Received: 17 December 2021 | Revised: 17 January 2022 | Accepted: 30 January 2022

DOI: 10.1111/jsr.13564

Journal of Sleep Research

RESEARCH ARTICLE

# Worry about COVID-19 as a predictor of future insomnia

Lily A. Brown[1] | Gabriella E. Hamlett[1] | Yiqin Zhu[1] | Joshua F. Wiley[2] | Tyler M. Moore[1,3] | Grace E. DiDomenico[3] | Elina Visoki[3] | David M. Greenberg[4] | Ruben C. Gur[1,3] | Raquel E. Gur[1,3] | Ran Barzilay[1,3,5]

[1]Department of Psychiatry, University of Pennsylvania Perelman School of Medicine, Philadelphia, Pennsylvania, USA

[2]School of Psychological Sciences and Turner Institute for Brain and Mental Health, Monash University, Clayton, Victoria, Australia

[3]Lifespan Brain Institute of the Children's Hospital of Philadelphia and Penn Medicine, Philadelphia, Pennsylvania, USA

[4]Bar Ilan University, Ramat Gan, Israel

[5]Children's Hospital of Philadelphia Department of Child Adolescent Psychiatry and Behavioral Sciences, Philadelphia, Pennsylvania, USA

**Correspondence**
Lily A. Brown, 3535 Market Street Suite 600N, Philadelphia, PA 19104, USA.
Email: lilybr@upenn.edu

**Funding information**
National Institute of Mental Health, Grant/Award Number: K23MH120437

## Summary

The coronavirus disease 2019 (COVID-19) pandemic resulted in significant increases in insomnia, with up to 60% of people reporting increased insomnia. However, it is unclear whether *exposure to risk factors* for the virus or *worries* about COVID-19 are more strongly associated with insomnia. Using a three-part survey over the course of the first 6 months of the pandemic, we evaluated associations between COVID-19 exposures, COVID-19 worries, and insomnia. We hypothesised that COVID-19-related worries and exposure to risk of COVID-19 would predict increases in insomnia. Participants ($N$ = 3,560) completed a survey at three time-points indicating their exposures to COVID-19 risk factors, COVID-19-related worries, and insomnia. COVID-19 worry variables were consistently associated with greater insomnia severity, whereas COVID-19 exposure variables were not. COVID-19 worries decreased significantly over time, and there were significant interactions between change in COVID-19 worries and change in insomnia severity over time. Individuals who experienced increases in COVID-19 worries also experienced increases in insomnia severity. Changes in worry during the COVID-19 pandemic were associated with changes in insomnia; worries about COVID-19 were a more consistent predictor of insomnia than COVID-19 exposures. Evidence-based treatments targeting virus-related worries may improve insomnia during this and future calamities.

**KEYWORDS**
anxiety, health-anxiety, psychology, sleep

## 1 | INTRODUCTION

Insomnia, the subjective perception of an inability to fall or stay asleep or early morning awakenings, occurs in 10%–30% of the population and can cause significant distress and impairment (Aernout et al., 2021; American Psychiatric Association, 2013; Dopheide, 2020; Ohayon, 2002; Sivertsen, Hysing, Harvey, & Petrie, 2021). Insomnia has significant deleterious consequences on physical health, including high blood pressure, congestive heart failure, diabetes, and stroke (Quan, 2009; Sofi et al., 2014). In addition, individuals with insomnia have a significantly elevated risk for psychiatric comorbidities, including major depressive disorder (MDD), post-traumatic stress disorder (PTSD), and generalised anxiety disorder (GAD) (Ford & Kamerow, 1989; Ohayon & Shapiro, 2000; Riemann, 2007; Soldatos, 1994).

During the global coronavirus disease 2019 (COVID-19) pandemic, 30%–60% of people reported increased insomnia symptoms, representing a doubling or tripling of risk (Cai et al., 2020; Gao & Scullin, 2020; Huang et al., 2020; Pappa et al., 2020; Zhan et al., 2020; Zhao et al., 2020). Given that the COVID-19 pandemic has far-reaching consequences on health, finances, job security, and social connection, each of which are independent predictors of insomnia (Burgard & Ailshire, 2009; Hamilton et al., 2007; Léger, Guilleminault, Bader, Lévy, & Paillard, 2002), it is important to understand which

  

aspects of the pandemic are associated with insomnia symptoms. Identifying the key drivers of insomnia can inform appropriate interventions to reduce insomnia symptoms during the COVID-19 pandemic and future calamities.

The tendency to worry before and in bed is associated with sleep interference and other adverse mental health outcomes (Bajaj, Blair, Schwartz, Dobbertin, & Blair, 2020; Harvey, 2002). Worries about COVID-19 in particular may exacerbate symptoms of insomnia during the pandemic, as demonstrated by cross-sectional data from India (Bajaj et al., 2020), China (Huang et al., 2020; Zhan et al., 2020; Zhang et al., 2020), Greece (Voitsidis et al., 2020), and France (Kokou-Kpolou, Megalakaki, Laimou, & Kousouri, 2020). In addition, the association between worry during the pandemic and subsequent depression is mediated by insomnia (Bajaj et al., 2020), which is independently associated with other negative health outcomes (Balikji et al., 2018; Grandner, Jackson, Pak, & Gehrman, 2012).

Emerging evidence also suggests that exposure to COVID-19 risk factors, such as knowing someone who tested positive for the virus, may account for increases in insomnia. For instance, healthcare workers who were directly exposed to patients who tested positive for COVID-19 were at higher risk of insomnia (Li et al., 2020; Zhan et al., 2020). However, it is not clear whether actual *exposure to risk factors* for COVID-19 or *worries* about the virus are more strongly associated with insomnia symptoms. One study found that individuals who were uncertain about whether their family had contracted the virus experienced more severe insomnia than individuals who *knew* that their family had contracted the virus (Voitsidis et al., 2020). This finding suggests that worries about the virus may be more predictive of insomnia symptoms than exposure to the virus itself, but more research is needed to understand the relative importance of worries about COVID-19 versus exposure to risk factors when predicting insomnia. This research could inform which individuals would benefit the most from intervention: those at highest risk of exposure to COVID-19, or those with greater worries about the virus regardless of exposure risk. In addition, research is needed to evaluate longitudinal associations between exposure to risk factors, worry, and insomnia over time.

This study aimed to investigate the associations among COVID-19-related exposures, worries about COVID-19, and changes in insomnia symptoms. We disseminated a survey at three time-points throughout a 6-month period between April and August 2020 using an interactive crowdsourcing research website to measure insomnia symptoms (www.covid19resilience.org). We assessed COVID-19-related worries (e.g., worries about contracting COVID-19, dying of COVID-19, family contracting COVID-19, unknowingly infecting others, having COVID-19, and finances); exposures related to COVID-19 (e.g., getting tested for COVID-19, having symptoms of COVID-19, knowing someone who tested positive for COVID-19, knowing someone who died from COVID-19, and job loss during the pandemic), and insomnia symptoms using the Insomnia Severity Index (ISI). We hypothesised that COVID-19-related worries and exposures both would predict increases in insomnia.

## 2 | METHODS

### 2.1 | Participants

Participants were recruited to complete a survey offered in English or Hebrew through a crowdsourcing website (Barzilay et al., 2020). The study was advertised through: (1) the researchers' social networks, including emails to colleagues around the world; (2) social media; (3) the University of Pennsylvania and Children's Hospital of Philadelphia internal notifications and websites; and (4) organisational mailing lists. As described in Table 1, participants ($N$ = 3,560) had a mean (range) age of 40 (13–90) years and were mostly women. The majority identified as White participants, and the majority reported being located in the United States. While recruitment was open across the lifespan, only 80 participants were aged <18 years during completion of the first survey. In addition to information reported in Table 1, participants endorsed self-reported history of diagnoses of the following: attention-deficit hyperactivity disorder (304 participants), anorexia (96), autism spectrum disorder (21), bipolar disorder (112), intellectual disability (42), language delay (seven), obsessive compulsive disorder (134), personality disorder (28), schizophrenia (four), and PTSD (86). On a single item assessing physical health ("Compared to others your age, how would you rate your physical health?") about half of the sample (43%) reported good health, one-quarter (24%) reported excellent health, one-quarter (24%) reported average health, and the remainder reported below average health or preferred not to specify.

### 2.2 | Measures

#### 2.2.1 | The ISI

The ISI is a seven-item assessment of insomnia symptoms over the prior 2 weeks, with items rated on a scale ranging from 0 ("no problems") to 4 ("very severe") (Bastien, Vallières, & Morin, 2001). The ISI is a reliable and valid instrument to determine perceived insomnia severity (Bastien et al., 2001). Total scores are categorised as not clinically significant (0–7), subthreshold insomnia (8–14), moderate insomnia (15–21), or severe insomnia (22–28).

#### 2.2.2 | COVID-19-related worries

Participants were asked to indicate to what degree they were worried about a variety of COVID-19-related outcomes on a 0 ("not at all") to 4 ("a great deal") point Likert scale that was developed for this survey. Worries included: (1) Contracting COVID-19; (2) Dying from COVID-19; (3) Family members contracting COVID-19; (4) Unknowingly infecting others with COVID-19; (5) Currently having COVID-19; and (6) Having significant financial burden because of the COVID-19 pandemic.

**TABLE 1** Demographics of sample who had Insomnia Severity Index available at Times 1–3

| Variable | Time 1 *N* = 3,560 | Time 2 *N* = 1,282 | Time 3 *N* = 944 |
|---|---|---|---|
| Age, years, mean (SD) | 42.56 (14.24) | 40.55 (13.47) | 41.25 (14.16) |
| Sex, *n* (%) | | | |
| Men | 782 (21.97) | 230 (17.94) | 157 (16.63) |
| Women | 2766 (77.70) | 1050 (81.90) | 786 (83.26) |
| Missing | 12 (0.33) | 2 (0.15) | 1 (0.11) |
| Race, *n* (%) | | | |
| White | 3067 (86.15) | 1142 (89.08) | 855 (90.57) |
| Other | 469 (13.17) | 135 (10.52) | 85 (9.00) |
| Missing | 15 (0.42) | 5 (0.40) | 4 (0.42) |
| Clinical diagnosis, *n* (%) | | | |
| GAD | 749 (21.04) | 321 (25.04) | 220 (23.31) |
| No GAD | 2811 (78.96) | 961 (74.96) | 724 (76.69) |
| MDD | 790 (22.19) | 313 (24.41) | 218 (23.09) |
| No MDD | 2770 (77.81) | 969 (75.59) | 726 (76.91) |
| Country, *n* (%) | | | |
| Israel | 601 (16.88) | 203 (15.83) | 146 (15.47) |
| USA | 2650 (74.43) | 1000 (78.00) | 745 (78.92) |
| Other country/missing | 399 (11.21) | 79 (6.16) | 0 (0.00) |

GAD, generalised anxiety disorder; MDD, major depressive disorder.

#### 2.2.3 | COVID-19-related exposures

Participants were asked to rate whether they had experienced the following: (1) Being tested for COVID-19; (2) Having experienced symptoms that they feel may be related to COVID-19; (3) Knowing anyone who tested positive for COVID-19; (4) Knowing someone who died from COVID-19; and (5) Job loss/reduced pay since the start of the COVID-19 pandemic. These variables were scored as "Yes" = 1 (experienced) or "No" = 0 (not experienced).

#### 2.2.4 | Mental health diagnoses

Participants were asked whether they had received a diagnosis of MDD or GAD prior to the COVID-19 pandemic.

### 2.3 | Procedure

The study was approved by the Institutional Review Board of the University of Pennsylvania. After completion of online informed consent, the survey followed and provided personalised feedback on participants' responses. The feedback aimed to enhance well-being and was offered as an incentive to participate and complete follow-up surveys, which were delivered to those who provided their email address and consent for future contact. The Time 1 (T1) survey occurred from April 6 to May 5, 2020; Time 2 (T2) occurred between May 12 and June 21; Time 3 (T3) occurred between August 25 and September 27, 2020.

### 2.4 | Data analytic plan

The present analysis was conducted on data from participants who provided their email at T1 ($N = 3,560$) and consented for future contact, from which 1,282 provided data at T2, and 944 provided data at T3. A total of 672 participants had data at all three time-points. Participants who completed T2 ($p < 0.001$) were significantly older at T1 than participants who did not, but there were no differences in age at T1 based on participants who were missing at T3. Male and White participants were significantly more likely to not complete the T2 and T3 assessments (all $p < 0.001$), as were participants with a self-reported diagnosis of GAD ($p < 0.05$) or MDD (only at T2, $p < 0.01$). Participants in Israel were less likely to complete the observations at T2 and T3 (all $p < 0.01$). Therefore, these variables were included as covariates in sensitivity analyses throughout. Table S1 provides comparisons between participants who provided longitudinal data and those who were lost to follow-up.

Cross-sectional multiple logistic regression analyses were run to establish the relative influence of COVID-19-related exposures variables and COVID-19-related worries variables (independent variables) in predicting ISI score (insomnia severity, the dependent variable) at each time-point. These analyses were repeated after controlling for age, gender, race (White participants, Other race), country (United

States, Israel), self-reported history of depression, and self-reported history of GAD. Then, mixed effects multilevel models were run in which observations across time were nested within participants, with time centred at T1 to allow for a determination of differences at baseline. Because surveys were completed ~1 and 5 months after baseline, time was coded in months. Mixed effects models included random intercepts and random effects of time and unstructured covariance matrices. Random slopes and intercepts of key variables from

**TABLE 2** Cross-sectional multivariable regression results predicting insomnia severity index severity from coronavirus disease 2019 (COVID-19)-related exposures and COVID-19-related worries

| Time point | *B* (SE) | *t* | *p* |
|---|---|---|---|
| Time 1 (Adjusted $R^2 = 0.1133$) | | | |
| COVID-19-related exposures | | | |
| Being tested for COVID-19 | 0.484 (0.326) | 1.48 | 0.138 |
| Experiencing symptoms of COVID-19 | 0.747 (0.212) | 3.52 | <0.001 |
| Knowing someone who tested positive for COVID-19 | −0.173 (0.193) | −0.90 | 0.370 |
| Knowing someone who died from COVID-19 | 1.022 (0.307) | 3.33 | 0.001 |
| Job loss/pay reduction due to COVID-19 | −0.439 (0.246) | −1.79 | 0.074 |
| COVID-19-related worries | | | |
| Worries about getting COVID-19 | 0.155 (0.137) | 1.13 | 0.258 |
| Worries about dying from COVID-19 | 0.236 (0.117) | 2.01 | 0.044 |
| Worries about family contracting COVID-19 | 0.470 (0.119) | 3.94 | <0.001 |
| Worries about infecting others | 0.234 (0.099) | 2.35 | 0.019 |
| Worries about having COVID-19 | 0.543 (0.110) | 4.95 | <0.001 |
| Worries about finances due to COVID-19 | 0.719 (0.083) | 8.64 | <0.001 |
| Time 2 (Adjusted $R^2 = 0.1493$) | | | |
| COVID-19-Related Exposures | | | |
| Being tested for COVID-19 | 0.470 (0.463) | 1.01 | 0.311 |
| Experiencing symptoms of COVID-19 | 0.581 (0.324) | 1.79 | 0.073 |
| Knowing someone who tested positive for COVID-19 | 0.440 (0.303) | 1.45 | 0.147 |
| Knowing someone who died from COVID-19 | 0.711 (0.425) | 1.67 | 0.095 |
| Job loss/pay reduction due to COVID-19 | −0.608 (0.380) | −1.60 | 0.110 |
| COVID-19-related worries | | | |
| Worries about getting COVID-19 | −0.108 (0.229) | −0.47 | 0.637 |
| Worries about dying from COVID-19 | 0.478 (0.206) | 2.32 | 0.020 |
| Worries about family contracting COVID-19 | 0.797 (0.190) | 4.18 | <0.001 |
| Worries about infecting others | −0.217 (0.159) | −1.37 | 0.172 |
| Worries about having COVID-19 | 0.992 (0.193) | 5.15 | <0.001 |
| Worries about finances due to COVID-19 | 0.962 (0.132) | 7.27 | <0.001 |
| Time 3 (Adjusted $R^2 = 0.1284$) | | | |
| COVID-19-related exposures | | | |
| Being tested for COVID-19 | 0.372 (0.336) | 1.11 | 0.268 |
| Knowing someone who tested positive for COVID-19 | −0.537 (0.371) | −1.45 | 0.148 |
| Knowing someone who died from COVID-19 | 1.421 (0.415) | 3.42 | 0.001 |
| Job loss/pay reduction due to COVID-19 | 0.395 (0.453) | 0.87 | 0.383 |
| COVID-19-related worries | | | |
| Worries about getting COVID-19 | −0.112 (0.262) | −0.45 | 0.654 |
| Worries about dying from COVID-19 | 0.454 (0.226) | 2.01 | 0.045 |
| Worries about family contracting COVID-19 | 0.459 (0.222) | 2.06 | 0.040 |
| Worries about infecting others | 0.155 (0.177) | 0.88 | 0.382 |
| Worries about having COVID-19 | 0.441 (0.224) | 1.97 | 0.049 |
| Worries about finances due to COVID-19 | 0.995 (0.156) | 6.39 | <0.001 |

the cross-sectional analyses (e.g., COVID-19-related worries) were extracted to allow for an examination of interactions between these key variables and change over time in ISI severity.

Given that there was some evidence for bidirectionality in the multilevel models (described below), we followed these analyses with a cross-lagged panel analysis to directly test directionality between Worry (calculated as a total score, a sum of all Worry variables to reduce the number of analyses) and ISI severity. We followed established procedures for this evaluation (Brown et al., 2015, 2018, 2019; Martens & Haase, 2006) using MPlus software. This procedure involves testing a series of four models to evaluate directional associations between two variables. Model 1 included only autoregressive paths, reflecting stability over time. Model 2 added paths from one construct (sleep at baseline) to the second construct at the subsequent time-point (worry at 1 month; Figure 2) in addition to the autoregressive paths. Model 3 added paths in the opposite direction to the autoregressive model: worry at baseline predicting sleep at 1 month. Model 4 included bidirectional paths (essentially, this is the combination of Model 2 and 3). Model fit was evaluated, and chi-square difference tests compared the fit of the models. After determining optimal model fit, a follow-up "constrained analysis" was conducted to compare model fit wherein cross-lagged path coefficients were constrained to be equal versus freely estimated. In other words, this model constrained the path from sleep at baseline -> worry at 1 month to be equal to the path from worry at baseline -> sleep at 1 month. Then, model fit was compared between the constrained versus freely estimated model, allowing for a determination of whether constraining the paths to be equal worsened model fit (an indication that one direction is stronger than the other, providing evidence for unidirectionality as opposed to bidirectionality). As we discuss elsewhere (Brown et al., 2015), the correlation matrix must be imported for this constrained analysis, which was calculated using full-information maximum likelihood to account for missing data using corFiml in the "psych" package in R (Revelle, 2013). The results of this constrained analyses must be interpreted with caution, although the comparison between the constrained and unconstrained model can provide useful information about strength of directionality.

## 3 | RESULTS

### 3.1 | Cross-sectional multivariable results

When all T1 COVID-19-related exposures and worries were entered into a simultaneous model, experiencing symptoms of COVID-19 ($p < 0.001$), knowing someone who died from COVID-19 ($p < 0.01$), worries about dying of COVID-19 ($p < 0.01$), worries about family contracting COVID-19 ($p < 0.001$), worries about infecting others with COVID-19 ($p < 0.05$), worries about having COVID-19 ($p < 0.001$), and financial worries were each significantly associated with insomnia severity ($p < 0.001$), whereas being tested for COVID-19 ($p = 0.138$), knowing someone who tested positive for COVID-19 ($p = 0.370$), experiencing job loss ($p = 0.074$), and worries about getting COVID-19 ($p = 0.258$) were not associated with ISI severity (Table 2). These results did not change after the inclusion of covariates. Multicollinearity was low (mean variance inflation factor [VIF] = 1.46).

At T2, when all exposure and worry variables were entered into a simultaneous model, worries about dying of COVID-19 ($p < 0.05$), worries about family contracting COVID-19 ($p < 0.001$), worries about having COVID-19 ($p < 0.001$), and financial worries were all significant predictors of ISI severity ($p < 0.001$), whereas all of the exposure variables and worries about getting COVID-19 and infecting others with COVID-19 were not (all $p > 0.073$). These results did not change with the inclusion of covariates. Multicollinearity was low (mean VIF = 1.45).

At T3, when all exposure and worry variables were entered into a simultaneous model, knowing someone who died from COVID-19 ($p < 0.01$), worries about dying of COVID-19 ($p < 0.05$), worries about family contracting COVID-19 ($p < 0.05$), worries about having COVID-19 ($p < 0.05$), and worries about finances were each significantly associated with ISI severity ($p < 0.001$). When covariates were included, only knowing someone who died from COVID-19 ($t = 3.32$, B = 1.357, SE = 0.409, $p < 0.01$) and worries about finances remained significantly associated with ISI severity ($t = 6.47$, B = 1.015, SE = 0.157, $p < 0.001$). Of note, the questions assessing self-reported symptoms of COVID-19 were not collected at T3. Multicollinearity was low (mean VIF = 1.45).

### 3.2 | Longitudinal analyses

Given that worry variables were consistently associated with ISI severity in multivariable cross-sectional analyses, whereas exposure variables were less consistently associated with ISI severity, longitudinal models

**TABLE 3** Change in coronavirus disease 2019 (COVID-19) worry variables over time

| Worries | *B* (95% CI) | *z* | *p* |
|---|---|---|---|
| Contracting COVID-19 | | | |
| Time | −0.018 (−0.0300, −0.005) | −2.74 | 0.006 |
| Intercept | 1.792 (1.769, 1.815) | 153.58 | <0.001 |
| Dying from COVID-19 | | | |
| Time | −0.026 (−0.038, −0.015) | −4.63 | <0.001 |
| Intercept | 1.129 (1.104, 1.154) | 89.37 | <0.001 |
| Currently having COVID-19 | | | |
| Time | −0.044(−0.057, −0.032) | −6.83 | <0.001 |
| Intercept | 0.878(.856,.900) | 78.55 | <0.001 |
| Family contracting COVID-19 | | | |
| Time | 0.025 (−0.038, −0.012) | −3.84 | <0.001 |
| Intercept | 2.494 (2.469, 2.517) | 206.19 | <0.001 |
| Infecting others with COVID-19 | | | |
| Time | −0.017 (−0.0329, −0.003) | −2.28 | 0.023 |
| Intercept | 2.129 (2.103,2.155) | 160.37 | <0.001 |
| Financial burden due to COVID-19 | | | |
| Time | −0.044 (−0.059, −0.0289) | −5.8 | <0.001 |
| Intercept | 1.428 (1.402,1.456) | 102.75 | <0.001 |

were run to evaluate the change in worry variables as predictors of the change in ISI severity. There were significant reductions in all worry variables over time (Table 3). Across all participants, a multilevel model with observations nested within participants and a random intercept and slope revealed that there was not a significant change in ISI over time ($p = 0.522$). However, there were significant interactions between Time and the Slope of all Worry variables (Table 4, all $p \leq 0.01$). Specifically, individuals who experienced increases in Worries about COVID-19 also experienced increases in ISI severity over time (see Figure 1a,b, for examples). However, a reverse multilevel model also demonstrated that there were significant interactions between Time and the Slope of ISI on all of the Worry variables (Table 5, all $p \leq 0.05$).

### 3.3 | Cross-lagged panel analysis

Both Model 2 (ISI – > Worry Total Score, Figure 2b, chi-squared (2) = 13.59, $p < 0.01$) and Model 3 (Worry Total Score – > ISI,

**TABLE 4** Longitudinal analyses exploring change in Insomnia Severity Index by change in worries

| | *B* (95% CI) | *z* | *p* |
|---|---|---|---|
| ISI | | | |
| Time | 0.023 (−0.046, 0.093) | 0.66 | 0.509 |
| Slope of Worries-Getting COVID-19 | −0.241 (−7.394, 6.912) | −0.07 | 0.947 |
| Time × Slope of Worries-Getting COVID-19 | 2.250 (1.001, 3.498) | 3.53 | <0.001 |
| Intercept of Worries-Getting COVID-19 | 1.725 (1.238, 2.211) | 6.95 | <0.001 |
| Intercept | 4.645 (3.857, 5.432) | 11.56 | <0.001 |
| ISI | | | |
| Time | 0.070 (−0.016, 0.156) | 1.60 | 0.110 |
| Slope of Worries-Dying from COVID-19 | 118.684 (32.035, 204.868) | 2.69 | 0.007 |
| Time × Slope of Worries-Dying from COVID-19 | 3.354 (1.164, 5.544) | 3.00 | 0.003 |
| Intercept of Worries-Dying from COVID-19 | 5.995 (2.680, 9.309) | 3.54 | <0.001 |
| Intercept | 4.151 (2.670, 5.613) | 5.57 | <0.001 |
| ISI | | | |
| Time | 0.086 (−0.004, 0.176) | 1.87 | 0.062 |
| Slope of Worries-Family getting COVID-19 | −5.735 (−18.583, 7.113) | −0.87 | 0.382 |
| Time × Slope of Worries-Family getting COVID-19 | 4.224 (1.746, 6.702) | 3.34 | 0.001 |
| Intercept of Worries-Family getting COVID-19 | 1.720 (1.333, 2.107) | 8.72 | <0.001 |
| Intercept | 3.338 (2.588, 4.087) | 8.73 | <0.001 |
| ISI | | | |
| Time | 0.037 (−0.038, 0.112) | 0.97 | 0.33 |
| Slope of Worries-Infecting others w/COVID-19 | −2.609 (−10.574, 5.357) | −0.64 | 0.521 |
| Time × Slope of Worries-Infect others w/COVID-19 | 3.195 (1.377, 5.014) | 3.44 | 0.001 |
| Intercept of Worries-Infect others w/COVID-19 | 1.462 (1.200, 1.723) | 10.94 | <0.001 |
| Intercept | 4.615 (4.089, 5.141) | 17.2 | <0.001 |
| ISI | | | |
| Time | 0.094 (0.022, 0.187) | 2.01 | 0.045 |
| Slope of Worries-Having COVID-19 | 10.179 (−5.612, 25.971) | 1.26 | 0.206 |
| Time × Slope of Worries-Having COVID-19 | 2.679 (1.094, 4.264) | 3.31 | 0.001 |
| Intercept of Worries-Having COVID-19 | 3.141 (1.972, 4.310) | 5.27 | <0.001 |
| Intercept | 5.507 (5.081, 5.935) | 25.27 | <0.001 |
| ISI | | | |
| Time | 0.041 (−0.041, 0.122) | 0.97 | 0.33 |
| Slope of Worries-Finances due to COVID-19 | 9.715 (3.181, 16.249) | 2.91 | 0.004 |
| Time × Slope of Worries-Finances due to COVID-19 | 1.582 (0.382, 2.782) | 2.58 | 0.01 |
| Intercept of Worries-Finances due to COVID-19 | 2.101 (1.735, 2.467) | 12.08 | <0.001 |
| Intercept | 5.277 (4.919, 5.635) | 28.87 | <0.001 |

COVID-19, coronavirus disease 2019; ISI, Insomnia Severity Index.

Figure 2c, chi-squared (2) = 17.81, $p < 0.001$) significantly improved model fit relative to Model 1 (Autoregressive Model; column 5, Table 6, Figure 2a). Model 4, which contained bidirectional paths between ISI and Worry Total Score, significantly improved model fit above and beyond Model 2 (chi-squared (2) = 16.70, $p < 0.001$) and 3 (chi-squared (2) = 12.38, $p < 0.01$; column 6, Table 6, Figure 2d). However, the constrained model had significantly worsened fit relative to the model with freely estimated paths (chi-squared (2) = 25.90, $p < 0.001$; column 7, Table 6). Examination of parameter estimates from Model 4 revealed that the strength of the association from ISI − > Worry was larger than from Worry − > ISI. However, the only significant cross-lagged paths were earlier in the longitudinal model (from baseline to one-month, and not from one- to four-months).

## 4 | DISCUSSION

Across three observations over the initial phase of the COVID-19 pandemic in the United States (April–August 2020), greater severity of COVID-19-related worries was consistently associated with elevations in insomnia symptom severity over and above COVID-19-related exposure. In contrast, COVID-19-related exposures were inconsistently associated with insomnia severity after controlling for COVID-19-related worries. This pattern of findings held after controlling for a variety of demographic factors as well as a self-reported history of GAD and MDD. In longitudinal analysis, the extent of change in COVID-19-related worries over time was associated with the extent of change in insomnia severity over time. As worries about COVID-19 became more severe, insomnia worsened over time. Among individuals who reported lessened severity of COVID-19 worries, insomnia improved. The opposite direction (in which sleep predicted COVID-19) was also observed but was not as consistent as the prediction from worries to insomnia. These findings suggest that the *interpretation* of risk about COVID-19, rather than exposure to risk factors for COVID-19 itself, influenced insomnia severity over time and there was some evidence to support unidirectionality for this association.

The findings from this study are consistent with prior cross-sectional studies. Specifically, in a Greek sample, worries about COVID-19 were associated with elevations in insomnia severity (Voitsidis et al., 2020). In this prior study, participants who reported "not knowing" whether they or their loved ones contracted COVID-19 had more severe insomnia than individuals who were certain that they or their loved ones had contracted the virus (Voitsidis et al., 2020). This is notable in that it provides further evidence that worries about the virus (or uncertainty in contemporary research, which may lead to worries) may account for more variance in sleep disruptions than exposure to the risk of the virus per se. Similarly, in China, COVID-related stress was associated with worsened insomnia symptoms during the pandemic (Yun et al., 2020; Zhang et al., 2020), as was increased non-specific (i.e., generalised) worry (Huang et al., 2020). France also had cross-sectional research demonstrating an association between COVID-19-related worries and insomnia (Zhao et al., 2020). The present study replicates these findings in a sample of individuals primarily from the United States and Israel, adding a key longitudinal perspective on the dynamics of worries and sleep over time during a chronic global stressor.

Consistent with at least one prior study (Huang et al., 2020), insomnia symptoms did not significantly change over time in this study over the entire sample. Some other studies have found evidence for increased insomnia and anxiety during the pandemic (Cai et al., 2020; Gao & Scullin, 2020). Our study potentially explains this discrepancy. Specifically, individuals with heightened COVID-19-related worries

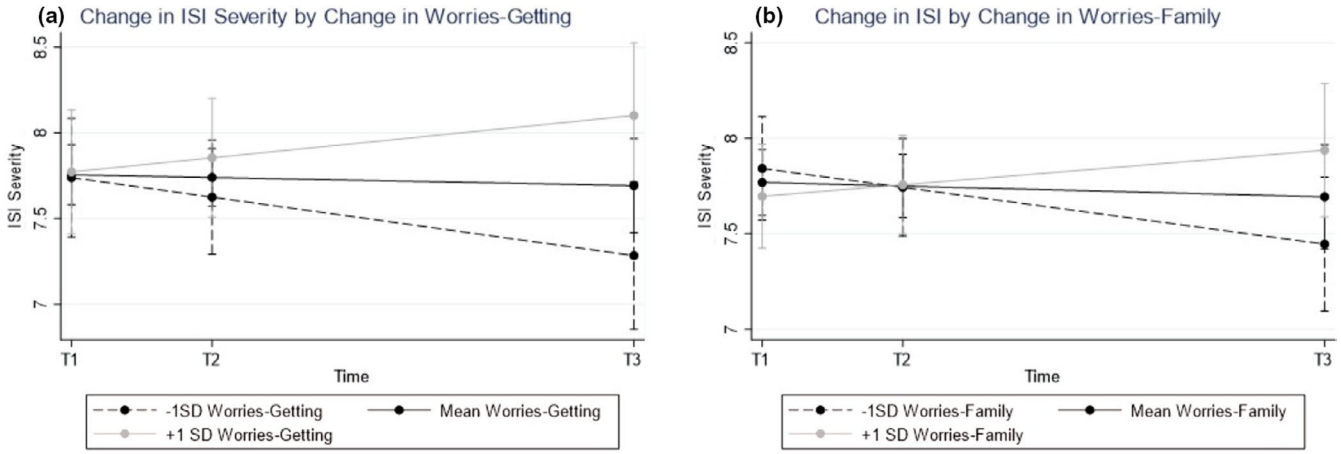


**FIGURE 1** (a) Change in Insomnia Severity Index (ISI) by change in worries about getting COVID-19. Lines indicate participants who were at the mean in change in worries about getting COVID-19 over time ("Mean Worries-Getting"), 1 standard deviation (SD) below the mean in changes in worries about getting COVID-19 over time ("−1 SD Worries-Getting"), or 1 SD above the mean in changes in worries about getting COVID-19 over time ("+1 SD Worries-Getting"). (b) Change in ISI by change in worries about Family contracting COVID-19. The lines indicate participants who were at the mean in change in worries about family getting COVID-19 over time ("Mean Worries-Family"), 1 SD below the mean in changes in worries about family getting COVID-19 over time ("−1 SD Worries-Family"), or 1 SD above the mean in changes in worries about family getting COVID-19 over time ("+1 SD Worries-Family")

**TABLE 5** Longitudinal analyses exploring change in Worries by change in Insomnia Severity Index

| | *B* (95% CI) | *z* | *p* |
|---|---|---|---|
| Worries about getting COVID-19 | | | |
| Time | −0.021 (−0.034, −0.009) | −3.27 | 0.001 |
| ISI Slope | −0.173 (−0.367, 0.023) | −1.73 | 0.083 |
| Time × ISI Slope | 0.065 (0.020, 0.110) | 2.85 | 0.004 |
| ISI Intercept | 0.044 (0.033, 0.054) | 8.19 | <0.001 |
| Intercept | 1.494 (1.410, 1.579) | 34.81 | <0.001 |
| Worries about dying of COVID-19 | | | |
| Time | −0.028 (−0.039, −0.016) | −4.72 | <0.001 |
| ISI Slope | −0.170 (−0.384, 0.045) | −1.55 | 0.121 |
| Time × ISI Slope | 0.077 (0.038,0.116) | 3.84 | <0.001 |
| ISI Intercept | 0.047 (0.036, 0.059) | 8.04 | <0.001 |
| Intercept | 0.786 (0.693, 0.879) | 16.61 | <0.001 |
| Worries about family contracting COVID-19 | | | |
| Time | −0.024 (−0.037, −0.012) | −3.73 | <0.001 |
| ISI Slope | −0.068 (−0.274, 0.138) | −0.64 | 0.520 |
| Time × ISI Slope | 0.064 (0.020, 0.108) | 2.85 | 0.004 |
| ISI Intercept | 0.058 (0.047, 0.069) | 10.17 | <0.001 |
| Intercept | 2.061 (1.972, 2.151) | 45.09 | <0.001 |
| Worries about infecting others with COVID-19 | | | |
| Time | −0.017 (−0.033, −0.002) | −2.19 | 0.028 |
| ISI Slope | −0.188 (−0.413, 0.037) | −1.64 | 0.101 |
| Time × ISI Slope | 0.073 (0.020, 0.125) | 2.71 | 0.007 |
| ISI Intercept | 0.049 (0.036, 0.061) | 7.78 | <0.001 |
| Intercept | 1.764 (1.667, 1.863) | 35.29 | <0.001 |
| Worries about having COVID-19 | | | |
| Time | −0.039 (−0.052, −0.026) | −5.87 | <0.001 |
| ISI Slope | −0.141 (−0.320, 0.039) | −1.53 | 0.125 |
| Time × ISI Slope | 0.062 (0.016, 0.108) | 2.63 | 0.008 |
| ISI Intercept | 0.047 (0.037, 0.056) | 9.75 | <0.001 |
| Intercept | 0.496 (0.420, 0.573) | 12.71 | <0.001 |
| Worries about finances during COVID-19 | | | |
| Time | −0.035 (−0.050, −0.020) | −4.54 | <0.001 |
| ISI Slope | 0.161 (−0.072, 0.394) | 1.35 | 0.176 |
| Time × ISI Slope | 0.057 (0.005, 0.109) | 2.15 | 0.032 |
| ISI Intercept | 0.077 (0.064, 0.089) | 12.06 | <0.001 |
| Intercept | 0.784 (0.683, 0.884) | 15.30 | <0.001 |

COVID-19, coronavirus disease 2019; ISI, Insomnia Severity Index.

experienced worsened insomnia, whereas individuals without these worries were protected from sleep disruption. However, prior studies did not measure changes in COVID-19-related worries over time, nor the impact of changes in COVID-19-related worries on insomnia. Our study adds to the literature in this regard.

In contrast to some prior studies (Sofi et al., 2014), being tested for COVID-19 did not emerge as an important predictor of insomnia symptoms. One prior study reported that being infected with COVID-19 was associated with an increased risk of clinically significant insomnia, but the odds ratio reported in their study actually indicated a *decreased* risk of insomnia (Kokou-Kpolou et al., 2020). In the present study, some exposure variables were associated with insomnia severity at a given time-point, which suggests that under certain circumstances these risk factors may be important to consider. In particular, knowing someone who died from COVID-19 was consistently associated with increased severity of insomnia at all time-points. However, this variable did not remain significant in all multivariable models. In contrast, all worry variables were associated with insomnia severity at all time-points regardless of covariate inclusion. In multivariable models, worry variables remained consistently associated with ISI severity over and above the influence of exposure variables.

Clinically, these findings suggest that it might be worthwhile to help individuals manage their COVID-19-related worries, although more research is needed. Existing research suggests that healthcare workers who are directly exposed to COVID-19 patients are at higher risk of insomnia (Li et al., 2020; Zhan et al., 2020). However, the present study suggests that increased risk of insomnia may be attributable to worries about COVID-19 as opposed to direct exposure to risk. This series of findings has implications for cognitive behavioural therapy, an evidence-based treatment for chronic worry (Covin, Ouimet, Seeds, & Dozois, 2008) that also results in significant improvements in insomnia symptoms (Harvey & Tang, 2003). Because healthcare workers and community members cannot completely reduce their risk of contracting COVID-19, it might be worthwhile to offer strategies to improve their worry (or ability to cope with worry), with the hope that this might reduce insomnia symptoms.

There are several notable limitations of this study. First, the majority of respondents were White participants and women, which is important as some studies have found that insomnia was elevated among women during the pandemic (Kang et al., 2020; Li et al., 2020). COVID-19 and COVID-19-related insomnia have

**TABLE 6** Cross-lagged panel analysis fit indices

| Model | df | chi-squared | Scale correlation factor | Satorra–Bentler scaled chi-squared from base model | Satorra–Bentler scaled chi-squared from full model | Constrained versus freely estimated model difference (using correlation matrix) | CFI | TLI | AIC | AIC difference from base model | AIC difference from full model | SRMR | RMSEA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Auto-regressive | 6 | 31.55 | 1.14 | - | 30.38** | - | 0.989 | 0.975 | 90183.8 | - | 26.4 | 0.04 | 0.02 |
| Sleep -> Worry | 4 | 18.13 | 1.161 | 13.59* | 16.70** | - | 0.994 | 0.979 | 90172.9 | -10.9 | 15.5 | 0.02 | 0.02 |
| Worry -> Sleep | 4 | 13.45 | 1.125 | 17.81** | 12.38* | - | 0.996 | 0.986 | 90167.0 | -16.8 | 9.6 | 0.03 | 0.02 |
| Full model | 2 | 1.38 | 1.157 | 30.38** | - | - | 1.000 | 1.002 | 90157.4 | -26.4 | - | 0.00 | 0.00 |
| Full model with constraints | 4 | 5.99 | 1.13 | 25.17** | 4.69 | 25.90** | 0.999 | 0.997 | 90158.5 | -25.3 | 1.1 | 0.01 | 0.01 |

*Note:* AIC, Akaike information criterion; CFI, comparative fit index; df, degrees of freedom; RMSEA, root mean square error of approximation; SRMR, standardised root mean residual; TLI, Tucker–Lewis index.

* indicates $p < 0.01$, ** indicates $p < 0.001$.

disproportionately impacted Black Americans (Cheng et al., 2022) and it will be important to study the effect of worry on insomnia among Black participants during the COVID-19 pandemic. Second, as is to be expected by a study that did not pay participants for survey completion, only about one-third of participants completed all three study assessments. Third, while we attempted to advertise the survey for international completion, most participants reported completing the survey in either the United States or Israel. Similarly, while we attempted to recruit across the lifespan, most participants were adults. Fourth, to allow for a larger sample, all data were collected using self-report and not clinician-rated assessments. Therefore, these findings should be replicated in a more diverse sample and with collateral information from trained clinical interviewers before strong conclusions are drawn. Fifth, participants were not followed after August 2020, which covers the first critical months of the global COVID-19 pandemic but worry and insomnia may have decreased since that time with more knowledge available about the disease and improved access to vaccinations. Finally, we did not assess self-reported diagnoses of sleep disorders or of medications, which is an important limitation. Despite these limitations, our findings are consistent with other cross-sectional studies from across the world, which increase confidence in the results.

In summary, this is the first longitudinal study to demonstrate that changes in worry during the COVID-19 pandemic were associated with changes in insomnia. It is also the first study to demonstrate that worries about COVID-19 is a more consistent predictor of insomnia than a variety of COVID-19-related exposures, such as being tested for COVID-19 or knowing someone who tested positive for COVID-19. Results point to the importance of offering evidence-based treatment for help-seeking individuals who report high levels of COVID-19-related worries, regardless of their level of risk of exposure to the virus. Given myriad deleterious health consequences of insomnia, offering evidence-based treatments for worry during the pandemic may reduce insomnia severity and consequently improve functioning.

## CONFLICT OF INTEREST

Dr Ran Barzilay serves on the scientific board and reports stock ownership in Taliaz Health, with no conflict of interest relevant to this work. All other authors have no conflicts of interest to disclose.

## AUTHOR CONTRIBUTIONS

Lily A. Brown developed the study concept. Data collection for the study was led by Ran Barzilay. Lily A. Brown and Yiqin Zhu performed the data analysis and interpretation. Gabriella E. Hamlett and Lily A. Brown drafted the manuscript, and all the authors provided critical revisions, including contributing to interpreting the results and grounding the study in the extant literature. All of the authors approved the final manuscript for submission.

## DATA AVAILABILITY STATEMENT

Data are available upon request.

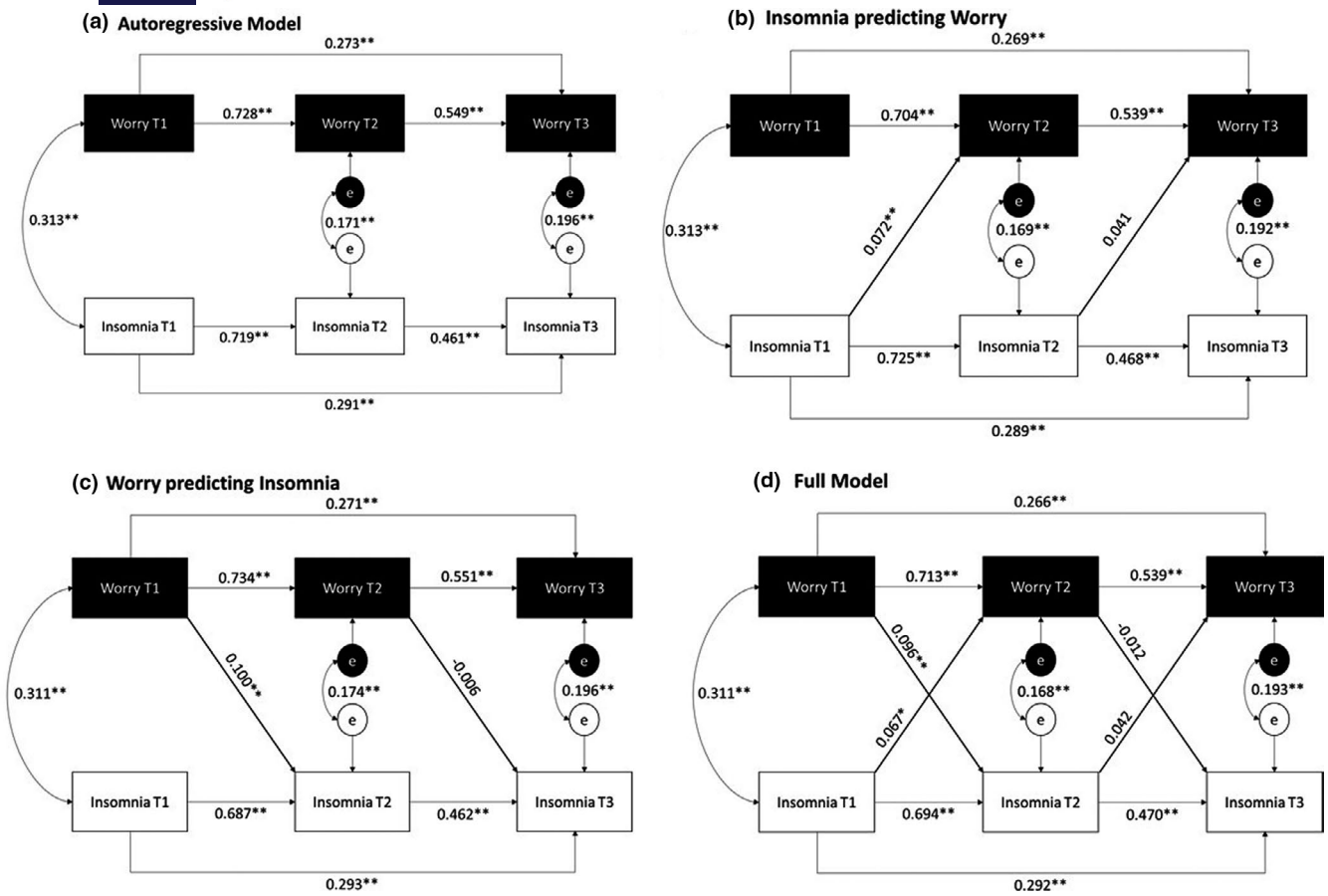


**FIGURE 2** Results of a cross-lagged panel analysis to directly test directionality between Worry (calculated as a total score, a sum of all Worry variables to reduce the number of analyses) and Insomnia Severity Index severity. (a) Model 1 includes only the autoregressive paths. (b) Model 2 adds paths from one construct (sleep at baseline) to the second construct at the subsequent time-point, worry at one-month. (c) Model 3 adds paths in the opposite direction to the autoregressive model: worry at baseline predicting sleep at one-month. (d) Model 4 is the full model including bidirectional paths (essentially a combination of Models 2 and 3)

## ORCID

*Lily A. Brown* https://orcid.org/0000-0002-0879-0110
*Gabriella E. Hamlett* https://orcid.org/0000-0003-3764-2966
*Joshua F. Wiley* https://orcid.org/0000-0002-0271-6702
*Grace E. DiDomenico* https://orcid.org/0000-0003-1036-9592

## REFERENCES

Aernout, E., Benradia, I., Hazo, J.-B., Sy, A., Askevis-Leherpeux, F., Sebbane, D., & Roelandt, J.-L. (2021). International study of the prevalence and factors associated with insomnia in the general population. *Sleep Medicine*, *82*, 186–192. https://doi.org/10.1016/j.sleep.2021.03.028

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders*, 5th ed. American Psychiatric Association.

Bajaj, S., Blair, K.S., Schwartz, A., Dobbertin, M., & Blair, R.J.R. (2020). Worry and insomnia as risk factors for depression during initial stages of COVID-19 pandemic in India. *PLoS One*, *15*(12), e0243527. https://doi.org/10.1371/journal.pone.0243527

Balikji, S., Mackus, M., Brookhuis, K.A., Garssen, J., Kraneveld, A.D., Roth, T., & Verster, J.C. (2018). The Association of Insomnia, perceived immune functioning, and irritable bowel syndrome complaints. *Journal of Clinical Medicine*, *7*(9), 238. https://doi.org/10.3390/jcm7090238

Barzilay, R., Moore, T.M., Greenberg, D.M., DiDomenico, G.E., Brown, L.A., White, L.K., … Gur, R.E. (2020). Resilience, COVID-19-related stress, anxiety and depression during the pandemic in a large population enriched for healthcare providers. *Translational Psychiatry*, *10*(1), 291.

Bastien, C.H., Vallières, A., & Morin, C.M. (2001). Validation of the Insomnia Severity Index as an outcome measure for insomnia research. *Sleep Medicine*, *2*(4), 297–307. https://doi.org/10.1016/s1389-9457(00)00065-4

Brown, L.A., Jerud, A., Asnaani, A., Petersen, J., Zang, Y., & Foa, E.B. (2018). Changes in posttraumatic stress disorder (PTSD) and depressive symptoms over the course of prolonged exposure. *Journal of Consulting and Clinical Psychology*, *86*(5), 452–463. https://doi.org/10.1037/ccp0000292

Brown, L.A., Krull, J.L., Roy-Byrne, P., Sherbourne, C., Stein, M.B., Sullivan, G., … Craske, M.G. (2015). An examination of the bidirectional relationship between functioning and symptom levels in patients with anxiety disorders in the CALM study. *Psychological Medicine*, *45*(3), 647–661. https://doi.org/10.1017/S0033291714002062

Brown, L.A., Wakschal, E., Russman-Block, S., Boisseau, C.L., Mancebo, M.C., Eisen, J.L., & Rasmussen, S.A. (2019). Directionality of change in obsessive compulsive disorder (OCD) and suicidal ideation over six years in a naturalistic clinical sample. *Journal of Affective Disorders*, *245*, 841–847. https://doi.org/10.1016/j.jad.2018.11.006

Burgard, S.A., & Ailshire, J.A. (2009). Putting work to bed: Stressful experiences on the job and sleep quality. *Journal of Health and Social Behavior*, *50*(4), 476–492.

Cai, Z., Cui, Q., Liu, Z., Li, J., Gong, X., Liu, J., … Wang, G. (2020). Nurses endured high risks of psychological problems under the epidemic of COVID-19 in a longitudinal study in Wuhan China. *Journal of Psychiatric Research*, *131*, 132–137. https://doi.org/10.1016/j.jpsychires.2020.09.007

Cheng, P., Casement, M.D., Cuellar, R., Johnson, D.A., Kalmbach, D., Cuamatzi Castelan, A., & Drake, C.L. (2022). Sleepless in COVID-19: Racial disparities during the pandemic as a consequence of structural inequity. *Sleep*, *45*(1), zsab242. https://doi.org/10.1093/sleep/zsab242

Covin, R., Ouimet, A.J., Seeds, P.M., & Dozois, D.J.A. (2008). A meta-analysis of CBT for pathological worry among clients with GAD. *Journal of Anxiety Disorders*, *22*(1), 108–116. https://doi.org/10.1016/j.janxdis.2007.01.002

Dopheide, J.A. (2020). Insomnia overview: Epidemiology, pathophysiology, diagnosis and monitoring, and nonpharmacologic therapy. *The American Journal of Managed Care*, *26*(4 Suppl), S76–S84. https://www.ajmc.com/view/insomnia-overview-epidemiology-pathophysiology-diagnosis-and-monitoring-and-nonpharmacologic-therapy

Ford, D.E., & Kamerow, D.B. (1989). Epidemiologic study of sleep disturbances and psychiatric disorders. An opportunity for prevention? *JAMA*, *262*(11), 1479–1484. https://doi.org/10.1001/jama.262.11.1479

Gao, C., & Scullin, M.K. (2020). Sleep health early in the coronavirus disease 2019 (COVID-19) outbreak in the United States: Integrating longitudinal, cross-sectional, and retrospective recall data. *Sleep Medicine*, *73*, 1–10. https://doi.org/10.1016/j.sleep.2020.06.032

Grandner, M.A., Jackson, N.J., Pak, V.M., & Gehrman, P.R. (2012). Sleep disturbance is associated with cardiovascular and metabolic disorders. *Journal of Sleep Research*, *21*(4), 427–433. https://doi.org/10.1111/j.1365-2869.2011.00990.x

Hamilton, N.A., Gallagher, M.W., Preacher, K.J., Stevens, N., Nelson, C.A., Karlson, C., & McCurdy, D. (2007). Insomnia and well-being. *Journal of Consulting and Clinical Psychology*, *75*(6), 939–946. https://doi.org/10.1037/0022-006X.75.6.939

Harvey, A.G. (2002). A cognitive model of insomnia. *Behaviour Research and Therapy*, *40*(8), 869–893. https://doi.org/10.1016/s0005-7967(01)00061-4

Harvey, A.G., & Tang, N.K.Y. (2003). Cognitive behaviour therapy for primary insomnia: Can we rest yet? *Sleep Medicine Reviews*, *7*(3), 237–262. https://doi.org/10.1053/smrv.2002.0266

Huang, Y., Wang, Y., Zeng, L., Yang, J., Song, X., Rao, W., … Zhang, X. (2020). Prevalence and correlation of anxiety, insomnia and somatic symptoms in a chinese population during the COVID-19 epidemic. *Frontiers in Psychiatry*, *11*, 568329. https://doi.org/10.3389/fpsyt.2020.568329

Kang, L., Ma, S., Chen, M., Yang, J., Wang, Y., Li, R., … Liu, Z. (2020). Impact on mental health and perceptions of psychological care among medical and nursing staff in Wuhan during the 2019 novel coronavirus disease outbreak: A cross-sectional study. *Brain, Behavior, and Immunity*, *87*, 11–17. https://doi.org/10.1016/j.bbi.2020.03.028

Kokou-Kpolou, C.K., Megalakaki, O., Laimou, D., & Kousouri, M. (2020). Insomnia during COVID-19 pandemic and lockdown: Prevalence, severity, and associated risk factors in French population. *Psychiatry Research*, *290*, 113128. https://doi.org/10.1016/j.psychres.2020.113128

Léger, D., Guilleminault, C., Bader, G., Lévy, E., & Paillard, M. (2002). Medical and socio-professional impact of insomnia. *Sleep*, *25*(6), 625–629.

Li, X., Yu, H., Bian, G., Hu, Z., Liu, X., Zhou, Q., … Zhou, D. (2020). Prevalence, risk factors, and clinical correlates of insomnia in volunteer and at home medical staff during the COVID-19. *Brain, Behavior, and Immunity*, *87*, 140–141. https://doi.org/10.1016/j.bbi.2020.05.008

Martens, M.P., & Haase, R.F. (2006). Advanced applications of structural equation modeling in counseling psychology research. *The Counseling Psychologist*, *34*(6), 878–911. https://doi.org/10.1177/0011000005283395

Ohayon, M.M. (2002). Epidemiology of insomnia: What we know and what we still need to learn. *Sleep Medicine Reviews*, *6*(2), 97–111. https://doi.org/10.1053/smrv.2002.0186

Ohayon, M.M., & Shapiro, C.M. (2000). Sleep disturbances and psychiatric disorders associated with posttraumatic stress disorder in the general population. *Comprehensive Psychiatry*, *41*(6), 469–478. https://doi.org/10.1053/comp.2000.16568

Pappa, S., Ntella, V., Giannakas, T., Giannakoulis, V.G., Papoutsi, E., & Katsaounou, P. (2020). Prevalence of depression, anxiety, and insomnia among healthcare workers during the COVID-19 pandemic: A systematic review and meta-analysis. *Brain, Behavior, and Immunity*, *88*, 901–907. https://doi.org/10.1016/j.bbi.2020.05.026

Quan, S.F. (2009). Sleep Disturbances and Their Relationship to Cardiovascular Disease. *American Journal of Lifestyle Medicine*, *3*(1_suppl), 55S–59S. https://doi.org/10.1177/1559827609331709

Revelle, W. (2013). *Psych: Procedures for Personality and Psychological Research* (1.3.2) [R]. http://CRAN.R-project.org/package=psych

Riemann, D. (2007). Insomnia and comorbid psychiatric disorders. *Sleep Medicine*, *8*(Suppl 4), S15–20. https://doi.org/10.1016/S1389-9457(08)70004-2

sivertsen, B., hysing, M., harvey, A.G., & petrie, K.J. (2021). the epidemiology of insomnia and sleep duration across mental and physical health: The SHoT study. *Frontiers in Psychology*, *12*, 2309. https://doi.org/10.3389/fpsyg.2021.662572

Sofi, F., Cesari, F., Casini, A., Macchi, C., Abbate, R., & Gensini, G.F. (2014). Insomnia and risk of cardiovascular disease: A meta-analysis. *European Journal of Preventive Cardiology*, *21*(1), 57–64. https://doi.org/10.1177/2047487312460020

Soldatos, C.R. (1994). Insomnia in relation to depression and anxiety: Epidemiologic considerations. *Journal of Psychosomatic Research*, *38*(Suppl 1), 3–8. https://doi.org/10.1016/0022-3999(94)90130-9

Voitsidis, P., Gliatas, I., Bairachtari, V., Papadopoulou, K., Papageorgiou, G., Parlapani, E., … Diakogiannis, I. (2020). Insomnia during the COVID-19 pandemic in a Greek population. *Psychiatry Research*, *289*, 113076. https://doi.org/10.1016/j.psychres.2020.113076

Yun, L.I., Qingsong, Q., Qimeng, S., Sanford, L.D., Vgontzas, A.N., & Xiangdong, T. (2020). Insomnia and psychological reactions during the COVID-19 outbreak in China. *Journal of Clinical Sleep Medicine*, *16*(8), 1417–1418. https://doi.org/10.5664/jcsm.8524

Zhan, Y., Liu, Y., Liu, H., Li, M., Shen, Y., Gui, L., … Yu, J. (2020). Factors associated with insomnia among Chinese front-line nurses fighting against COVID-19 in Wuhan: A cross-sectional survey. *Journal of Nursing Management*, *28*(7), e13094. https://doi.org/10.1111/jonm.13094

Zhang, C., Yang, L., Liu, S., Ma, S., Wang, Y., Cai, Z., … Zhang, B. (2020). Survey of insomnia and related social psychological factors among medical staff involved in the 2019 novel coronavirus disease outbreak. *Frontiers in Psychiatry*, *11*, 306. https://doi.org/10.3389/fpsyt.2020.00306

Zhao, K., Zhang, G., Feng, R., Wang, W., Xu, D., Liu, Y., & Chen, L. (2020). Anxiety, depression and insomnia: A cross-sectional study of frontline staff fighting against COVID-19 in Wenzhou, China. *Psychiatry Research*, *292*, 113304. https://doi.org/10.1016/j.psychres.2020.113304

## SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

**How to cite this article:** Brown, L. A., Hamlett, G. E., Zhu, Y., Wiley, J. F., Moore, T. M., DiDomenico, G. E., Visoki, E., Greenberg, D. M., Gur, R. C., Gur, R. E., & Barzilay, R. (2022). Worry about COVID-19 as a predictor of future insomnia. *Journal of Sleep Research*, 00, e13564. https://doi.org/10.1111/jsr.13564