The Association of Insomnia with Long COVID:
An International Collaborative Study (ICOSS-II)

Abstract

Background

There is evidence of a strong association between insomnia and COVID-19, yet few studies have examined the relationship between insomnia and long COVID. The aim of the current study was to investigate whether COVID-19 patients with pre-pandemic insomnia have a greater risk for developing long COVID and whether long COVID is in turn associated with higher incident insomnia following infection.

Study design

Data were collected (May–Dec 2021) as part of an international collaborative study involving participants from 16 countries. A total of 2,222 participants (18–99 years old) with COVID-19 provided valid responses to a web-based survey about sleep, insomnia, and health-related variables. Study outcomes were occurrence of long COVID and onset of insomnia after infection. Analyses were adjusted for age, sex, and health conditions, including sleep apnea, attention and memory problems, chronic fatigue, depression, and anxiety.

Results

COVID-19 patients with pre-pandemic insomnia showed a higher risk of developing long COVID than those without insomnia (adjusted relative risk [RR]: 1.33, 95% confidence interval [CI]: 1.07-1.65). Among COVID-19 cases without a history of insomnia before the pandemic, the rates of insomnia after COVID infection were 24.4% for short COVID cases, 86.5% for long COVID cases with long-lasting insomnia (≥ 3 months during illness) and 32.6% for long COVID cases without long-lasting insomnia symptoms ($P < .001$). Compared with short COVID cases, long COVID cases without long-lasting insomnia symptoms were associated with an increased risk of developing insomnia when controlling for age and sex (adjusted RR: 1.39; 95% CI: 1.03-1.84); this association was no longer significant after further adjusting for health conditions (adjusted RR: 1.17; 95% CI: 0.82-1.68).

Conclusions

Pre-pandemic insomnia was associated with a significantly greater risk of developing long COVID in infected patients. Long COVID cases without a prior insomnia history had high rates of insomnia but the incidence rates were not significantly higher than short COVID cases. These findings highlight the importance of addressing sleep and insomnia in the prevention and management of long COVID.

1. Introduction

Individuals exposed to SARS-CoV-2 may experience long-term symptoms which develop after recovery from acute COVID-19 episode or persist from previous illness (Soriano, Murthy, Marshall, Relan, & Diaz, 2022). This condition is commonly referred to as post COVID-19 condition or long COVID, which will have impacts on multiple systems, such as respiratory, cardiovascular, neurological systems, and psychological effects (Crook, Raza, Nowell, Young, & Edison, 2021; Groff et al., 2021; Subramanian et al., 2022; Vargas, Muench, Grandner, Irwin, & Perlis, 2023). Long COVID has been linked to various symptoms (Del Rio, Collins, & Malani, 2020; Groff et al., 2021; Nalbandian et al., 2021), with fatigue, shortness of breath and cognitive dysfunction among the most commonly reported symptoms according to World Health Organization (WHO) definition (Soriano et al., 2022), whereas recent studies have found that sleep disturbances including insomnia and excessive daytime sleepiness are also prominent features of long COVID (Davis et al., 2021; Huang et al., 2021; Merikanto et al., 2023). In particular, insomnia symptoms such as difficulties falling or staying asleep were present in almost half of the patients with long-lasting symptoms after hospitalization for COVID-19 (Merikanto et al., 2023), which suggests the potential long-term effect of COVID-19 on sleep. On the other hand, given the impact of insomnia on psychological and physical well-being, it may be more than a secondary condition to long COVID(Hertenstein et al., 2019; Kyle, Morgan, & Espie, 2010), and it may contribute toward the development of long COVID. In addition, as there is a significant increase of insomnia in the global communities since the COVID-19 pandemic (Merikanto, Kortesoja, et al., 2022; Morin et al., 2021), it is important to understand the interaction between long

COVID and insomnia to facilitate prevention and early detection of long COVID, as well as to improve sleep health.

While insomnia has been identified as one of the common symptoms of long COVID, very few studies have quantified the incidence and relative risk of insomnia in patients with long COVID. Two studies based on health records of patients in the USA found that COVID-19 was associated with an increased incidence of insomnia compared with other health events (e.g., COVID-19 versus influenza during the first 14 to 90 days after infection: 1.9% versus 0.6%), regardless of psychiatric history (Taquet, Geddes, Husain, Luciano, & Harrison, 2021; Taquet, Luciano, Geddes, & Harrison, 2021). Another large UK cohort study further showed that patients with a history of SARS-CoV-2 had an increased risk of developing insomnia symptoms at ≥12 weeks after infection than non-infected controls (Subramanian et al., 2022). However, previous studies did not distinguish between short COVID and long COVID in their impact on sleep. Furthermore, reliable estimation of a potential increased risk of developing insomnia among patients with long COVID requires well-controlled studies in global communities.

Another important question is whether pre-existing insomnia contributes to greater risk of developing long COVID, given the key role which sleep plays in the regulation of the immune functions in humans (Irwin et al., 2008; Spiegel, Sheridan, & Van Cauter, 2002). In addition, detecting and understanding potentially modifiable risk factors for long COVID might have important implications for developing intervention strategies to modify the trajectory of COVID-19. Insomnia can affect both sleep quality and duration (Morin & Benca, 2012; Vgontzas, Fernandez-Mendoza, Liao, & Bixler, 2013), which may lead to an increased risk for infectious

diseases, as short sleep duration and trouble sleeping have been found to be associated with higher risks of developing an influenza or respiratory infection (Forthun, Eliassen, Emberland, & Bjorvatn, 2023; Patel et al., 2012; Prather, Janicki-Deverts, Hall, & Cohen, 2015; Prather & Leung, 2016). Indeed, a large Taiwan cohort study showed that insomnia itself is an independent risk factor for pneumonia (Lin, Liu, Chung, & Chien, 2018). Similarly, experiencing insomnia symptoms has been found to be associated with a greater risk of having COVID-19 (Kim et al., 2021) and developing a more severe disease (Merikanto et al., 2023). Despite the close association between insomnia and the liability to infections, there is limited knowledge on the long-term effect of insomnia on the course and subsequent health outcomes of infectious diseases, especially COVID-19. Nonetheless, a prior study with a nationwide USA sample has found that insomnia was associated with prolonged COVID-19 duration (Vargas et al., 2023), indicating the possible role of insomnia in increasing the risk of developing persistent symptoms among patients with COVID-19.

Taken together, existing evidence suggests that insomnia may contribute to the development of long COVID and long COVID may in turn be associated with higher risk of developing new incident insomnia. To our knowledge, no research has examined both directions of association simultaneously in COVID-19 patients. The current study aimed to investigate whether COVID-19 patients with pre-pandemic insomnia have a greater risk for developing long COVID and whether long COVID is associated with increased incident cases of insomnia following infection.

2. Methods

2.1 Study and participants

This study is part of the second collaborative investigation led by the International Covid Sleep Study (ICOSS-II) group, which involved investigators from 16 countries and aimed to examine the associations of COVID-19 with sleep and circadian problems. A harmonized questionnaire and a standard methodology were developed and the details of the research protocol and survey questionnaires can be found elsewhere (Merikanto, Dauvilliers, et al., 2022). Several papers based on the ICOSS-II data are currently in progress. The participating countries included Austria, Brazil, Bulgaria, Canada, China (Hong Kong), Croatia, Finland, France, Germany, Israel, Italy, Japan, Norway, Portugal, Sweden, and the United States.

The study was conducted in accordance with the Declaration of Helsinki. All investigators obtained ethical approval or exemptions from their local ethics committee. The survey was answered anonymously via online platforms, such as Redcap and Qualtrics. Completion of the survey varied by country from May to December 2021.

Participants aged 18 years or older were invited through various sources, such as local media (e.g., newspapers, television), social media (e.g., Facebook and Twitter), newsletters and webpages of different institutes. A total of 15,813 participants who completed the survey provided their informed consent and indicated their sex and age (mandatory for weighting). The participants included in the current study were those who reported a history of COVID-19 confirmed by COVID-19 antigen/polymerase chain reaction (PCR) test. Participants whose onset of symptoms was less than three months before they completed the survey, or those who provided no information on insomnia status, were excluded from the analysis, leaving a final sample of 2,222 participants.

2.2 Measures

The survey consisted of 47 questions from validated questionnaires and additional questions that were developed specifically for this study. The estimated survey completion time was about 40 min. The current study focuses on data about insomnia and long COVID derived from the following measures.

Insomnia

Participants were asked to indicate whether they had been diagnosed in the past with insomnia by a physician, and if so, when (i.e., before or during the pandemic or after having coronavirus infection). This item was used to identify participants who had pre-existing insomnia (i.e., before the pandemic), and relevant data was used to investigate whether pre-pandemic insomnia was a risk factor for long COVID.

Incident insomnia following COVID-19 was defined by a total score of ≥ 10 on the Insomnia Severity Index (ISI), a cut-off score recommended for detecting insomnia cases in community samples (Morin, Belleville, Belanger, & Ivers, 2011).

COVID-19 status

Long COVID was defined according to WHO criteria (Soriano et al., 2022), i.e., a positive COVID-19 antigen/PCR test and the presence of any of the following 19 symptoms for ≥ 3 months: a) shortness of breath/difficulty breathing/chest pain, b) joint pain (arthralgia)/muscle pain, muscle aches, c) migraine, d) headache other than migraine, e) abdominal pains, colics, f) palpitations/cardiac arrhythmia, g) tachycardia, fast pulse rate, h) post exertional malaise referring to prolonged weakness/poor functionality after exertion, such as muscle weakness, difficulties walking long distances, i) dizziness when standing, j) low blood pressure (hypotension), k) urinary problems, l) problems of sweating/trouble tolerating

cold/heat, m) problems of attention or concentration/brain fog, cognitive dysfunction, memory problems, n) loss of smell/taste, o) hallucinations, psychotic symptoms, p) feverishness/flu-like symptoms, such as sore throat, runny nose, etc., q) diarrhea/nausea/vomiting, r) symptoms of fatigue, and s) excessive daytime sleepiness. Participants who reported a positive COVID-19 antigen/PCR test without any long-term symptoms were classified as short COVID cases.

When investigating the association between long COVID and the risk of developing new insomnia after COVID-19, participants without pre-infection insomnia were classified into three subgroups according to COVID-19 status and duration of insomnia symptoms during illness. The three group were: 1) short COVID cases, 2) long COVID cases without long-lasting insomnia symptoms, and 3) long COVID cases with long-lasting insomnia symptoms (defined as the presence of difficulties falling or staying asleep for ≥ 3 months during illness).

Potential Confounders

The following characteristics were examined as potential confounders: age, sex, and selected health conditions that were diagnosed before the pandemic and are frequently associated with insomnia and/or long COVID, including sleep apnea, problems of attention or concentration/attention-deficit/hyperactivity disorder (ADHD), memory problems, chronic fatigue, depression, and anxiety. Depression and anxiety are both associated with insomnia and long COVID (Jansson-Fröjmark & Lindblom, 2008; Subramanian et al., 2022; Sweetman et al., 2021), while chronic fatigue, cognitive dysfunction (e.g., poor attention), and memory problems are common symptoms in long COVID patients (Davis et al., 2021; Merikanto et al., 2023), and have been used to defined long COVID (Soriano et al., 2022). Health

conditions diagnosed before the pandemic were measured with questions asking whether participants had been diagnosed by a physician with any of the above-mentioned conditions and when the diagnosis was made (i.e., before or during the pandemic or after having coronavirus infection).

2.3 Statistical analysis

As the two objectives of the current study required different samples, the data analyses were described separately.

2.3.1. Pre-pandemic insomnia status and long COVID (Analysis 1)

The first question of interest was to determine whether pre-pandemic insomnia was a risk factor for long COVID. Subjects with insomnia that developed during the COVID-19 pandemic or after infection (n = 331) were excluded, and thus a total of 1,891 participants were included in these analyses (Figure 1). Log-binomial regression with generalized estimating equations for correlated outcomes within countries was used to calculate risk ratios (RRs) for the association of pre-pandemic insomnia with long COVID. Both crude and adjusted (for age, sex, and health conditions diagnosed before pandemic, including sleep apnea, attention and memory problems, chronic fatigue, depression, and anxiety) analyses were conducted.

[Insert Figure 1 Here]

2.3.2 COVID-19 status and insomnia after infection (Analysis 2)

The next question was about the risks of developing insomnia after infection according to COVID-19 status. Individuals were excluded if they had pre-infection

insomnia (n = 397) or had missing items on ISI (n = 432). As the exact onset date of insomnia was not available, long COVID cases who reported long-lasting insomnia symptoms (≥ 3 months) were also excluded from those analyses to avoid reverse causation (n = 440), leaving a final sample of 953 participants (Figure 2). Log-binomial regression with generalized estimating equations for correlated outcomes within countries was used to determined relative risks of developing insomnia for long COVID cases without persistent insomnia symptoms. Both crude and adjusted (for age, sex, and health conditions diagnosed before pandemic, including sleep apnea, attention and memory problems, chronic fatigue, depression, and anxiety) analyses were conducted.

All analyses were weighted and took into account sex, age, and country to correct for under/over-sampling. For the details of the weighting procedures, please refer to the previous publication (Morin et al., 2021). Data analyses were performed using the SAS 9.4 statistical software with standard two-tailed alpha of 0.05.

[Insert Figure 2 Here]

3. Results

3.1 Pre-pandemic Insomnia status and long COVID

Table 1 shows the characteristics of COVID-19 patients by pre-pandemic insomnia status. Compared with subjects without insomnia, subjects with pre-pandemic insomnia were older, and more likely to be female and have diagnosed health conditions before pandemic, including sleep apnea, problems of attention or concentration/ADHD, memory problems, chronic fatigue, and depression/anxiety

than those without insomnia (all *Ps* < .05).

[Insert Table 1 Here]

Table 2 presents the association between pre-pandemic insomnia and long COVID. When adjusting for age and sex, the risk of developing long COVID was higher for subjects with pre-pandemic insomnia compared with subjects without insomnia (adjusted RR: 1.31, 95% confidence interval [CI]: 1.13-1.52). A similar result was found in the model when controlling for pre-pandemic health conditions, including sleep apnea, problems of attention or concentration/ADHD, memory problems and chronic fatigue (adjusted RR: 1.31; 95% CI: 1.05-1.62). In addition, RR increased to 1.33 (95% CI: 1.07-1.65) after additional adjustment for pre-pandemic depression and anxiety.

[Insert Table 2 Here]

3.2 COVID-19 status and insomnia after infection

Table 3 presents the characteristics of three COVID-19 subgroups: short COVID, Long COVID with long-lasting insomnia symptoms (≥ 3 months), and Long COVID without long-lasting insomnia symptoms. Only cases without pre-infection insomnia were included in the present analyses. The rates of insomnia were 24.4% for short COVID cases,86.5% for long COVID cases with long-lasting symptoms, and 32.6% for long COVID cases without long lasting insomnia symptoms. Long COVID cases with long-lasting insomnia symptoms during illness were older and more likely to have

pre-pandemic sleep apnea than the other two groups (all *Ps* < .05).

[Insert Table 3 Here]

Table 4 presents the association of long COVID with incident insomnia. Only long COVID cases without long-lasting insomnia symptoms were included in the analyses to avoid reverse causation. As shown in Table 4, the risk of developing new insomnia after COVID-19 were greater for long COVID cases than short COVID cases in the age- and sex-adjusted model (adjusted RR: 1.39; 95% CI: 1.03-1.84), while this association became non-significant after adjustment for pre-pandemic health conditions (adjusted RR: 1.17; 95% CI: 0.82-1.68).

[Insert Table 4 Here]

4. Discussion

The present study demonstrated that insomnia seems to be an independent risk factor for the development of long COVID. In addition, we also documented a relatively high rate of insomnia in long COVID cases without prior history of insomnia. However, this latter group of long COVID cases did not present a higher risk of developing incident insomnia compared with short COVID cases. The results in our study extend the findings of previous studies (Kim et al., 2021; Merikanto et al., 2023; Subramanian et al., 2022; Taquet, Geddes, et al., 2021; Taquet, Luciano, et al., 2021) and provide further evidence about the long-term effect of insomnia on the course of COVID-19.

The association of pre-existing insomnia with long COVID has rarely been examined, although there is growing evidence that insomnia is associated with an increased likelihood of developing respiratory infections, including COVID-19 (Kim et al., 2021; Lin et al., 2018). To our knowledge, only one study based on a nationwide sample of Americans has linked insomnia to prolonged COVID-19 duration (Vargas et al., 2023), which is consistent with our finding with an international sample. In addition, we found that the association between insomnia and long COVID remained significant after controlling for other health conditions, suggesting that insomnia has an independent effect on the development of long COVID.

Insomnia may lead to increased risk of developing long COVID for several reasons. First, long COVID may result from changes in immune system caused by insomnia, as previous studies have shown that insomnia is associated with elevated levels of cytokines, such as interluekin-6 (IL-6), interleukin-1 beta (IL-1β), and tumor necrosis factor-alpha (TNF-a) (Irwin, Olmstead, & Carroll, 2016; Ren et al., 2021), which were also found in patients with long COVID (Peluso et al., 2021; Schultheiß et al., 2022). Second, the increased risk of developing long-term COVID-19 symptoms may be related to various medical problems that are often comorbid with insomnia (Taylor et al., 2007). Prior study has demonstrated significant overlaps between insomnia and multiple medical problems, including breathing, urinary, and gastrointestinal conditions, and chronic pain (Taylor et al., 2007), which have been identified as risk factors for long COVID (Subramanian et al., 2022). Third, a previous episode of insomnia (pre-pandemic insomnia) may predispose individuals to increased risks of having a more severe disease and a prolonged COVID-19 duration (Liu et al., 2021).

Consistent with previous studies (Merikanto et al., 2023; Rogers et al., 2020; Subramanian et al., 2022; Taquet, Geddes, et al., 2021; Taquet, Luciano, et al., 2021), we found a relatively high rate of newly developed insomnia after COVID-19, especially among long COVID cases, and even when controlling for pre-existing episodes of insomnia. The occurrence of insomnia after COVID-19 may result from the neuroinflammation potential of the coronavirus (Yachou, El Idrissi, Belapasov, & Ait Benali, 2020), given that sleep impairment is one of the common neuropsychiatric symptoms (Krystal, 2020). Other factors, such as impaired immune response and corticosteroids use during treatment, may also be associated with the sleep consequences of infection (Rogers et al., 2020; Warrington & Bostwick, 2006). With regard to varying insomnia rates between long COVID and short COVID cases, the higher rates of insomnia in long COVID cases may be related to other long COVID symptoms, such as bodily pain and urinary problems, which have been associated with comorbid insomnia (LeBlanc et al., 2009; Singareddy et al., 2012).

There are several limitations that needed to be noted. First, the current study is retrospective in design, which can lead to recall bias and limited the measurements of some important statistics (e.g., fluctuating course of insomnia). Second, since the exact diagnosis date of insomnia was not available, it was not possible to determine whether the new insomnia occurred before onset of COVID or during the course of the illness. Future longitudinal studies are needed to further explore the potential difference between short COVID and long COVID in terms of their impacts on sleep. Third, the assessments were all based on self-administered questionnaires rather than diagnostic interviews or objective measures. Nonetheless, this international investigation in COVID-19 patients provided novel information to enhance our

understanding about the independent effect of insomnia on the development of long COVID. In particular, timely and effective intervention targeting insomnia, such as cognitive behavioral therapy for insomnia, may have the potential to modify the trajectory of long COVID.

5. Conclusion

The current study demonstrated the independent association of pre-pandemic insomnia with increased risk of developing long COVID. In addition, high rates of insomnia in long COVID cases without a prior insomnia history were documented but those rates were not significantly higher for long COVID cases relative to short COVID cases. These findings indicate the need for routine assessment and management of insomnia in order to facilitate prevention and management of long COVID.

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Figure Captions

Figure 1. Flow chart for the inclusion of participants in analysis 1 (pre-pandemic insomnia status and long COVID)

Figure 2. Flow chart for the inclusion of participants in analysis 2 (COVID-19 status and insomnia after infection)

Table 1. Characteristics of COVID-19 patients by insomnia status before the pandemic

Characteristic	Total (n = 1,891)	Without pre-pandemic insomnia (n = 1,560)	With pre-pandemic insomnia (n = 331)	*P* value
Age, year, mean (SD)	43.6 (17.4)	42.6 (17.2)	48.2 (18.2)	< .001
Sex, female, %	51.8	50.4	57.2	.01
Sleep apnea, %	8.6	4.9	21.2	< .001
Attention/concentration, %	10.6	7.8	22.9	< .001
Memory problems, %	8.8	4.9	26.4	< .001
Chronic fatigue, %	7.4	5.1	17.3	< .001
Depression/anxiety, %	19.9	15.2	37.8	< .001
Long Covid, %	55.5	51.4	70.8	< .001

SD, standard deviation.

Table 2. Relative risks of long COVID for COVID-19 patients with insomnia diagnosed before the pandemic

	Model 1 (n = 1,891)		Model 2 (n = 1,428)		Model 3 (n = 1,404)	
Regression variables	RR	95%CI	RR	95%CI	RR	95%CI
Age	1.00	1.00-1.01	1.00	1.00-1.01	1.00	1.00-1.01
Sex	1.23***	1.10-1.36	1.10**	1.12-1.60	1.10**	1.11-1.60
Sleep apnea	NA	NA	1.13*	1.06-1.70	1.14*	1.06-1.77
Attention/concentration	NA	NA	1.22	0.78-1.69	1.22	0.77-1.68
Memory problems	NA	NA	1.19	0.79-1.56	1.20	0.77-1.56
Chronic fatigue	NA	NA	1.18	0.62-1.19	1.22	0.59-1.29
Depression/anxiety	NA	NA	NA	NA	1.09	0.84-1.17
Insomnia	1.31***	1.13-1.52	1.31*	1.05-1.62	1.33*	1.07-1.65

Model 1 adjusted for age and sex; model 2 adjusted for age, sex, sleep apnea, problems of attention or concentration/ADHD, memory problems, and chronic fatigue; Model 3 adjusted for age, sex, sleep apnea, problems of attention or concentration/ADHD, memory problems, chronic fatigue, and depression/anxiety.
Cases with insomnia developed during COVID-19 pandemic or after infection were excluded from the analyses.
***p<0.001; **p<0.01; *p<0.05.

Table 3. Characteristics of COVID-19 patients by COVID-19 status and duration of insomnia symptoms during illness

Characteristic	Total (n = 1,393)	Short COVID cases (n = 493)	Long COVID cases without long-lasting insomnia symptoms (n = 460)	Long COVID cases with long-lasting insomnia symptoms (n = 440)	*P* value
Age, year, mean (SD)	43.3 (16.5)	$37.4\ (18.5)_a$	$44.8\ (16.3)_b$	$49.7\ (14.2)_c$	< .001
Sex, female, %	52.5	40.8_a	60.7_b	59.8_b	< .001
Sleep apnea, %	4.7	2.0_a	5.0_b	8.1_c	< .001
Attention/concentration, %	8.6	5.9_a	13.1_c	7.9_a	< .001
Memory problems, %	5.0	1.8_a	7.3_b	8.8_b	< .001
Chronic fatigue, %	5.0	3.5_a	7.7_b	4.8_{ab}	.02
Depression/anxiety, %	16.0	13.0	18.2	18.1	.07
ISI ≥ 10, %	45.8	24.4_a	32.6_b	86.5_c	< .001

Long-lasting insomnia symptoms was defined as the presence of difficulties falling or staying asleep for ≥ 3 months. ISI, Insomnia Severity Index; SD, standard deviation. Means with different subscript (letter) are significantly different.

Table 4. Relative risks of insomnia for long COVID cases without long-lasting insomnia symptoms

	Model 1 (n = 953)		Model 2 (n = 752)		Model 3 (n = 743)	
Regression variables	RR	95%CI	RR	95%CI	RR	95%CI
Age	0.99	0.98-1.00	0.99	0.98-1.00	0.99	0.98-1.01
Sex	0.92	0.61-1.39	0.76	0.45-1.27	0.76	0.45-1.28
Sleep apnea	NA	NA	0.66	0.22-2.01	0.56	1.18-1.76
Attention/concentration	NA	NA	1.37	0.87-2.15	1.29	0.82-2.03
Memory problems	NA	NA	0.95	0.60-1.50	1.11	0.82-1.51
Chronic fatigue	NA	NA	1.17	0.68-2.02	1.03	0.61-1.74
Depression/anxiety	NA	NA	NA	NA	1.13	1.00-1.27
Long COVID	1.39*	1.03-1.84	1.16	0.81-1.65	1.17	0.82-1.68

Insomnia was defined as Insomnia Severity Index (ISI) score ≥ 10, Model 1 adjusted for age and sex; model 2 adjusted for age, sex, sleep apnea, problems of attention or concentration/ADHD, memory problems, and chronic fatigue; Model 3 adjusted for age, sex, sleep apnea, problems of attention or concentration/ADHD, memory problems, chronic fatigue, and depression/anxiety.

Cases who had pre-infection insomnia, provide no information on current insomnia status, or had insomnia symptoms as one of the long-lasting symptoms were excluded from the analyses.

*$p<0.05$.

Figure 1. Flow chart for the inclusion of participants in analysis 1 (pre-pandemic insomnia status and long COVID)

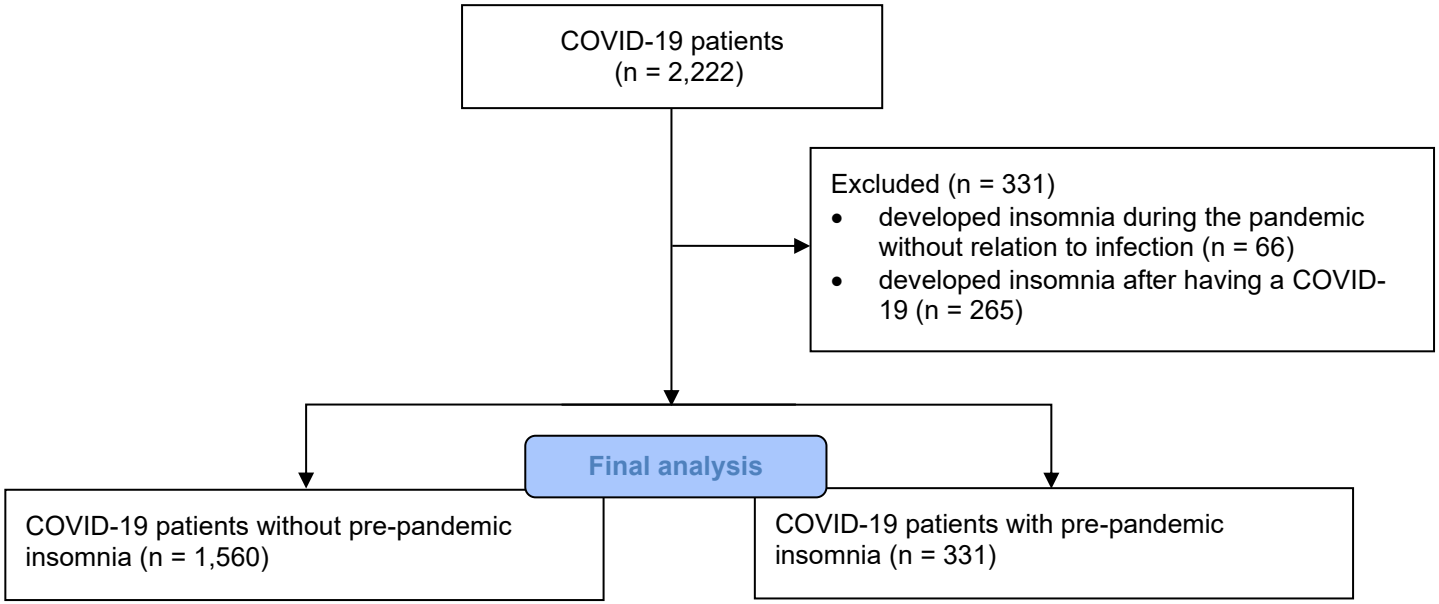

Figure 2. Flow chart for the inclusion of participants in analysis 2 (COVID-19 status and insomnia after infection)