Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Temporal associations between insomnia and depression symptoms in adults during the COVID-19 pandemic: A cross-lagged path modelling analysis

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ABSTRACT

It is well recognised that there is an intimate relationship between sleep and depression, with poor quality or short duration sleep associated with greater symptoms of depression. However, it is not clear from the current evidence base what the temporal relationship is between symptoms of insomnia and depression. Further, it is also unclear how the COVID-19 pandemic may impact on such relationships. In this study we have examined the longitudinal relationships between symptoms of depression and insomnia during the COVID-19 pandemic at two points separated by one year (April/May 2020 and March/April 2021) in a sample of 1032 Irish adults using a cross-lagged paths model. We report that there is a bidirectional relationship across time between depression and insomnia symptoms (β = -0.115 between Insomnia symptoms and subsequent depression symptoms and β = -0.163 between depression symptoms and subsequent insomnia symptoms; scales scored in opposite directions), and that these relationships persist when COVID-19 anxiety, age and sex are introduced into the model. Our analyses suggest that during the first year of the COVID-19 pandemic that insomnia symptoms predicted depression symptoms one year later, and conversely that depression symptoms predicted subsequent insomnia symptoms.

1. Introduction

Recent studies assessing the impact of the COVID-19 pandemic on psychological distress have reported increased depression and anxiety in the initial months of the pandemic (Kocevska et al., 2020; Mandelkorn et al., 2021; Pieh et al., 2021) although meta-analysis indicates that levels of anxiety and depression returned to pre-pandemic levels after a brief initial increase (Robinson et al., 2022). The early pandemic and consequent imposition of societal mitigation measures have also resulted in profound changes in the timing of and quality of sleep (Blume et al., 2020; Korman et al., 2020). Further, prevalence of insomnia disorder increased during the early pandemic (2020) with COVID-19 infection, female sex, younger age, long confinement periods, financial worries and living alone as factors associated with higher odds of insomnia symptoms or syndrome (Alimoradi et al., 2021; Morin et al., 2022). Evidence from studies conducted in the early stages of the pandemic highlight a consistent link between sleep disturbance and psychological distress (Kocevska et al., 2020; Kokou-Kpolou et al., 2020; Xiao et al., 2020).The association between psychological distress and sleep during the pandemic is perhaps not surprising as pre-pandemic evidence strongly suggests that sleep disturbances are intimately associated with mental disorders such as depression and anxiety (Fernandez-Mendoza and Vgontzas, 2013).

Insomnia disorder, defined as difficulty initiating or maintaining sleep, or sleep that is non-restorative (American Psychiatric Association, 2013), is strongly associated with depression symptoms (Riemann et al., 2020). Insomnia has historically been explored as "secondary" to depression, and more recently, as a risk factor for depression with meta-analyses reporting that the risk of depression increased two-to-three fold in those with antecedent insomnia disorder (Hetenstein et al., 2019; Li et al., 2016). Indeed, the relationship between sleep and mental disorders is complicated by the fact that clinical diagnostic criteria for mood disorders include the presence of sleep disturbances, and the criteria for insomnia disorder requires that it is not better explained by a co-existing mental disorder (American Psychiatric Association, 2013). There is strong empirical evidence for bidirectional relationships depression and insomnia symptoms, although the temporal and mechanistic nature of such relationships remain unclear

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(Riemann et al., 2020; Alvaro et al., 2013). A recent six-year longitudinal study in New Zealand indicated that sleep duration predicted subsequent levels of psychological distress, but that psychological distress did not predict subsequent sleep duration (Marques et al., 2021). Such an antecedent/precipitating relationship for insomnia symptoms to depression symptoms is supported by recent findings that cognitive behavioural therapy for insomnia (CBTi) leads to durable decreases in depression symptoms in parallel with reductions in insomnia severity (Cunningham and Shapiro, 2018; Cheng et al., 2019; Henry et al., 2021). Predictive directional relationships from sleep quality to depression symptoms may be further complicated by confounding by concurrent symptoms of other mental disorders such as anxiety disorders, and by factors such as age and sex (Alvaro et al., 2013; Oh et al., 2019).

While there is evidence that psychological distress and insomnia symptoms are associated during the COVID-19 pandemic, the directionality and temporal nature of those relationships is not currently clear. Furthermore, anxiety specifically related to concerns about the pandemic (COVID19 anxiety) presents as a unique variable of interest to investigate in the association between insomnia symptoms and depression in the context of a pandemic. The current study aimed to examine (a) the concurrent (cross-sectional) association and the predictive (cross-lagged) associations of insomnia symptoms and depression in adults during the first year of the pandemic in Ireland, and (b) to explore if COVID-19 anxiety, sex and age as control variables at the start of the pandemic impacted the temporal relationship between insomnia symptoms and depression approximately a year later.

2. Methods

2.1. Participants and recruitment

The Irish arm of the COVID-19 Psychological Research Consortium (C19PRC) study (McBride et al., 2021; Spikol et al., 2021) was launched to assess the mental health impact of COVID-19 in Ireland in the first year of the pandemic during 2020. Participants aged 18 years or older and residing in Ireland were recruited via quota sampling (based on age, sex and geographical distribution as per the 2016 Irish census) to ensure a nationally representative sample. The longitudinal survey, completed in five waves over 12 months, was conducted online via the Qualtrics survey platform (an on-line research services provider, www.qualtrics.com); starting with Wave 1 in April/May 2020 during the first week of the first country-wide full restrictions in Ireland, and ending with Wave 5 in March/April 2021, a year later and while Ireland was under a third set of societal restrictions (Fig. 1 illustrates the timeline of societal restrictions and the type of restrictions imposed in Ireland, and the death and hospitalization numbers in Ireland from the start of the pandemic to contextualize the period of data collection). Ethical approval was granted by the Research Ethics Committee of Maynooth University.

Measures for depression and COVID-19 anxiety were used in all five waves, and a sleep specific questionnaire was added from Wave 2, which was approximately six weeks into the first restrictions. As we were interested in examining the relationship between insomnia symptoms and depression at the start of the pandemic and at approximately a year later, this report is based on the entire sample at Wave 2, referred to as Time 1 in the analysis (data collection was between April 30th and May 19th, 2020), and the Wave 2 participants who participated at Wave 5, referred to as Time 2 (data collection was between March 19th and April 9th, 2021). There were 1032 participants at Time 1. Of these, 388 (recontact rate =37.6%) responded to the call to participate at Time 2 ($N = 1100$); the remainder of the participants at Time 2 were either new recruits or had participated in prior waves of data collection but not Time 1.

2.2. Measures

The Sleep Condition Indicator (SCI) was used to assess insomnia symptoms. The SCI is a self-report scale designed to facilitate diagnosis of insomnia based on the DSM-5 threshold criteria for insomnia disorder (Espie et al., 2014). The eight items on the SCI are rated on a five-point Likert scale from zero to four, with possible total scores between zero and 32. Higher scores reflect better sleep quality and a score of 16 or less is indicative of possible insomnia. The internal reliability of the SCI at Time 1 ($\alpha = 0.88$) was excellent. The Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001) was used to assess symptoms of depression. Higher scores on the PHQ-9 indicate more symptoms of depression with a score of 10 or more indicating a possible DSM-5 diagnosis of depression. The PHQ-9 includes a sleep item. To avoid multicollinearity with the SCI, we removed this item from the total score of the PHQ-9. The internal reliability of the revised eight item version of the PHQ at Time 1 ($\alpha = 0.91$) was excellent. The results on the subsequent analyses did not vary substantively if the modified PHQ-8 was used versus the full PHQ-9, indicating that multicollinearity may not be a barrier to using

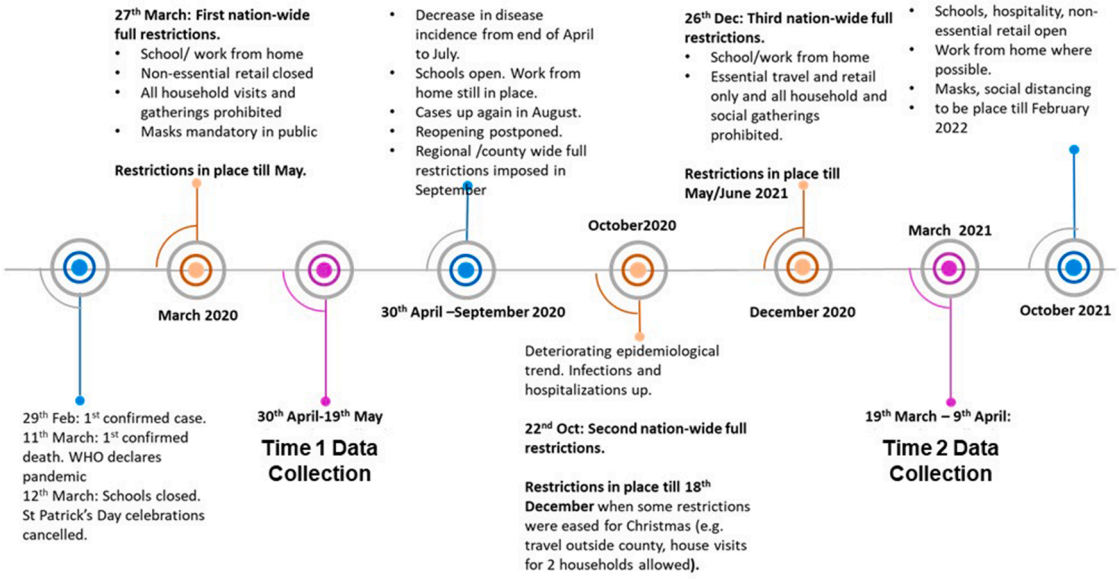

Fig. 1. Illustration of the timelines of the COVID-19 pandemic in Ireland and the societal level mitigation measures, relative to the points of data collection used in the current study.

the PHQ-9 with the sleep item included for such analyses. We have used the diagnostic categories for a descriptive reporting of prevalence of depression and insomnia in the sample at Time 1, and the total scores from both the PHQ-9 (higher scores corresponding to depression symptoms) and SCI (lower scores corresponding to insomnia symptoms) for the path model analysis.

COVID-19 anxiety was assessed via a single question "How anxious are you about the COVID-19 pandemic?", with a scale ranging zero to 100 and higher scores reflecting greater anxiety. A single item measure may have psychometric limitations but aims to efficiently capture highly context-specific anxiety about the pandemic, which may be significantly divergent from measures of general anxiety which reference general worry and anxiety, restlessness and fear. The General Anxiety Disorder 7-item scale (GAD-7; Spitzer et al., 2006) was also included in the survey, and we ran a correlation test between the single item COVID-19 anxiety and the total score on the GAD; there was a moderate correlation ($r = 0.347$, $p < .001$) between COVID-19 anxiety at Time 1 and the total score on the GAD.

2.3. Statistical analysis

Cross-lagged path modelling was conducted using Mplus version 8.2 (Muthen and Muthen, CA, USA). Three models were tested: a cross-lagged model with autoregressive and cross-lagged paths was specified to determine the unadjusted relationships between insomnia symptoms and depression (Model 1; Fig. 1A); we then added COVID-19 anxiety as a covariate to assess the impact of pandemic related anxiety on the relationships between insomnia symptoms and depression (Model 2; Fig. 1B); then sex and age were added as additional covariates (Model 3; Fig. 1C) to determine if the relationship between depression and insomnia were influenced by these demographic variables. These models were compared using two relative fit indices, the Akaike Information Criteria (AIC) and the Bayesian Information Criteria (BIC). The model with the lowest value is considered to be statistically superior. The BIC contains a penalty for increasing model complexity. Overall fit of the model to the sample data was assessed using multiple indices including the chi-square, the Comparative Fit Index (CFI), the Tucker-Lewis index (TLI), the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root Mean Square Residual (SRMR). Standard recommendations were followed to assess model fit where a non-significant chi-square value, CFI and TLI values > 0.90, and RMSEA and SRMR values < 0.08 indicate acceptable fit. Full information maximum likelihood estimation, widely recognized as an effective method for unbiased parameter estimates and standard errors for randomly missing data in structural equation modelling (Schafer and Graham, 2002; Widaman, 2006), was used to estimate these models and to manage missing data from non-responders at Time 2.

3. Results

3.1. Demographics of study sample and prevalence of insomnia and depression symptoms

At Time 1, the mean age of participants was 44.86 years (± 15.74) and 52% of them were females (Table 1). Time 1 participants who responded at Time 2, when compared to the those who did not participate at Time 2, were significantly more likely to be male (χ^2 (1, n = 1029) = 6.37, $p = 0.01$), older (t (1030) = 10.48, $p < .001$), and reported higher COVID-19 anxiety (t (832) = 2.69, $p = 0.007$) but lower depression symptoms (t (896) = −4.52, $p < .001$). The responders and non-responders did not differ significantly in terms of their insomnia symptoms. Table 1 summarizes the demographics of the sample at Time 1 and the key comparisons between those that did and did not participate at Time 2. 30% of the participants at Time 1 had scores indicating possible insomnia and 26% had scores indicating possible depression. Insomnia symptoms correlated strongly with depression symptoms at both time points ($r = -0.555$, $p < 0.001$ at Time 1 and $r = -0.610$, $p < 0.001$ at Time 2). COVID-19 anxiety had weak correlations with insomnia symptoms ($r = -0.259$, $p < 0.001$) and depression symptoms ($r = 0.253$, $p < 0.001$) at Time 1. Age demonstrated a weak correlation with insomnia symptoms ($r = 0.175$, $p < 0.001$) and a correlation of medium strength with depression ($r = -0.367$, $p < 0.001$). There was a significant but weak correlation between COVID-19 anxiety and age ($r = 0.097$, $p = .002$).

Table 1
Demographics and SCI, PHQ-9 and COVID-19 anxiety scores for study sample, including participants who were common to Time 1 and Time 2, and those at Time 2 who were not represented at Time 1. Time 1 participants who responded at Time 2, when compared to the non-recontacts, were significantly more likely to be male ($p = .01$), older ($p < .001$), and reported higher COVID-19 anxiety ($p = .007$) and lower depression ($p < .001$). There was no significant difference in sleep scores at Time 2 between recontact and non-recontact participants. Third and fourth columns refer to participants from Time 1 who responded to the survey at Time 2 (Recontacts) and those who did not (Non-Recontacts). Data presented in these two columns refer to the measures for these participants at Time 1.

	Time 1 sample N = 1032	Time 2 Recontact N = 388	Time 2 Non-recontact N = 644
Age mean (years; s.d)	44.86 ± 15.74	51.15 ± 14.61	41.07 ± 15.19
Age groups (%): 18–24	11	4	16
25–34	19	12	24
35–44	21	18	22
45–54	16	18	15
55–64	20	28	15
65 +	13	20	9
Sex (% females)	52	47	55
Insomnia (Mean SCI Score, SE,% possible insomnia disorder)	21.06 (0.25) 30%	21.63 (0.42) 29%	20.72(0.311) 31%
Depression (Mean PHQ-9 Score, SE, % possible depressive disorder)	6.22 (0.19) 26%	5.13 (0.29) 22%	6.87(0.25) 28%
COVID-19 anxiety	61.10 (0.83)	63.95 (1.33)	59.39(1.06)

3.2. Cross-lagged analysis

Model 1 was a saturated model, and as such the model fit statistics are not reported; the AIC = 17 691.931 and the BIC = 17 761.080 for this model. Model 1 showed that insomnia symptoms at Time 1 significantly predicted Time 2 depression symptoms ($\beta = -0.115$, $p < .05$) and depression symptoms at Time 1 also significantly predicted Time 2 insomnia symptoms ($\beta = -0.163$, $p < .001$; Fig. 2A). Time 1 insomnia symptoms were highly predictive of insomnia symptoms at Time 2 ($\beta = 0.691$, $p < .001$), and Time 1 depression symptoms were highly predictive of Time 2 depression symptoms ($\beta = 0.652$, $p < .001$). Insomnia and depression symptoms correlated significantly at both Time 1 ($r = -0.555$, $p < .001$) and Time 2 ($r = -0.416$, $p < .001$). The model accounted for 63% variance in insomnia symptoms and 52% of the variance in depression symptoms at Time 2.

Model 2 incorporated COVID-19 anxiety as a covariate and the model fit statistics were: $\chi^2(2) = 1.795$, $p = 0.408$, RMSEA = 0.000 (CI = 0.000 to 0.060), SRMR = 0.008, TLI = 1.001, CFI = 1.000. The BIC and AIC decreased substantially from model 1 to model 2 (BIC = −77.05 and AIC = −86.93) as COVID-19 anxiety was included in the model. Covid-19 anxiety had a significant but weak impact on insomnia ($\beta = -0.259$, $p < .001$) and depression ($\beta = 0.253$, $p < .001$) at Time1, but the cross-lagged associations between insomnia and depression symptoms were unchanged compared to model 1 (Fig. 2B).

Model 3 incorporated sex and age as covariates and provided acceptable fit to the sample data: $\chi^2_{(6)} = 17.367$, $p < 0.05$; RMSEA = 0.043, CI = 0.020 to 0.067; SRMR = 0.034; TLI = 0.975 and CFI =

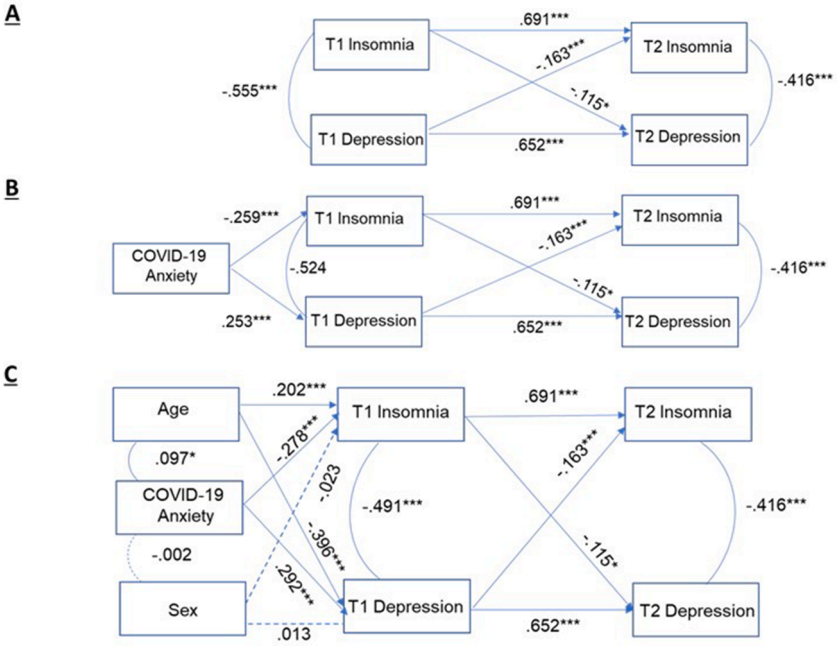

Fig. 2. Cross-lagged path models (A) incorporating PHQ-9 scores (depression) and SCI (insomnia) scores at Time 1; (B) the inclusion of COVID-19 Anxiety scores are Time 1; (C) the further inclusion of age and sex into the model. Time 1 represents data from March to April 2020 and Time 2 represents data from March/April 2021. Dashed arrows represent non-significant correlations. *** $P < .001$, * $P < .005$.

0.992). The BIC and AIC decreased further from model 2 (BIC = −159.93 and AIC = −179.69), suggesting inclusion of age and sex further improved model fit. COVID-19 anxiety had a moderate predictive effect on insomnia symptoms (Fig. 2C; $\beta = -0.278$, $p < 0.001$) and depression symptoms ($\beta = 0.292$, $p < 0.001$) at Time 1. Age had a significant effect on Time 1 insomnia symptoms (Fig. 1C; $\beta = 0.202$, $p < 0.001$) and on Time 1 depression symptoms ($\beta = -0.396$, $p < 0.001$); younger participants reported more insomnia and depression symptoms. Sex had no significant effects on both Time 1 insomnia symptoms ($\beta = -0.023$, $p = 0.433$) and Time 1 depression symptoms ($\beta = 0.013$, $p = 0.631$). Age, sex and COVID-19 anxiety together accounted for a variance of 11% in insomnia symptoms and 22% in depression symptoms at Time 1. However, the temporal associations between insomnia and depression symptoms was not altered compared to models 1 or 2.

4. Discussion

The goal of this study was to understand the longitudinal relationship between insomnia symptoms and depression symptoms during the first year of the COVID-19 pandemic in Ireland. Our findings indicate insomnia and depression symptoms during the early stages of the pandemic were strongly associated cross-sectionally and predicted each other 12 months later. The second aim of the study was to explore the impact of COVID-19 anxiety, sex and age on the longitudinal relationship between sleep and depression. We found that higher COVID-19 anxiety and younger age had significant associations with insomnia and depression symptoms. Furthermore, these variables did not alter the longitudinal association between insomnia and depression symptoms.

Somewhat surprisingly, there is limited evidence on the reciprocal temporal relationships between insomnia and depression symptoms, and there is not a coherent picture of such relationships that emerges from the current evidence base. Published studies have reported bidirectional temporal relationships between sleep quality and depression and anxiety, no temporal relationships or unidirectional relationships from sleep to mood (reviewed in Alvaro et al., 2013). A number of other studies have assessed only the directional relationship of sleep to mood, but not the converse relationship (e.g. Yokoyama et al., 2010; Maglione et al., 2014), or on the predictive value of antecedent insomnia disorder on subsequent diagnosis of depressive disorder (Hertenstein et al., 2019). However, a fundamental transdiagnostic neurobiological and psychosocial framework indicates several pathways through which insufficient sleep might impact on psychological distress and through which psychological distress may impact on sleep quality and duration (Riemann et al., 2020). A recent 6-year longitudinal study using a cross-lagged panel approach of over 17,000 adolescent and adult participants in New Zealand reported that longer sleep duration predicted lower psychological distress one year later (utilizing a measure that captures elements of depression and anxiety; Marques et al., 2021). The measure of sleep duration in the New Zealand study may capture only part of the full spectrum of insomnia symptoms measured by the SCI as used in the current study, and this difference may account for the fact that we report a bidirectional relationship between insomnia symptoms and depression whilst Marques et al. (2021) only report a unidirectional relationship from sleep duration to distress. Clearly, the presence of the COVID-19 pandemic and the attendant psychological impacts is another important consideration in comparing the current results with findings from pre-pandemic studies and the current findings may be context-dependant to the early phase of the COVID-19 pandemic.

The longitudinal relationships between insomnia symptoms and depression held when we controlled for COVID-19 anxiety, age, and sex. Furthermore, insomnia and depression symptoms were reasonably stable and had strong effects on themselves across the two assessment time points. As such, we believe that the reciprocal temporal relationships observed are not trivial, and that the data provides evidence that insomnia and depression are mutually dependant constructs sharing a dependant relationship with COVID-19 anxiety, age and sex at a concurrent assessment time point, but their predictive relationship on each other and on themselves at a later time point appears to be fairly robust and independent of these confounding variables. It is of importance to interpret these findings within the specific context of the early phase of the COVID-19 pandemic; the existing evidence for the temporal association between sleep and depression symptoms is not consistent enough to make a claim regarding if the pandemic has altered the nature of these relationships, but future studies post-COVID19 pandemic mat be

instructive. The current observations may further support the wider use of sleep health interventions that may not only increase sleep quality but also decrease population level psychological distress; for example, an internet-delivered programme of CBTi has been reported to decrease psychological distress and increase sleep-related quality of life in a large adult sample (Espie et al., 2019).

5. Limitations

There are caveats to the interpretation and applications of the results from the current study. Firstly, in our study we did not distinguish between pre-pandemic and pandemic onset insomnia and depression symptoms. Maeklim et al. (2021) for example reported that individuals who developed insomnia during the pandemic reported significantly higher depression and anxiety than those with pre-pandemic insomnia or no insomnia. In another study, Kocevska et al. (2020) reported that one third of participants with pre-pandemic clinical insomnia reported better sleep quality during the pandemic, but that pre-pandemic good sleepers reported decreased sleep quality. Subgroup analyses of pre- and pandemic-onset insomnia and depression would have provided a clearer indication of the true impact of COVID-19 anxiety on onset of symptoms and the persistence and longitudinal association of insomnia and depression symptoms during the pandemic; however, pre-pandemic measures are not available for the current study cohort to allow for such an analysis.

A second limitation is related to the measurement of COVID-19 anxiety via a single item, and as such may have limited psychometric utility. The construct of COVID-19 anxiety may encompass features of general anxiety as well as COVID-19 specific features such as fear of infection, threat monitoring and avoidance behaviours (Nikčevića and Spada, 2020). At the onset of the data collection for the current study (Spring, 2020), psychometric scales for COVID-19 anxiety were not yet published and it was felt that the use of a single item was an appropriate utilitarian approach to capturing information of COVID-19 anxiety. We subsequently undertook correlational analysis and found that COVID-19 anxiety scores correlated moderately with general anxiety scores from the GAD-7. However, there were specific features of COVID-19 anxiety that were not shared with general anxiety; COVID-19 anxiety is highest in the older participants (presumably reflecting risk of severe disease increasing with age), whilst general anxiety was greatest in the youngest adults in the study.

A third limitation pertain to the general issues of sample demographics, missing data and the statistical choices and assumptions made. While the maximum likelihood method used in the analysis is widely regarded as the best available method for handling missing data (Widman et al., 2006), we are aware that it may not eliminate all limitations and bias. We urge caution in generalizing our findings as there were important significant differences in age and sex between the recontacts and non-recontacts from Time 1 to Time 2. A recent review estimates the median age for onset for mental health disorders (which includes depression and other mood disorders) is in young adulthood and females are estimated to have three-fold higher incidence of depression than males (Solmi et al., 2021). While in our overall sample at Time 1 there was suggestion that females and younger people experienced more insomnia and depression symptoms, the recontacts at Time 2 were more likely to be male and older. The recontacts at Time 2 had significantly lower depression symptoms but higher COVID-19 anxiety as anticipated as the virus at the start of the pandemic had more adverse effects for older people. Thus our findings might not represent the experiences of females and younger people and those who had more depression symptoms at the start of the pandemic or those with lower anxiety about the pandemic.

Another statistical consideration is that the cross-lagged panel modelling is a discrete time analysis, meaning the results are specific to the time-interval between the assessment points (Kuiper and Ryan, 2018). Thus, the longitudinal relationships we report between insomnia symptoms and depression from this two-wave analysis is specific to the 12-month interval between the two-waves assessed, and such bidirectional relationships between insomnia and depression may be altered with different intervals of assessment.

6. Conclusion

We found that insomnia and depression symptoms had strong concurrent morbidity as well as a significant longitudinal predictive relationship during the first year of the COVID-19 pandemic in Ireland. As COVID-19 shows signs of becoming endemic, identifying the long-term bidirectional risk insomnia and depression present on each other might shed light on the aetiology and persistence of both disorders during and after the pandemic, and have implications in terms of public health measures targeting improvement in sleep and psychological health.

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CRediT authorship contribution statement

Sudha Raman: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Philip Hyland:** Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Andrew N. Coogan:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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