleep (SD = 116.52), 22 minutes to fall asleep (SD = 23.15), 3.54 (SD = 1.51) sleep quality on a 7-point scale, and 3.49 (SD = 1.58)
fatigue on a 7-point scale. For objective measures, the average sleep duration was approximately 7 hours (SD = 117.87), and sleep efficiency was 88.53% (SD = 3.85).

For daily average loneliness (Table 2), the model indicated significant fixed effects for within-person loneliness predicting lower subjective sleep duration (p = .024), lower subjective sleep quality (p = .002), and higher fatigue (p < .001), a marginal effect for objective sleep efficiency (p = .05), and no significant effects for self-reported sleep latency (p = .26) nor objective sleep duration (p = .08). Results showed no significant between-person effects for daily average loneliness.

For daily loneliness max scores (Table 3), the models indicated significant fixed effects for within-person loneliness predicting higher subjective sleep latency (p = .042), lower subjective sleep quality (p = .002), and higher fatigue (p < .001), but no significant effects for self-reported sleep duration (p = .14), objective sleep quality (p = .18), nor objective sleep duration (p = .14). Results showed no significant between-person effects for daily max loneliness.

For daily loneliness variability (Table 4), the models indicated significant fixed effects for within-person loneliness predicting greater fatigue (p = .013), but no significant effects for subjective sleep latency (p = .07), subjective duration (p = .97), subjective quality (p = .10), objective sleep duration (p = .66), nor objective efficiency (p = .28). Results showed no significant between-person effects for daily loneliness variability.

Discussion

The purpose of this study was to evaluate if the shape of loneliness throughout the day – daily average, daily max, and daily variability – shows differential relationships to sleep outcomes. To the best of our knowledge, this is the first study to utilize EMA methodology assessing in-the-moment loneliness multiple times a day across days to compare aggregation methods. It is further strengthened by utilizing actigraphy data in addition to subjective measures for sleep.
Momentary loneliness and subjective measures of sleep

Generally, our results support the hypothesis that momentary loneliness throughout the day predicts poor sleep outcomes at night. First, higher daily average loneliness predicted less subjective sleep duration, lower subjective sleep quality, and more fatigue. The average daily loneliness model is the closest approximation to prior studies utilizing an end-of-day recall for daily loneliness and supports past findings where daily loneliness predicted next-day daytime dysfunction regardless of sleep duration. While the present study did not evaluate daytime dysfunction as a sleep outcome, we did find that average daily loneliness predicted subsequent fatigue, which is synonymous with the “fatigue” question on daytime dysfunction that was used by Hawkley and colleagues. Further, while we cannot make direct comparisons to the John-Henderson et al study due to different outcome measures, we can conclude that our study supports their findings of a relationship between daily loneliness and sleep, and further expands on it by measuring in-the-moment loneliness across the day.

Second, higher day max loneliness scores predicted lower subjective sleep quality and more fatigue, as well as increased subjective sleep latency. Unlike the other models, when participants experienced a higher daily max score of loneliness, they reported taking longer to fall asleep. There might be physiological or psychological consequences that are different for having a severe lonely event rather than having more or less loneliness on average. For example, given that loneliness is linked to rumination, perhaps participants are ruminating at night about having a particularly lonely moment that day and thus making it take longer to fall asleep.

Interestingly, when looking at loneliness as a daily variability score, only fatigue remains significant. This suggests that having a highly variable loneliness experience throughout the day is not as impactful on sleep as having a higher-than-average loneliness day or a high loneliness moment on any given day. These results may align with work examining variability in daily affect that found that variability in negative affect across the day was not significantly related to sleep (but variability in positive affect was). Given research suggesting most people tend to rate their mood as happy, a deviation from that happy state may be particularly noticeable. Future research may wish to explore whether variations in positive social environments (e.g., perceived social support) may exhibit relationships with sleep outcomes.

Surprisingly, none of the three loneliness models predicted objective sleep outcomes. However, there was a marginal effect for daily average loneliness predicting objective sleep efficiency. This marginal finding supports the conclusion from a recent meta-analysis that there is a significant association between loneliness and sleep efficiency, but does not replicate other research finding a link between loneliness and other objective sleep measures. It is important to note that most prior studies utilized between-person methods essentially comparing “lonely” vs. “non-lonely” participants, which may contribute to the differential findings when comparing the current study to prior work. One study that utilized actigraphy for objective sleep measures and daily loneliness scores did find a significant relationship between daily loneliness and wake after sleep onset, a variable not measured in the present study. Perhaps wake after sleep onset is uniquely related to daily loneliness regardless of duration and efficiency. This would not be surprising given Hawkley et al’s findings that loneliness predicted daytime dysfunction regardless of sleep duration. It may be that moments of loneliness lead to increased physiological arousal that impedes staying asleep that night. Prior research has shown that loneliness predicts increased blood pressure and has an accumulative effect, supporting the notion that there may be immediate physiological arousal in response to loneliness moments that builds up over time, but this research question has yet to be tested.

Limitations and future directions

The dataset for the present study did not have some variables that prior research has suggested controlling for, such as depression, anxiety symptoms, and perceived stress. While we did not control for depression in the present models, the results are strengthened by the fact that we evaluated daily loneliness across time and compared it to each individual’s typical loneliness. Further, there were no significant findings with objective sleep measures, and this may be due to the objective measures we used. For example, future work may want to use wake after sleep onset as an outcome measure given it’s been significant in the past.

With the findings from the present study, there are many intriguing considerations for EMA loneliness methodology moving forward. First, we may want to consider not just looking at the max scores each day, but rather, max scores with a threshold. There may be some days when the max score is relatively low but still the max for that day, and these scores may be very different than a higher max loneliness score on another day. One option is to consider any max score that falls over an individual’s weekly average loneliness score, while excluding those below their average. Second, future work should consider when loneliness moments occur and assess if there are differential effects on sleep from max loneliness moments that occur close to sleep onset compared to moments occurring earlier in the day. While we had an evening loneliness measure, it occurred anytime between 6:00 PM to 8:30 PM. To adequately evaluate feelings of loneliness before sleep onset, future work should aim to measure loneliness closer to sleep onset. Third, future work may consider assessing loneliness variability in a different way, such as average real variability, or the amount of change from one loneliness moment to the next. Fourth, future work should consider evaluating an interaction term for average daily loneliness and daily loneliness variability to elucidate any unique impacts on sleep when one experiences high levels of loneliness and low variability vs. low levels of loneliness and high variability. Finally, future work should evaluate the potential bidirectional relationship between loneliness and sleep using EMA methods.

Implications and conclusions

Looking at all three models, evaluating loneliness with an average daily score is the most predictive model, however daily max loneliness is the preferred method for sleep latency. Loneliness and poor sleep have both been linked to mental and physical health outcomes including depression, anxiety, and cardiovascular disease. Understanding the relationship between daily loneliness experience and sleep may aid in the development of interventions targeting these behaviors to improve mental well-being, physical health, and quality of life. For example, interventions utilizing cognitive-behavioral therapies, increasing social support, and/or lifestyle behavioral changes aimed at reducing loneliness or coping with loneliness can be informed by understanding daily loneliness experience. This study is the first to combine EMA evaluating multiple loneliness moments across the day over many days with subjective and objective sleep outcome measures, and it is the first to evaluate several different models for daily loneliness experience. In the present study, there were no significant between-person findings, but several within-person findings suggesting the connection between loneliness and sleep may not be only about more lonely people vs. less lonely people, but rather a dynamic relationship between a person’s relative individual loneliness on any given day.
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Author contributions

Kayla T. Johnson: Formal analysis, Writing - original draft, Writing - reviewing and editing. Matthew J. Zawadzki: Conceptualization, Funding acquisition, Methodology, Investigation. Data curation, Formal analysis, Writing - reviewing and editing. Carmen Kho: Investigation, Writing - reviewing and editing. All authors have approved the final article.

Data availability

The datasets generated during and/or analyzed during the current study are unavailable due to not obtaining consent from participants to share deidentified data.

Declaration of conflicts of interest

The authors have no conflicts of interest to declare.

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