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RESEARCH ARTICLE

Links between well-being and sleep while awaiting breast biopsy results

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Abstract

Poor sleep is associated with several negative consequences, including poor health, depression, anxiety, and memory deficits, among others. Although the link from sleep to health and well-being is well-established, fewer studies have examined the reverse relationship. The current study examined the role of one particular challenge to well-being, stressful uncertainty, in the association between well-being and sleep quantity and quality. Female patients (n = 120 for the purpose of analyses) awaiting the results of a breast biopsy participated in an initial interview at their biopsy appointment and then completed daily surveys at home each day until they received their results. Patients who reported poorer well-being on various measures also reported poorer and less sleep on average during the wait for biopsy results, even after controlling for individual differences and well-being at the biopsy appointment. However, when patients experienced positive emotions on a given day, they tended to sleep better that night. Our findings suggest that stressful uncertainty about one's health may have detrimental effects on sleep, but positive emotions may improve sleep during stressful waiting periods.

KEYWORDS
anxiety, sleep, sleep quality, stressful uncertainty

1 | INTRODUCTION

Perhaps one of the most beneficial things people can do for their health is to sleep well and for a sufficient length of time. One long-standing recommendation is that adults should sleep anywhere between seven and 9 h per night to promote optimal health and well-being (Watson et al., 2015). Failure to get an adequate amount and quality of sleep is associated with a number of negative consequences, including decrements in physical health (e.g., weight gain, diabetes, heart disease), mental health (e.g., greater depression and anxiety), and cognitive abilities (e.g., decreased memory ability). The negative effects of poor or insufficient sleep are well-established, but fewer studies have examined the reverse—namely, whether and how distress leads to sleep disruption. However, limited evidence suggests that stressful life events may lead to decreased sleep quality (e.g., Kim & Dimsdale, 2007). In the current investigation, we examine links between psychological distress and sleep disruption in the context of a highly stressful life event: awaiting the result of a diagnostic breast biopsy.

2 | A BIDIRECTIONAL RELATIONSHIP BETWEEN STRESS AND SLEEP

Sleep disruption affects various aspects of health and well-being. Poor sleep promotes unhealthy weight gain, risk for heart disease, and even all-cause mortality (Barone & Menna-Barreto, 2011; Gallicchio & Kalesan, 2009; Grandner et al., 2014; Liu et al., 2013). Aside from physical health, a plethora of studies reveals that sleep deprivation impairs memory processes such as those involved with encoding, retention, and consolidation (see Walker & Stickgold, 2006 for a review). Emotion regulation also suffers due to poor sleep (van

der Helm et al., 2010; Yoo et al., 2007), and poor sleep contributes to one's allostatic load, thus increasing stress levels and affecting mental health (McEwen, 2006). Of note, despite a focus on sleep quantity in public health recommendations (e.g., Centers for Disease Control, 2017), sleep quality is a better predictor of health and well-being (Bassett et al., 2015; Benham, 2009).

The negative consequences of sleep disruption for health and well-being are well-established and quite significant. However, that link is not unidirectional. Rather, stress and sleep are bidirectionally entangled such that poor sleep leads to poorer well-being, and poor well-being in turn disrupts sleep (Barone & Menna-Barreto, 2011; Benham, 2009; Stewart et al., 2021; van Laethem et al., 2015; for a study using actigraphy rather than self-reported sleep, see Slavish et al., 2021). As examples of the latter association, both depression (Bowman et al., 2021) and anxiety (LeBlanc et al., 2009) prospectively predict sleep disruption, including new-onset insomnia symptoms, and daily emotional stress prospectively predicts poorer sleep even among previously healthy sleepers (Kim & Dimsdale, 2007; Lund et al., 2010). More broadly, high levels of psychological stress in daily activities predict shorter sleep duration and lower sleep quality (Rutledge et al., 2009; Suarez, 2008). Beyond these correlational findings, experimental studies have documented a clear causal link between well-being and sleep quality, such that people exposed to stressful experimental stimuli spend less time in slow-wave sleep (a sleep phase important for memory consolidation) and experience more spontaneous awakening throughout the night (for a review, see Kim & Dimsdale, 2007).

Although day-to-day stress is certainly detrimental to sleep quality, acute stressors can also have negative consequences for sleep. Results from actigraphy (an objective and ambulatory method of assessing sleep) revealed that exposure to stress in a single day was associated with less total sleep time (Slavish et al., 2021), and both self-report and polysomnographic measures of sleep (the latter being the gold standard for sleep assessment) confirm that stressful life events have significant negative effects on both sleep duration and sleep quality (Kim & Dimsdale, 2007; Li et al., 2019). For example, a 1-year longitudinal study found that the number of stressful life events people experienced over their lives predicted a decline in sleep quantity and quality in the subsequent year (Pillai et al., 2014), likely due to the persistent presence of perseverative thoughts (i.e., rumination and worry) during such life events (van Leathem et al., 2015).

One of the most commonly mentioned stressful life events in studies of sleep disruption is illness, such that those who report having more health concerns also report poorer sleep (Healy et al., 1981; Morin et al., 2003). Breast cancer patients are no exception, such that breast cancer patients and survivors report high levels of sleep disruption, at least in part due to illness-related stress (see Palesh et al., 2013 for a review). However, these studies focus on the period following diagnosis of an illness, despite considerable research identifying the uncertain period prior to diagnosis as even more stressful than periods of treatment or illness management (e.g., Sweeny & Falkenstein, 2015; see Poole, 1997 for a review in the context of breast cancer diagnosis). Waiting for news about one's health presents psychological challenges that are different from those following, for example, the bad news of a diagnosis. Waiting periods are fraught with a combination of uncertainty about and little or no control over one's future, which makes coping with the stress of waiting particularly difficult (Sweeny, 2018).

To our knowledge, only one study has examined the association between stress and sleep disruption during a significant personal waiting period (Howell & Sweeny, 2016). This study found robust associations between distress (e.g., worry about the uncertain outcome) and poor self-reported sleep quality. Although those findings suggest that distress and sleep are linked during stressful waiting periods, the findings were entirely correlational, assessed only every 2 weeks rather than daily, and limited to a broad self-assessment of sleep disruption.

3 | OVERVIEW AND HYPOTHESES

The present investigation examines daily links between well-being and sleep disruption in the context of the wait for breast biopsy results. Specifically, we surveyed women at their biopsy appointment and then daily (measures of well-being in the evening, sleep reports the next morning) for the approximately week-long wait for biopsy results. As described in more detail below, we operationalised sleep disruption in a number of ways, including duration, bed time, wake time, sleep latency (i.e., the duration between going to bed and falling asleep), and self-reported sleep quality.

Although we present analyses that prospectively predict both sleep experiences from well-being and well-being from sleep experiences, our hypotheses focus on the less-studied link from well-being to sleep. We anticipate that poor sleep will also predict poorer well-being; however, given that all participants in our study were in a situation that is challenging to well-being (i.e., undergoing a diagnostic breast biopsy), we were less interested well-being as an outcome. Thus, we hypothesised that poorer well-being on a given day, by various measures, would predict greater sleep latency (*Hypothesis 1*), shorter sleep duration (*Hypothesis 2*), and poorer sleep quality (*Hypothesis 3*) that night. We did not have a priori hypotheses about specific bed or wake times. The current investigation was part of a broader study that included additional measures; see below for a link to the full interview and set of measures on the Open Science Framework.

4 | METHOD[1]

4.1 | Participants

Female patients (N = 212 at the initial interview; 74% Latina, M_{age} = 46.0, 64% completed high school, 38% employed, 49% married) participated in a two-part study. We aimed for 200 participants to provide sufficient power for our broad set of analyses, tentatively

predicting an attrition rate of approximately 50% between the two parts of the study due to the challenges of recontacting patients during such a challenging period in their lives (100 participants are typically sufficient for the relevant approach to multilevel modelling; Haas & Cox, 2005). The study was halted in March 2020 due to COVID-19 restrictions that prohibited our research team from entering the hospital; fortunately, our recruitment goal was complete at that point (although we would have continued recruitment to boost the size of the sample who completed the daily surveys if we had the opportunity; see below for attrition rate).

In the first part of the study, patients were interviewed immediately prior to undergoing a breast biopsy in the radiology department of a large county hospital in Southern California between April 2017 and March 2020. Participants were alerted to the study opportunity by hospital staff; all participants who indicated an interest in the study completed the interview at their biopsy appointment. In the second part of the study, most relevant to the current investigation, patients were asked to complete daily surveys at home in the days that followed until they had received their breast biopsy results. Due to attrition, 120 participants completed the daily surveys. The most common cause of attrition was an inability to reach the participant to schedule a time to meet in person to collect the daily surveys; others dropped out because their biopsy procedure was not conducted as planned. Of the participants who completed some daily surveys, 76% completed all seven surveys; 93% completed at least five of the seven surveys, and 80% participants completed the seventh and final daily survey.

Patients were eligible to participate if they were over 18 years of age, fluent in either English or Spanish (no patient was excluded due to language constraints), and not currently incarcerated. Patients were referred to the radiology department for a biopsy following one or more abnormal mammogram results. Patients typically wait 1–2 weeks for their biopsy result following the procedure at the research site.

4.2 | Procedure

Department staff provided a brief description of the study when they called patients to remind them about their biopsy appointment. If patients were interested in learning more about the study, they arrived 30 min prior to their biopsy appointment and were met by a trained member of the research team (undergraduate and postgraduate students), who conducted consent procedures and the interview. The researcher escorted the patient to a private, quiet room in the radiology department to complete the interview. Patients were given the choice to either read the consent form on their own or have the researcher go over the document with them (most participants chose the latter). Following consent, the researcher conducted a structured interview with the patient (see below for study measures). Although all interview questions were directed to the patient, in 29% of cases the patient had a family member or friend with her during the interview, by the patient's request. Participants received $10 for completing the initial interview.

In the second part of the study, participants were given a packet that included short daily surveys. We had to use paper-and-pencil surveys because many patients did not have reliable access to the Internet, due to the socioeconomic profile of the patient population. Participants were to complete these surveys each evening at home, at participants' leisure, until they received their biopsy results. Specifically, participants received the following verbal instructions:

> I'm going to leave the packet of surveys you'll complete during the week with the nurse, so you can get it before you leave. As you can see, there's a tab for each day between now and your follow-up appointment. That means you'll complete the surveys in this packet each morning and evening between now and that appointment, starting this evening. You'll see that there is a survey for each morning and evening, labelled with the date you'll complete each one. If you miss one, don't worry—just pick up with the next one. I'd suggest keeping this packet near your bed so you can complete the surveys right before you go to sleep and right after you wake up each day. You could also set an alarm, maybe on your phone, to remind you to complete the surveys. Can you think of things you can do that will help you remember?

In many cases, participants received results via phone, so they were met at various locations to return the packets and receive payment (participants received $30 for the daily surveys as long as they completed at least one and returned the packet).

This study was approved by the Institutional Review Boards at both the authors' institution and the county hospital where data collection procedures took place. The interview included a number of questions not pertinent to the current investigation; full study materials are available on the Open Science Framework.

5 | MEASURES

Measures at the biopsy appointment are included as covariates in the focal analyses.

5.1 | Biopsy appointment

5.1.1 | Patient characteristics

In the initial interview, we collected demographics and other patient characteristics (see above for sample characteristics). Regarding demographics, we asked about the following: ethnicity ('Are you Hispanic or Latino?' *yes/no*), age ('How old are you?' *open-ended*), employment status ('Are you employed?' *yes/no*; if yes, 'What do you do for a living?' *open-ended*), education ('What is the highest grade in school you completed?' *open-ended*), and marital status ('Are you

married?' *yes/no*; if no, 'Are you living with a romantic partner right now?' *yes/no*). We also asked about health literacy (Chew et al., 2008; 'How confident are you filling out medical forms by yourself?' 1 = *not at all confident*, 10 = *extremely confident*; $M = 7.62$, SD = 2.52) and religiosity (How religious are you?' 1 = *not at all*, 10 = *extremely*; $M = 6.32$, SD = 2.29).

5.1.2 | Health and health history

We assessed personal and family history of breast cancer ('Have you ever been diagnosed with breast cancer?' *yes/no*, 10% of the full sample and 8% of the daily survey subsample responded yes; 'Has anyone in your family ever been diagnosed with breast cancer?' *yes/no*, 35% of the full sample and 36% of the daily survey subsample responded yes), history of diagnostic testing ('Prior to the experience that brought you here today, have you ever had an abnormal mammogram result?' *yes/no*, 39% of the full sample and 35% of the daily survey subsample said yes), and subjective health ('In general, would you say your health is excellent, very good, good, fair, or poor?' 1 = *poor*, 5 = *excellent*; $M = 2.83$, SD = 1.03).

5.1.3 | Intolerance of uncertainty

As described below, we included a measure of intolerance of uncertainty as a covariate in some analyses. We assessed intolerance of uncertainty with the Intolerance of Uncertainty Scale—Short Form (Carleton et al., 2007, p. 12 items, e.g., 'Unforeseen events upset me greatly,' 'Uncertainty keeps me from living a full life'; 1 = *not at all characteristic of me*, 7 = *entirely characteristic of me*; responses averaged to form a composite measure of intolerance of uncertainty, $M = 4.98$, SD = 1.22, $\alpha = 0.84$).

5.1.4 | Markers of well-being

Participants indicated their emotional state on three items ('How much of the time today have you felt [emotion]?' happy: $M = 2.58$, SD = 0.97; sad: $M = 1.69$, SD = 0.86, anxious: $M = 2.35$, SD = 0.99; for all, 1 = *none of the time*, 4 = *all of the time*). Somatic symptoms over the past week were assessed with 12 items from the Physical Symptom Inventory (PSI; Spector & Jex, 1998; 'Thinking about the past week, have you had any of the following symptoms?' *yes/no*; e.g., upset stomach, acid digestion or heart burn, dizziness; responses averaged to create a somatic symptom composite, $M = 0.30$, SD = 0.23, $\alpha = 0.76$). Finally, repetitive thoughts about cancer were assessed with three items from the Impact of Events Scale, Revised, adapted for relevance to our context (IES-R; Weiss & Marmar, 1996; 'I couldn't stop thinking about breast cancer,' 'Thoughts about breast cancer limited my enjoyment in life,' 'Breast cancer was never far from my mind'; 1 = *strongly agree*, 7 = *strongly disagree*; responses averaged to create a rumination composite, $M = 4.70$, SD = 1.91, $\alpha = 0.78$).

5.2 | Daily surveys

Participants varied in the number of surveys they completed, given that they were instructed to complete surveys each day until they received their biopsy result. For the purpose of this investigation, we include up to 7 days of surveys.

5.2.1 | Self-reported sleep measures

Each morning, participants reported the time they went to bed and the time they fell asleep the night before, the time they woke up and got up that morning, and the overall quality of their sleep ('How would you rate the quality of your sleep last night?' 1 = *very bad*, 4 = *very good*). For the purpose of analyses, the following metrics were calculated: bed time (in minutes after 4 pm; $M = 380.50$ or 10:20 PM, SD = 74.30), wake time (in minutes after 1 am; $M = 351.41$ or 6:51 am, SD = 72.57), total sleep (in minutes between the reported time they fell asleep and the time they awoke; $M = 458.23$, SD = 71.11), and sleep latency (in minutes between the reported time they went to bed and the time they fell asleep; $M = 52.57$, SD = 50.44). Sleep quality was treated as reported ($M = 2.89$, SD = 0.60). For each of these metrics, we also calculated individual standard deviations for each participant to represent variability across the wait for biopsy results.

5.2.2 | Well-being

In the daily surveys, participants reported their anxious emotions, positive emotions, and negative emotions with an adapted version of the GRID (Fontaine et al., 2007; Scherer, 2005; anxious emotions: three items averaged into a composite, anxiety, stress, fear, $M = 1.73$, SD = 0.65, αs 0.83–0.88; positive emotion: nine items averaged into a composite, e.g., happiness, contentment, pride; $M = 2.01$, SD = 0.56, αs 0.80–0.84) and negative emotions (12 items averaged into a composite; e.g., shame, sadness, irritation; $M = 1.35$, SD = 0.42, αs 0.84–0.89). Participants reported somatic symptoms ($M = 0.21$, SD = 0.20, αs 0.73–0.81) and repetitive thoughts about breast cancer ($M = 2.63$, SD = 1.12, αs 0.83 to 0.89) they had experienced that day using the PSI and adapted IES-R, as they did at the biopsy appointment interview.

6 | ANALYSIS PLAN

Because we did not have a priori plans for covariates, we took a data driven approach. That is, we sought to identify any demographic or health history variable that was associated with both sleep experiences and well-being, and thus could be an explanatory third variable in any observed relationship. We thus began by conducting bivariate correlation analyses (for continuous measures) and independent-samples *t*-tests (for categorical measures) examining whether sleep

experiences differed by any demographic or health variable. Older participants reported later wake times, $r(104) = 0.22$, $p = 0.03$, and longer sleep latencies, $r(104) = 0.25$, $p = 0.01$. More religious participants reported better quality sleep, $r(103) = 0.29$, $p = 0.003$, and participants higher in health literacy reported later bed times, $r(104) = 0.21$, $p = 0.03$. Turning to health variables, participants who felt healthier (i.e., better subjective health) reported better quality sleep, $r(104) = 0.29$, $p = 0.003$, and shorter sleep latencies, $r(104) = -0.20$, $p = 0.046$. Finally, participants with a family history of breast cancer reported poorer quality sleep, $t(98) = 2.33$, $p = 0.02$. No other demographic or health characteristic predicted sleep experiences. At this stage, age, religiosity, health literacy, subjective health, and family history of breast cancer are candidates to serve as covariates in our predictive models.

We then examined whether markers of well-being differed by any demographic or health variable that was a candidate to serve as a covariate. Participants higher in health literacy reported only greater positive emotion, $r(105) = 0.21$, $p = 0.04$. More religious participants reported greater positive emotion, $r(104) = 0.24$, $p = 0.02$, and fewer somatic symptoms, $r(103) = -0.19$, $p = 0.05$. Participants who felt healthier (i.e., better subjective health) reported less negative emotion, $r(105) = -0.23$, $p = 0.02$, less anxiety, $r(105) = -0.26$, $p = 0.007$, less rumination, $r(104) = -0.24$, $p = 0.01$, and fewer somatic symptoms, $r(104) = -0.33$, $p = 0.0006$. Because only religiosity and subjective health were associated with sleep experiences and well-being with any consistency, we included them as covariates in our models.

To test our hypotheses, we conducted multilevel models using PROC MIXED in SAS 9.4 predicting individual sleep metrics from person mean-centered (within-person effects) and grand mean-centered (between-person effects) well-being, controlling for religiosity and subjective health.[1] All models control for equivalent or identical well-being measures at the biopsy appointment.[2] We also tested models that controlled for intolerance of uncertainty to control for general tendencies towards worry and discomfort during periods of uncertainty; because no finding changed when controlling for this potential third variable, we present the results of the simpler models here. When models failed to converge, we removed person mean-centered predictors from the random line (all models converged via this strategy).

We then conducted an equivalent set of multilevel models reversing the predictors and outcomes—predicting individual well-being metrics from person mean-centered (within-person effects) and grand mean-centered (between-person effects) sleep metrics, controlling for religiosity and subjective health.

7 | RESULTS

We first examined differences between patients who completed daily surveys and those who dropped out of the study after the initial interview. Among all of the measures included in the biopsy appointment interview, only three differences emerged. Those who participated in the daily surveys were higher in health literacy, $t(195) = 2.06$, $p = 0.04$, more likely to be cohabitating with a romantic partner if they were not married, $\chi^2(1, 100) = 5.05$, $p = 0.02$, and (despite considerable effort to remain in contact with those who were not English fluent) more likely to have completed the initial interview in English, $\chi^2(1, 197) = 5.45$, $p = 0.02$.

Table 1 presents key parameters from multilevel models predicting sleep experiences from well-being. Only one within-person association emerged: Positive emotion predicted better sleep quality, such that participants reported better-than-typical sleep quality, compared to their personal average during the week, following days when they experienced high levels of positive emotion compared to their personal average (consistent with *Hypothesis 3*).

Regarding between-person effects, no marker of well-being predicted sleep latency, contrary to *Hypothesis 1*. Consistent with *Hypothesis 2*, negative emotion, anxiety, and repetitive thought predicted total sleep, such that participants who experienced high levels of distress on those markers during the wait for biopsy results also reported less sleep during the wait. All markers of well-being predicted sleep quality, consistent with *Hypothesis 3*, such that participants who experienced more negative emotion, anxiety, repetitive thoughts, and somatic symptoms and less positive emotion also reported poorer sleep quality across the wait. Positive emotion and anxiety predicted bed times, such that participants who reported more positive emotion or anxiety overall also went to bed later on average; no measure of well-being predicted wake times.

Table 2 presents key parameters of multilevel models predicting well-being from sleep experiences. Within-person associations were far more prevalent in these models. Bed times predicted negative emotion, such that participants reported higher-than-typical negative emotion, compared to their personal average during the week, following days when they went to bed later compared to their personal average. Wake times predicted anxiety and repetitive thought, such that participants reported higher-than-typical anxiety and repetitive thought following days when they woke up earlier compared to their personal average. Total sleep predicted positive emotion and anxiety, such that participants reported higher-than-typical positive emotion and lower-than-typical anxiety following days when they slept longer than their personal average. Sleep quality predicted positive emotion, such that participants reported greater-than-typical positive emotion following days when they slept better than their personal average. Sleep latency did not predict any measure of well-being at the within-person level.

Regarding between-person effects, bed times predicted anxiety, such that participants who went to bed later during the wait for biopsy results also reported greater anxiety during the wait. Wake times predicted anxiety and positive emotion, such that participants who woke up earlier during the wait for biopsy results also reported less anxiety and greater positive emotion during the wait. Total sleep predicted negative emotion, anxiety, and repetitive thought, such that participants who slept less during the wait for biopsy results also reported greater distress during the wait. Finally, sleep quality predicted all measures of well-being, such that participants who

TABLE 1 Results of multilevel models linking well-being and sleep experiences

	Bed time β (SE) [95% CI]	Wake time β (SE) [95% CI]	Total sleep β (SE) [95% CI]	Sleep latency β (SE) [95% CI]	Sleep quality β (SE) [95% CI]
Positive emotion					
Within-person	−0.02 (0.03) [−0.09, 0.04]	0.03 (0.03) [−0.03, 0.09]	0.04 (0.04) [−0.03, 0.11]	−0.003 (0.03) [−0.07, 0.07]	0.08* (0.04) [0.006, 0.16]
Between-person	0.16* (0.08) [0.002, 0.33]	0.11 (0.08) [−0.05, 0.28]	−0.02 (0.07) [−0.16, 0.13]	−0.07 (0.09) [−0.25, 0.11]	0.26** (0.06) [0.13, 0.38]
Negative emotion					
Within-person	−0.006 (0.04) [−0.09, 0.07]	0.06 (0.05) [−0.04, 0.16]	0.06 (0.05) [−0.03, 0.15]	−0.02 (0.03) [−0.07, 0.04]	−0.01 (0.03) [−0.07, 0.05]
Between-person	0.15 (0.11) [−0.06, 0.36]	−0.007 (0.11) [−0.22, 0.20]	−0.24** (0.09) [−0.41, −0.06]	0.09 (0.12) [−0.14, 0.32]	−0.39** (0.08) [−0.54, −0.23]
Anxiety					
Within-person	0.007 (0.03) [−0.06, 0.08]	−0.003 (0.03) [−0.06, 0.06]	0.02 (0.04) [−0.06, 0.10]	−0.04^{+} (0.02) [−0.09, 0.008]	−0.05 (0.04) [−0.12, 0.03]
Between-person	0.24** (0.08) [0.07, 0.41]	0.06 (0.09) [−0.12, 0.23]	−0.26** (0.07) [−0.40, −0.11]	0.10 (0.10) [−0.09, 0.29]	−0.43** (0.06) [−0.55, −0.31]
Repetitive thought					
Within-person	0.007 (0.03) [−0.05, 0.07]	0.01 (0.03) [−0.05, 0.07]	0.006 (0.03) [−0.06, 0.07]	−0.02 (0.03) [−0.07, 0.03]	−0.05 (0.03) [−0.10, 0.01]
Between-person	0.08 (0.08) [−0.09, 0.25]	−0.07 (0.09) [−0.24, 0.10]	−0.24** (0.07) [−0.38, −0.09]	0.15 (0.09) [−0.04, 0.33]	−0.18* (0.07) [−0.33, −0.03]
Somatic symptoms					
Within-person	−0.007 (0.04) [−0.09, 0.08]	0.02 (0.03) [−0.03, 0.08]	0.06 (0.05) [−0.05, 0.17]	−0.009 (0.04) [−0.10, 0.08]	−0.007 (0.03) [−0.07, 0.05]
Between-person	0.05 (0.09) [−0.13, 0.23]	−0.02 (0.09) [−0.21, 0.17]	−0.16^{+} (0.08) [−0.32, 0.0006]	0.02 (0.10) [−0.18, 0.22]	−0.34** (0.07) [−0.49, −0.20]

Note: Analyses control for relevant baseline measures (see Footnote 2), religiosity, and subjective health.

**$p < 0.01$, *$p < 0.05$, $^{+}p < 0.10$.

TABLE 2 Results of multilevel models linking well-being and sleep experiences

	Positive emotion β (SE) [95% CI]	Negative emotion β (SE) [95% CI]	Anxiety β (SE) [95% CI]	Repetitive thought β (SE) [95% CI]	Somatic symptoms β (SE) [95% CI]
Bed time					
Within-person	−0.04^{+} (0.02) [−0.07, 0.0006]	0.04* (0.02) [0.002, 0.08]	0.007 (0.02) [−0.04, 0.05]	−0.03 (0.02) [−0.08, 0.02]	0.03 (0.03) [−0.04, 0.09]
Between-person	0.16^{+} (0.08) [−0.003, 0.32]	0.09 (0.08) [−0.07, 0.24]	0.19* (0.08) [0.04, 0.35]	−0.06 (0.08) [−0.22, 0.10]	0.07 (0.08) [−0.09, 0.23]
Wake time					
Within-person	0.004 (0.02) [−0.03, 0.04]	0.004 (0.02) [−0.03, 0.04]	−0.05* (0.02) [−0.10, −0.008]	−0.05* (0.02) [−0.09, −0.009]	0.0004 (0.02) [−0.04, 0.04]
Between-person	0.16* (0.08) [0.003, 0.32]	−0.10 (0.08) [−0.25, 0.05]	0.03 (0.08) [−0.13, 0.18]	−0.14^{+} (0.08) [−0.30, 0.01]	−0.03 (0.08) [−0.20, 0.14]
Total sleep					
Within-person	0.04* (0.02) [0.0009, 0.08]	−0.03 (0.02) [−0.07, 0.01]	−0.06* (0.02) [−0.10, −0.01]	−0.04^{+} (0.02) [−0.08, 0.004]	−0.03 (0.02) [−0.07, 0.008]
Between-person	0.01 (0.08) [−0.16, 0.17]	−0.24** (0.08) [−0.39, −0.09]	−0.23** (0.08) [−0.39, −0.08]	−0.19* (0.08) [−0.35, −0.03]	−0.16^{+} (0.08) [−0.33, 0.003]
Sleep latency					
Within-person	−0.02 (0.02) [−0.06, 0.02]	0.005 (0.02) [−0.03, 0.04]	0.03 (0.02) [−0.02, 0.07]	0.02 (0.02) [−0.03, 0.07]	0.03 (0.02) [−0.007, 0.07]
Between-person	−0.009 (0.08) [−0.17, 0.15]	0.02 (0.08) [−0.13, 0.17]	0.05 (0.08) [−0.10, 0.20]	0.05 (0.08) [−0.11, 0.20]	0.03 (0.08) [−0.14, 0.19]
Sleep quality					
Within-person	0.05* (0.02) [0.005, 0.09]	−0.006 (0.02) [−0.05, 0.03]	−0.02 (0.03) [−0.09, 0.04]	−0.03 (0.03) [−0.08, 0.02]	−0.01 (0.02) [−0.06, 0.03]
Between-person	0.30** (0.09) [0.13, 0.47]	−0.48** (0.09) [−0.62, −0.34]	−0.58** (0.07) [−0.71, −0.45]	−0.31** (0.08) [−0.48, −0.14]	−0.49** (0.08) [−0.65, −0.33]

Note: Analyses control for religiosity and subjective health.

**$p < 0.01$, *$p < 0.05$, $^{+}p < 0.10$.

reported better sleep during the wait for biopsy results also reported better well-being on every measure during the wait. Sleep latency did not predict any measure of well-being at the between-person level.

8 | DISCUSSION

The present investigation sought to test bidirectional links between well-being and sleep during a particularly challenging period of acute uncertainty: the wait for breast biopsy results. The findings provide mixed support for our hypotheses, although the pattern of effects is generally consistent with a protective role of positive emotion and a harmful role of negative emotion, anxiety, repetitive thought, and somatic symptoms, particularly for subjective sleep quality.

Positive emotion in particular emerged as the sole predictor of day-to-day sleep quality. That is, when people reported high levels of positive emotion on a given day compared to their typical level of positive emotion during the study, they then reported better sleep quality the following morning. Positive emotions have an 'undoing effect' on the physiological stress response that results from negative emotional experiences (e.g., Fredrickson et al., 2000; Fredrickson & Levenson, 1998), which may be a particularly useful function when it comes to buffering the effects of stressful uncertainty on sleep quality.

Surprisingly, negative markers of well-being did not predict sleep experiences at the within-person level. In contrast, these measures showed consistent between-person associations with various sleep experiences, such that people who reported more negative emotion, anxiety, and repetitive thoughts about breast cancer over the course of the wait for biopsy results also consistently reported poorer sleep quality and less total sleep (positive emotions and somatic symptoms also predicted sleep quality), as well as later bed times in the case of both positive emotion and anxiety. Numerous potential third-variable explanations could account for such between-person associations, but it is noteworthy that these associations emerged after controlling for well-being markers at the biopsy interview, as well as religiosity and subjective health, and held when controlling for intolerance of uncertainty. If associations between poor well-being and sleep experiences during the wait for biopsy results simply reflected a general tendency towards negative life experiences or even a negative reporting bias, those covariates would substantially reduce or even eliminate the links. Thus, our findings point to a context-specific, but not day-level, link between poor well-being and poor sleep experiences during the wait for biopsy results.

Although our data are correlational and thus cannot definitively test causal ordering between sleep and well-being, we also tested models predicting evening well-being from the previous night's sleep experiences. We would first note that more associations emerged in these models compared to the previous set, perhaps in part because we did not have sleep measures available at the biopsy appointment to control for typical sleep experiences in patients' lives (parallel with the measures of well-being available at the biopsy appointment). With that caveat, results from these models points to a fairly reliable day-over-day effect of sleep on well-being, such that later bedtimes predicted greater next-day negative emotion; earlier wake times predicted more next-day anxiety and repetitive thoughts; more total sleep predicted greater next-day positive emotion and lower next-day anxiety; and better sleep quality predicted greater next-day positive emotion. Consistent with our focal set of models, total sleep and sleep quality consistently predicted well-being at the between-person level, across the wait on average.

Taking these results together, we draw several conclusions. First, our findings support a bidirectional relationship between sleep and well-being, albeit one that varies across measures of both sleep and well-being. Second, positive emotion and sleep quality may be most consistently associated at a day-over-day level, such that getting a good night of sleep likely boosts positive emotions, and having a good day likely promotes sleep quality. Third, sleep latency is consistently unassociated with well-being, perhaps because people are unreliable in their perceptions of the latency between going to bed and falling asleep (addressed further below).

Our study had a number of strengths, namely the understudied sample (e.g., largely Latina, low income, low educational attainment), the daily assessment of sleep reports during a highly stressful period of uncertainty, and the varied measures of both well-being and sleep experiences. However, our study also had a number of notable limitations. We tested our hypotheses in a single sample at a single medical facility, which leaves open the question of generalisability, and our data are correlational, which leaves open questions regarding causal direction.

We also limited our study to (biological) females by necessity, given the very low rates of breast cancer among (biological) males. The association between sex or gender and sleep experiences is quite complex (see Krishnan & Collop, 2006, for a review), but we know of no evidence that would point to gender differences in the effect of well-being on sleep experiences. Nonetheless, future studies can test the generalisability of our findings in other stressful health contexts that are unique to males or that are not linked to biological sex or gender.

We also used self-reported sleep experiences, given the significant challenges associated with capturing objective measures of sleep in the daily lives of people undergoing a stressful health experience. We suspect that participants were not precisely accurate in recalling the time at which they went to bed, fell asleep, woke up, and got out of bed (e.g., see Lauderdale et al., 2008), nor were they precisely accurate in reporting their sleep quality. Thus, our conclusions address patients' perceptions of their sleep experiences, which may depart from objective reality. Of course, it is difficult to imagine how inaccuracy of sleep reports could account for many of our findings, for example, the between-person associations between poor well-being and sleep experiences after controlling for indicators of general negativity. Nonetheless, future work should attempt to replicate our findings with gold-standard assessments of sleep experiences (e.g., polysomnography).

We also saw considerable attrition from the initial biopsy interview through the daily surveys of interest in this investigation. The

full sample and the sample that completed daily surveys were largely equivalent on available measures, but those who completed the daily surveys were higher in health literacy, more likely to be cohabiting (if not married), and more likely to be English fluent. We expended considerable effort to retain all participants, but future research in more controlled settings (e.g., a university medical center or HMO) can attempt to replicate our findings with lower attrition.

Finally, because we relied on paper-and-pencil surveys for the daily measures, due to patients' unreliable access to the Internet, it is possible that some participants completed the daily surveys retrospectively (e.g., on the day they were to return the packet to the researcher). Given the well-established importance of sufficient and high-quality sleep, we encourage researchers to extend our findings to other samples with objective sleep measures and experimental methods.

Despite these limitations, our findings point to several potential targets for interventions to improve sleep during the wait for biopsy results or other medical tests and diagnostic procedures. First, positive emotions may be a key target to improve sleep during stressful waiting periods—and in fact, it may be easier to boost positive emotions during acute periods of uncertainty about one's health (e.g., by encouraging patients to seek out social interaction, spend time on hobbies, watch an enjoyable program) rather than attempting to eradicate the persistent worry and anxiety that almost inevitably arise during these periods. Second, it may be helpful to draw patients' attention to the importance of consistent sleep habits, noting that rising anxiety may interfere with their typical routine. These low-investment interventions, which could be readily administered at biopsy appointments via conversations with clinicians or an informational pamphlet, could serve to alleviate one challenge during the wait for biopsy results: getting a good night's sleep.

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CONFLICT OF INTEREST

All authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

Research materials and deidentified data are available on the Open Science Framework: https://osf.io/m6zwb/

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ENDNOTES

[1] We also explored associations between variability in sleep experiences (i.e., intraindividual standard deviations) and well-being but found no significant associations.

[2] Covariates used in these analyses were as follows: sadness at the appointment for negative emotion, happiness at the appointment for positive emotion, anxiety at the appointment for anxiety, somatic symptoms at the biopsy appointment for somatic symptoms, and repetitive thought at the appointment for repetitive thought.

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