Symptomatology throughout pandemic: network analysis and latent transition analysis of prolonged post-traumatic stress symptoms, depressive symptoms, and sleep disturbance

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GLOSSARY OF ABBREVIATIONS

ABIC	Adjusted Bayesian information criterion
AIC	Akaike information criterion
BIC	Bayesian information criterion
CCMHS	CMERC cohort online mental health survey
CD-RISC	Connor-Davidson resilience scale
CFA	Confirmatory factor analysis
CI	Confidence interval
CMERC	Cardiovascular and metabolic etiology research center
COVID-19	Coronavirus disease 2019
CS	Correlation stability
EFA	Explanatory factor analysis
GAD-7	General anxiety disorder-7
CMERC	Patient health questionnaire-9
PHQ-9	General anxiety disorder-7
GAD-7	PTSD Checklist for DSM-5
IC	Information criterion
LASSO	Least absolute shrinkage and selection operator
LCA	Latent class analysis
LL	Log-likelihood
LTA	Latent transition analysis
MERS	Middle east respiratory syndrome
PCL-5	PTSD Checklist for DSM-5
PHQ-9	Patient health questionnaire-9
PSQI	Pittsburgh sleep quality index
PTSD	Post-traumatic stress disorder
PTSS	Post-traumatic stress symptom
SARS	Severe acute respiratory syndrome
SE	Standard error

ABSTRACT

Symptomatology throughout pandemic: network analysis and latent transition analysis of prolonged post-traumatic stress symptoms, depressive symptoms, and sleep disturbance

BACKGROUND

After the declaration of Coronavirus disease 2019 (COVID-19) as a pandemic, it has been considered a mass trauma or collective trauma for the general population. Given that those who are psychologically affected by the pandemic have outnumbered those who are physically infected with COVID-19 and given that experiencing traumatic events could trigger a wide variety of psychological distresses, the prolonged COVID-19 pandemic could lead to a significant increase in the prevalence of psychiatric comorbidity, especially between post-traumatic stress symptoms (PTSS) and depressive symptoms among the public. In addition, the symptom-level interplay between PTSS and depressive symptoms during the pandemic could cause a tilting pattern for deterioration and improvement of comorbidity. Accordingly, capturing the comorbid structure between PTSS and depressive symptoms and understanding the mechanisms of comorbid symptoms over time might be an intervention point for the public.

METHODS

Participants aged 30–64 years completed an online mental health survey from the Cardiovascular and Metabolic Etiology Research Center across three phases of the COVID-19 pandemic (*N*s= 1925, 1754, 1595). The PTSS and depressive symptoms were estimated by online survey versions of the post-traumatic stress disorder Checklist for the DSM-5 (PCL-5) and Patient Health Questionnaires-9 (PHQ-9). After the goldbricker test for redundancy, we conducted network analyses to find the symptom-level mechanism between PCL-5 and PHQ-9 through four steps: 1) network estimation, 2) network inference, 3) network robustness, and 4) network comparison. To capture the changing patterns of comorbid symptoms, we applied latent transition analysis and inferred a significant status transition throughout COVID-19 and a possible impact on PTSS/depressive symptoms over time, stratified by age and sex.

RESULTS

From the comorbidity network, the PCL-5 and PHQ-9 formed two separate communities. Moreover, sleep problems were consistently identified as the most influential bridge symptom throughout COVID-19, whereas the central symptoms varied. Each structure of the comorbidity network was stable but suggested a significant difference between the subacute and chronic phases of COVID-19. After building on the network model, we conducted latent transition analysis on the bridge symptom, which was sleep problems in our study. The sleep problems were defined by scores of nine items of sleep disturbance

components among the Pittsburgh Sleep Quality Index. As a result of latent transition analysis, the sleep disturbance was categorized as three latent statuses: reference (status 1), sleep continuity problems (status 2), and overall sleep problems (status 3). When transitioning from the subacute to chronic phase, changing patterns from reference or overall sleep problems into sleep continuity problems were primarily reported. This pattern showed a significant negative association with PCL-5 and PHQ-9 during the pandemic, especially for women and participants aged 50-60 years. Further, the sleep continuity problems status had a possible negative impact on PCL-5 and PHQ-9 over time.

CONCLUSION

Our results suggest that there might exist a changing pattern in network structure throughout the COVID-19 phases, while the bridge symptom, and sleep problems in our study, remain constant. In addition, the transition to sleep continuity problems, primarily from other sleep disturbances occurred during the time flow from the subacute to chronic phases, and this transition has a negative association with PTSS and depressive symptoms. Hence, from a public health perspective, if an infectious epidemic situation (i.e., next pandemic) arises in the future, prompt screening of associated sleep problems and considering its status would be effective as an effort to alleviate both the comorbidity of PTSS and depressive symptoms and adverse psychological effects, especially by focusing on the tilting point from the subacute to the chronic phase of the pandemic.

Key words: network analysis, latent transition analysis, post-traumatic stress symptoms, depressive symptoms, sleep problems, COVID-19

I. INTRODUCTION

1. Backgrounds

Psychological impact during phases of the COVID-19 pandemic

Coronavirus disease 2019 (COVID-19) first emerged in China in December 2019, and within 2 months, it promptly became a pandemic worldwide. The COVID-19 pandemic has been considered a mass trauma or collective trauma, that triggered a wide variety of psychological distresses, such as anxiety, depression, and post-traumatic stress symptoms (PTSS).[1] Among the major infectious epidemics that erupted in the twenty-first century, the COVID-19 pandemic is comparable to previous infectious diseases, such as Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS), which had higher infectiousness and global impact. Previous studies about SARS and MERS have reported that those who were psychologically infected by the pandemics outnumbered those who were physically affected, demonstrating massive impacts on psychological health.[2-4] Therefore, those who are exposed to the COVID-19 pandemic, including the population in general not just infected patients and healthcare workers, might experience an adverse effect on psychological health as a stressor. Thus, the prolonged pandemic could affect psychological health at society-level, as opposed to merely an individual-level, thereby increasing the prevalence of psychological distress as a collective form of intense stress.

The psychological epidemic of stress caused by COVID-19 may have spread more quickly than the pandemic itself, as pandemic-related fear extends to the public.[5] Following the COVID-19 outbreak, a significant increase in the incidence of psychiatric consequences, such as PTSS, depression, anxiety, substance use, suicide, and other mental disorders, was expected.[6-8] During the first year of the COVID-19 pandemic, psychological distress among the public globally was elevated than was before COVID-19.[9,10] In particular, PTSS and symptoms of mood disorders have been common and considerable during the COVID-19 pandemic. Several meta-analyses for the general population have shown that the prevalence of PTSS during the COVID-19 pandemic was 15% to 18%.[11,12] In addition, in the United States, nearly 41% of people reported experiencing at least one adverse psychological condition, including symptoms of anxiety or depression (30.9%) and PTSS (26.3%).[9] Furthermore, following the shutdown in South Korea, nearly half (47.5%) and one-fifth (20.2%) of the Korean population had COVID-19-related anxiety or depression and sleep disorders, respectively.[13] Prior studies from China, especially those with a focus on COVID-19, have verified the high prevalence of PTSS and depression among the public, indicating that the prevalence of PTSS and depressive symptoms were 2.7% to 4.6% and 16.5% to 34.7%, respectively.[14-18] Given that PTSS has frequently included comorbidity with depressive symptoms and longitudinally those symptoms were prone to increase simultaneously, we need to consider the increased comorbidity between PTSS and depressive symptoms after the outbreak of COVID-19.[19]

PTSS, depressive symptoms, and comorbidity during the COVID-19 pandemic

During the COVID-19 pandemic, the public suffered from PTSS as a result of the increasing number of infections, the lack of clear and definite information about the virus from the media, and implementation of social distancing.[20] Given that the COVID-19 pandemic is a series of traumatic events that causes mass or collective trauma for the general population, it is necessary to investigate the characteristics of PTSS following the pandemic and its related comorbidities in people who were exposed to the COVID-19 crisis.[1] PTSS frequently co-occurs with other mental disorders. Furthermore, prolonged traumatic events may result in comorbid psychiatric conditions in different populations and vary according to the type of trauma.[18,21-23] Especially, among individuals with PTSS, the comorbid depressive symptoms are particularly high and the rates of comorbidity range from 21% to 94%.[23-29] Even longitudinally, the comorbid structure of PTSS and depressive symptoms were prone to move simultaneously.[19] Moreover, compared with individuals with one mental disorder, those with comorbid PTSS and depressive symptoms are more likely to experience deleterious outcomes. These outcomes not only impact the individual, but also create a significant social burden. For example, comorbid status reduced social functioning and significantly elevated the risk for chronic symptoms and suicide, and caused a greater burden through the frequent use of health care.[30,31] However, there is no consensus to explain the comorbidity of PTSS and depressive symptoms. Thus, capturing the comorbid structure between PTSS and depressive symptoms and understanding the associated mechanisms might be considered as an intervention point.

As the pandemic has continued for several years, people have adapted to prolonged COVID-19, which decreases awareness of the pandemic-related trauma. However, the psychological effects of COVID-19 do not go away and may continue to affect people in different patterns over time. For example, a Chinese longitudinal study of the general population evaluated psychological effects during the early COVID-19 outbreak, including PTSS, depression, anxiety, and related comorbidity, and reported high PTSS as well as a significant reduction in psychological impact over time.[15] Additionally, in a meta-analysis of longitudinal cohort studies, overall psychological symptoms showed a slight increase in the early phases of COVID-19; however, the severity of psychological symptoms decreased significantly over subsequent phases.[32] These changing patterns (deterioration and then improvement) in psychological symptoms during the different phases of the pandemic may represent an acute response to an unexpected traumatic event, which may result from psychological adaptation and resilience.[33,34] Nonetheless, the specific implication of the comorbid structure over time has not been adequately considered. To further investigate the association between PTSS and depressive symptoms, our study applied a network approach.

Network approach to PTSS and depressive symptoms

Psychological symptoms might be interconnected by symptom-level interaction. In particular, the network approach has several advantages. First, instead of depending solely on a global screening tool or categorical diagnosis, network analysis may contribute to the goal of identifying informative symptoms that are primarily related to the clinical condition

or prognosis of individuals.[35,36] Second, because the network approach is a kind of explanatory research, it provides a theoretical framework for understanding psychological symptoms.[37] The approach is appropriate for psychopathology study because it makes no assumptions about a priori causal relationships between nodes; moreover, the connection between symptoms could be bidirectional.[37] Third, centrality indices of the network analysis methodologically examine the role of certain nodes in the network system.[37,38] Therefore, utilizing the network approach to estimate symptom-level interplay might provide a source in understanding the comorbid structure between PTSS and depressive symptoms. From the clinical perspective, a network approach for an in-depth understanding of symptom-level interplay might be novel because psychological symptoms do not activate alone. Recently, the network approach has been utilized in psychological symptomatology to capture the symptom structures of particular disorders and discern the central and/or bridge features between comorbid disorders.[37-40] The network analysis conceptualizes mental disorders as networks of related psychological symptoms, as opposed to the conventional belief that mental disorders cause their associated symptoms.[37-40] In network analysis, the symptoms are termed nodes, and the computation of centrality is quantified by central- or bridge- node centrality indices.[26,41] Interpreting the node-centrality determines which symptoms are dependent on each other and most relevant to a disorder, which reveals the most important target of clinical interventions.[42] Therefore, central and bridge symptoms represent recommended intervention targets because they may promote the deactivation of symptom-level spread of comorbidity.[40]

According to the network perspective of comorbidity, each psychological symptom is associated with dynamic and causal relations which activate each other.[26] Identification of both central symptoms, because of their key role in the strong associations with the majority between-disorder symptoms, and bridge symptoms, because of their mediating role between disorders, has some implications. While network analysis can be readily used to examine the bridging role of more specific causes of high comorbid rates of PTSS and depressive symptoms, few studies included depressive symptoms in their network analysis of PTSS.[26,43-45] Across studies that implemented comorbidity network models to estimate central and/or bridge symptoms, results vary considerably.[26,43-46] In some studies of veterans, the most central symptoms were having flashbacks, getting emotionally upset by trauma reminders, having concentration difficulties, and experiencing anhedonia.[26,46] Estimation of key bridge symptoms to explore between-disorder connections revealed the presence of sleep difficulties, avoidance of thoughts, and emotional upset resulting from trauma reminders.[43-45] Further, when COVID-19 was regarded as a mass or collective trauma, reckless and self-destructive behavior acted most centrally as a symptom of PTSS in the general population, and depressed mood was the bridge symptom of PTSS and depressive symptoms.[42,47] These heterogeneous results regarding central and bridge symptoms might be explained by the exposure to different types of trauma-related events and the observed timing after the traumatic event; therefore, in the face of novel exposure to the COVID-19 pandemic, we must consider specific network structures and the patterns over time between PTSS and depressive symptoms.

However, those networks of psychological symptoms of traumatic events could show changing patterns over time. According to previous network analyses in people with PTSS, by experiencing trauma-related events, PTSS was activated at the acute phase, and those symptoms interacted with each other, making strong connections as time elapsed; finally, the symptom connection was reduced while a minority suffered long-term psychological problems.[36,48,49] For example, one network study of PTSS in earthquake survivors found that flashbacks were the most central symptom in all periods, connection between reexperiencing and avoiding thoughts arose as PTSS became chronic, and connectivity became a threat to mental health.[36] Furthermore, veteran post-traumatic stress disorder (PTSD) studies revealed that reexperiencing and avoidance clusters have high centrality and dynamically change over time.[48,49] Thus, understanding the central psychological symptoms at the acute phase of a traumatic might provide the potential to understand how initial stress symptoms develop into longer-term problems and to consider the early intervention strategies as a focus for secondary prevention. From this point of view, deep consideration of the bridge symptoms between PTSS and the depressive symptom network at an acute phase might offer the opportunity to understand how comorbid symptoms interact with each other and develop into comorbidity. In the same vein, as COVID-19 has been prolonged for several years, the comorbid structure between PTSS and depressive symptoms is likely to have changed; thus, the need to capture the changing patterns of the symptom interaction over time is emerging.

Sleep problems during COVID-19

Sleep disorders are common in the general population. Formally, sleep disorders were expressed as more than 80 different types in the International Classification of Sleep Disorders.[50] In the general population, about a third of people have suffered insomnia symptoms, and 6% to 15% of people have been diagnosed with insomnia.[50,51] Poor sleep status is associated with mental and physical disorders and even mortality among the general population.[52,53] During COVID-19, sleep problems have been quite common and have affected about 40% of the general population.[54] Given that before COVID-19 sleep-related difficulties were estimated to be present in between 12% and 18% of the general population, the prevalence of sleep problems among the general population might appear to be higher during COVID-19.[55,56] Similar to these increasing patterns in the prevalence of sleep problems, other mental disorders were also prone to be more prevalent and increased simultaneously with sleep problems during COVID-19.[57] After the outbreak of the pandemic, a Chinese study reported a strong association between sleep problems and flashbacks, and Saudi Arabian studies have suggested sleep problems are a strong predictor of psychological distress such as depressed mood, rumination, and avoidance related to the pandemic.[42,56] Additionally, a prior systematic study reported that sleep problems were found to be associated with higher levels of psychological distress during COVID-19, and vice versa.[58] Accordingly, associations might differ depending on the profile of sleep problems over time after traumatic events, and by capturing the tilting point of the profile, psychological distress may be alleviated with the intervention of sleep problems.[58] To this

point, in-depth understanding of patterns of sleep problems after the pandemic outbreak and its impact on psychological symptoms over time might be important for preventing possible comorbidities in the general public.[59] To further investigate both the changing patterns of latent classes in sleep problems across phases of COVID-19 and their possible association with PTSS and depressive symptoms over time, we applied a latent transition analysis (LTA).

Latent transition analysis with sleep problems

Despite the abundance of variable-centered studies on clustering, such as confirmatory factor analysis (CFA) and explanatory factor analysis (EFA), there are few person-centered studies involving latent class analysis (LCA) and LTA. Recently, researchers have highlighted the relevance of repeated measurement in the estimation of psychological networks due to the limitations of cross-sectional data.[60] Therefore, person-centered analysis might provide perspective on how participants might be categorized in accordance with their profile of sleep problems.[61-63] Further, certain longitudinal studies are needed, especially those with a focus on the COVID-19 phases, as this is a time of great change globally. Capturing the transition between these sleep profiles over time would go a long way to determine future efforts to suggest more targeted interventions to participants with specific sleep profiles and to encourage the more efficient use of resources.

A prior LCA of the Chinese elderly, utilizing part of the Pittsburgh Sleep Quality Index (PSQI), suggested four distinct sleep problems profiles: inadequate sleep, disturbed sleep,

trouble falling asleep, and multiple problems.[64] Although those four profiles showed no significant difference in demographics and psychiatric characteristics among the study population, the authors proposed that different sleep problems do occur in a rather heterogeneous manner among the elderly and they can generally be classified into the four different profiles.[64] In addition, another LCA of women was conducted to identify latent homogeneous subgroups according to seven components of the PSQI, and the authors suggested that sleep quality is multifaceted and selected the two-class latent model.[65] In a study including the United States' elderly population involving longitudinal data and utilizing PSQI, repeated measures of latent profile for sleep quality were estimated as homogenous latent profiles across six time points, and two-latent profile patterns were derived: consistently good sleepers and chronically poor sleepers.[66] Furthermore, cohort data for Australian women were consistent for four sleep difficulty profiles: troubled sleepers, early wakers, trouble falling asleep, and untroubled sleepers; moreover, those profiles proved to be a potential indicator of mortality.[67,68]

As shown in these prior studies, LCA is the most commonly used statistical method to identify and delineate different profiles of psychiatric disorders in a systematic manner.[69-71] Their findings may offer an interesting preliminary view into how the observed profiles can be subtyped. Furthermore, by extension of the LCA, LTA could evaluate the longitudinal transition of the observed profiles; however, few studies have utilized the LTA to identify a change in repeated measures of sleep disturbances during COVID-19 phases.[72]

2. Objectives of the study

The primary measures in this study were PTSS, depressive symptoms, and sleep disturbances, which are commonly examined psychological consequences in post-trauma-related research.[73] Although existing studies have investigated the comorbidity between PTSS and depressive symptoms, important knowledge gaps about symptom-level interactions throughout COVID-19 remain. Therefore, we aimed to assess the interaction between PTSS and depressive symptoms throughout the phases of COVID-19 and identify the bridge symptoms (i.e., PTSS with strong associations with depressive symptoms) utilizing network analysis in the general population. Further, by applying LTA, we divided the multifaceted bridge symptoms, which were identified by the network analysis as maintaining this type of comorbid structure, into several homogeneous symptom subgroups and aimed to discover the prominent subgroups throughout the COVID-19 phases. Finally, we considered the possible effect of bridge symptoms on PTSS and depressive symptoms over time. The detailed aims of the current study are shown below.

By utilizing **network analysis** on PTSS and depressive symptoms, we aimed to:

1. Characterize which symptoms are the most influential in a comorbidity network throughout the COVID-19 pandemic.

   : Considering the outbreak of the pandemic as collective or mass trauma, COVID-related flashbacks or avoidance were hypothesized to serve as the central symptoms between PTSS and depressive symptoms. Based on previous research, the prominent PTSS were flashbacks and avoidance after the trauma and intrinsically related to each other.[36,74-76]

2. Characterize which symptoms account for identified associations in a comorbid structure in each phase of COVID-19.

   : Given that dysphoric mood (concentration problems and sleep problems) overlapped between PTSS and depressive symptoms, we hypothesized that the bridge symptoms of the comorbidity networks would include either COVID-related concentration problems or sleep problems. We built upon previous literature that focused on flashback-sleep problem connections by examining symptom structure after the pandemic.[42]

3. Compare the results of each phase statistically.

   : Following previous research, it was also hypothesized that the subacute phases of COVID-19 have led to a different symptom structure compared with that resulting from its chronic aspects. The networks of psychological symptoms of traumatic events could show changing patterns over time.[36,48,49]

Further, by utilizing **LTA** on bridge symptoms, we secondarily aimed to:

1. Capture latent status of the bridge symptom across all COVID-19 phases.

   : Considering the heterogeneity of psychological symptoms, we hypothesized that bridge symptoms are multifaceted and have distinct latent homogeneous profiles.

2. Estimate the changing patterns of the bridge symptom and its effect on both PTSS and depressive symptoms throughout COVID-19 phases.

   : Given that the profiles of psychological symptoms might change over time after a traumatic event, we hypothesized that there exist changing patterns of subgroups of the bridge symptoms over time, which has different effects on the PTSS and depressive symptoms.

3. Infer the possible effect of the latent status during COVID-19 on both PTSS and depressive symptoms over time.

   : We hypothesized that the pandemic would demonstrate the massive impact on psychological health over time, and further, have a heterogeneous impact depending on the profile of psychological symptoms in the long term.[2-4]

II. MATERIALS AND METHODS

1. Data collection and participants

This study used data from a previous community-based prospective cohort study known as the Cardiovascular and Metabolic Etiology Research Center (CMERC) study, which was conducted from 2013 to 2018, and finally enrolled 4,060 participants aged 30–64 years as a baseline.[77] For the baseline study, we investigated a wide range of demographic characteristics (age, sex, education, marriage, cohabitation, income, subjective economic status, and occupation), medical history, current medication intake, health-related behaviors (smoking, drinking, physical activity, sleep, and obstructive sleep apnea, usual dietary intake), psychological conditions, physical examinations (body size, composition, and blood pressure) as well as biochemical indicators.[77] The information on demographic characteristics, medical history, current medication intake, and health-related behaviors was obtained based on participants' self-reports through a face-to-face interview utilizing standardized questionnaires. Psychological conditions were assessed in a self-administered manner rather than a face-to-face-interview. A trained researcher conducted face-to-face interviews and reviewed all responses, including the self-administered responses, to check for any instances of misreading, miswriting, or missing answers. All the participants completed questionnaires and examinations according to a predefined protocol.

Since the occurrence of COVID-19 in South Korea, the CMERC cohort online mental health survey (CCMHS) was conducted several times for the CMERC cohort participants: 1) the 2020 survey was conducted right after the first outbreak of COVID-19; 2) the 2021 survey was conducted about 1 year after the first outbreak of COVID-19, and 3) 2022 survey was conducted about 2 years after the first outbreak of COVID-19. Specifically, the 2020 survey was investigated within 1 to 3 months after the outbreak of COVID-19 and was defined as a "subacute phase," while the 2021 and 2022 surveys were investigated after 3 months and defined as a "chronic phase." Detailed information about the time points of each of the surveys and the trend of confirmed cases of COVID-19 in South Korea is shown in Figure 1. For each survey, we contacted 3,940 people out of the 4,060 baseline participants asking them to participate in the survey, excluding 59 participants who had withdrawn consent or died and 61 who could not be reached by mobile phone contact. By accessing the URL of the mobile phone, participants responded to the self-reported questionnaires. As part of the online mental health study, we investigated the Patient Health Questionnaire-9 (PHQ-9), General Anxiety Disorder-7 (GAD-7), PTSD Checklist for DSM-5 (PCL-5), Pittsburgh Sleep Quality Index (PSQI), and questions about awareness of COVID-19, material/mental support, and thoughts on COVID-19 vaccines. All responses were reviewed by trained researchers to examine any instances of inaccurate reading, inaccurate writing, or missing answers. Detailed information about the timeline of the baseline study and CCMHS as well as the main measurements used in this study are shown in Figure 2.

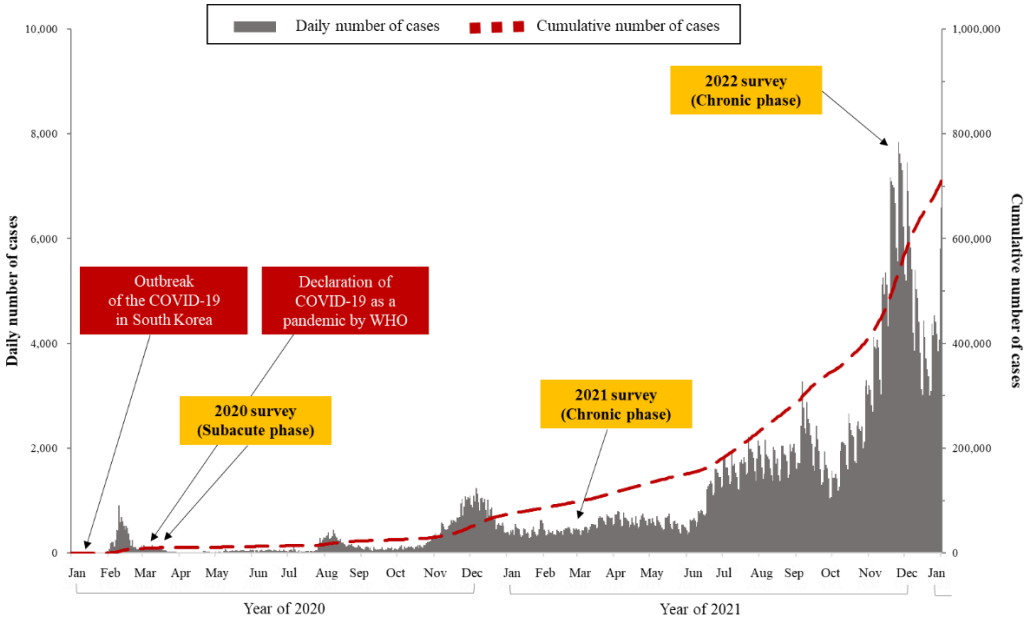


Figure 1. The trend of daily new cases and cumulative cases of COVID-19 in South Korea and the time points of the CCMHS

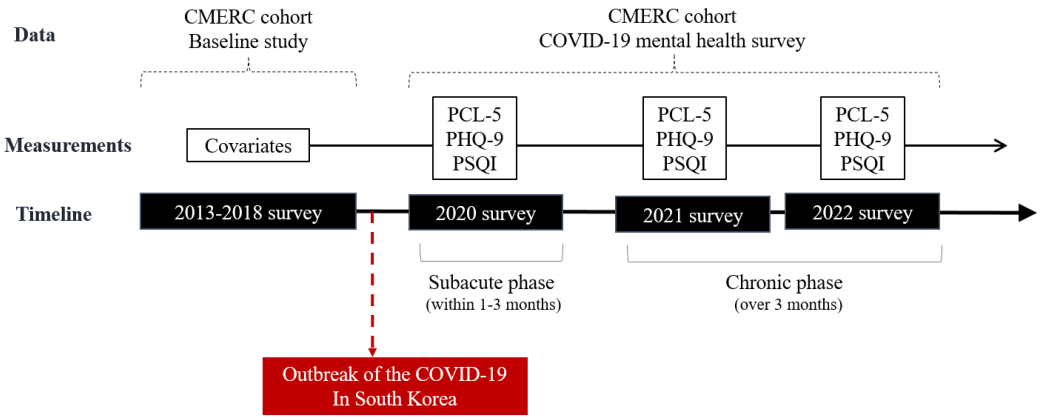


Figure 2. Timelines and measurements of the CMERC cohort baseline study and CCMHS

A. Participants for network analysis

Among the respondents, we excluded individuals who did not provide information regarding the PCL-5 and PHQ-9.[78,79] The number of respondents for each survey are as follows: 1) 2020 survey (among 1,970 respondents, a total of 1,925 individuals were finally included); 2) 2021 survey (1,791 respondents for the follow-up survey and a total of 1,754 individuals were included), and 3) 2022 survey (among 1,633 respondents, a total of 1,595 individuals completed the survey) (Figure 3). Further, among the participants who completed the answers to the PCL-5 and PHQ-9, the number of respondents who participated in all three surveys was 1,019, and sensitivity analysis was conducted with these participants.

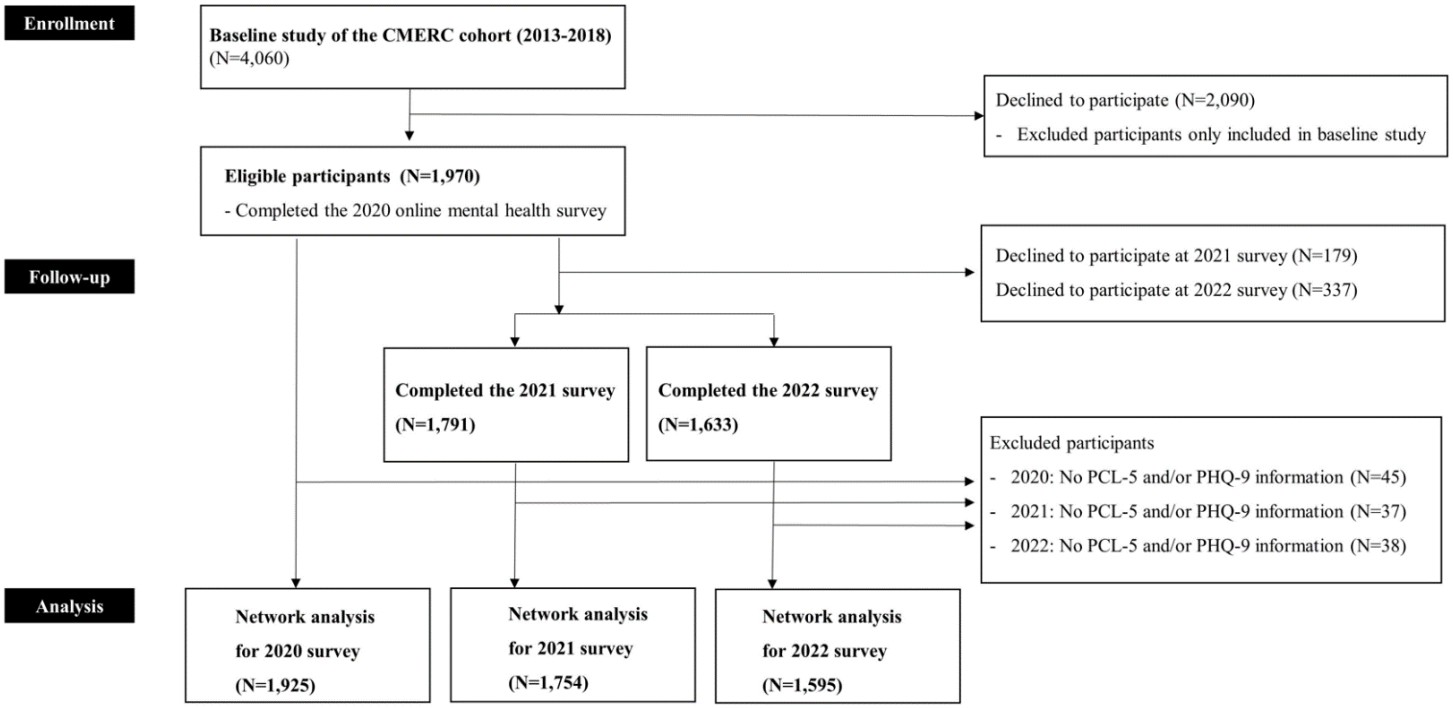


Figure 3. Flow diagram of study participants for network analysis

B. Participants for latent transition analysis

For LTA, participants who did not respond to more than one follow-up regarding the PSQI during the 2020 through 2022 surveys were excluded. The LTA utilizes full-information maximum likelihood estimation for all available data. Finally, 1,930 respondents who answered the PSQI through more than one follow-up were included (Figure 4). Additionally, among the respondents who completed the PSQI, sensitivity analysis was carried out on the 1,005 respondents who took part in all three surveys.

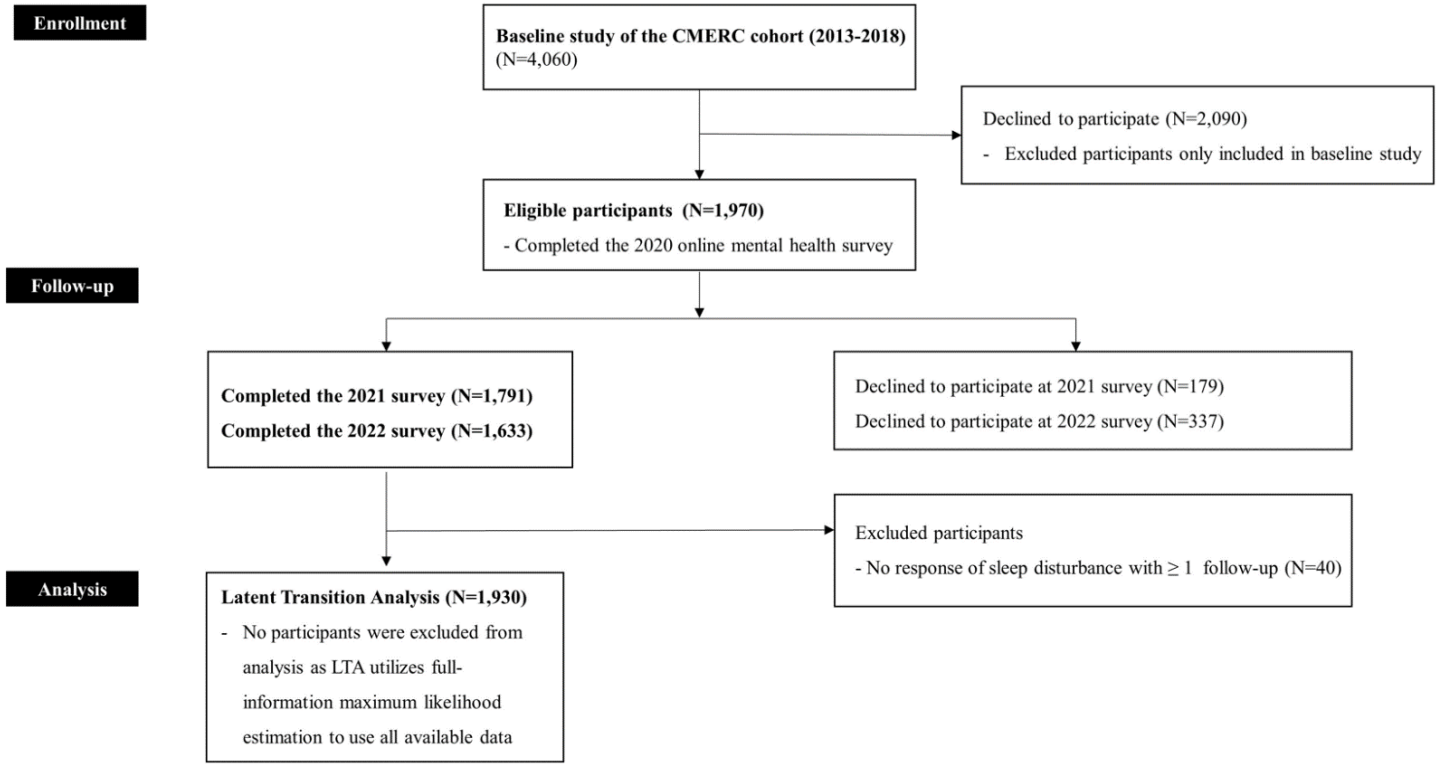


Figure 4. Flow diagram of study participants for LTA

2. Measurements

A. Assessing for network analysis: depressive symptoms

In the CMERC online mental health survey, the self-reported PHQ-9 questionnaire is utilized for measuring depressive symptoms (Appendix 1).[79] The PHQ-9 contains nine items that measure the frequency of depressive symptoms over the preceding 2 weeks. Each item is rated in frequency on a 4-point scale as follows: 0 = *not at all*, 1 = *several days*, 2 = *more than half of the days*, and 3 = *nearly every day*. Scores on the PHQ-9 range from 0–27. This questionnaire has been validated for use in the Korean population, for which Cronbach's alpha of the whole scale was 0.81 and test-retest reliability was good (r = 0.89).[80]

B. Assessing for network analysis: PTSS

Symptoms of post-traumatic stress were considered utilizing the PCL-5 (Appendix 2).[78] The PCL-5 is a 20-item questionnaire assessing the severity of PTSS in the past month using a 5-point scale from 0 (not at all) to 4 (extremely) and based on DSM-5. Scores on the PCL-5 range from 0 to 80. The PCL-5 is an indicator that includes 20 items to assess four clusters of post-traumatic stress syndrome, categorizing intrusive symptoms (questions 1-5), avoidance symptoms (questions 6 and 7), negative alteration in cognition and mood (questions 8-14), and hyperarousal symptoms (question 15-20). The validity of the PCL-5 has been verified in a previous study, which exhibited strong internal

consistency (α = .94) and test-retest reliability (*r* = .82).[78] The PCL-5 was also validated in the Korean population, for which Cronbach's alpha of the whole scale was 0.93 and test-retest reliability was 0.90.[81]

C. Assessing for LTA: sleep disturbance

The overall sleep disturbance was estimated using the PSQI at every time point. In general, the PSQI is a 19-item questionnaire that assesses self-reported sleep quality and duration over the course of the previous 4 weeks (Appendix 3).[82] Global PSQI scores consist of seven components for each of the following: sleep disturbances (9 items), daytime dysfunction (2 items), sleep latency (2 items), subjective sleep quality (1 item), sleep duration (1 item), sleep medication (1 item), and habitual sleep efficacy (3 items). Of those components, we utilized the 9-items of the sleep disturbance section for our analysis.

The observed 9-items on sleep disturbance have 4-point Likert scale responses relating to the frequency of specified sleep problems in past the 4 weeks ("never=0," "less than 1 time per week=1," "1 or 2 times per week=2," and "more than three time per week =3"). The observed indicators and mean scores of the 9-items of sleep disturbance throughout all surveys are suggested in Appendix 4. Previous literature suggested that response options of the observed items may also influence the latent status; response options with small cell sizes were proposed as collapsed into one level to interpret the latent status easily.[83] For our analysis, we collapsed the two smallest response options (i.e., "1 or 2 times per week," and "more than three times per week") into one response,

therefore, the response options of the 9-items in sleep disturbance have three-levels ("never=0," "less than 1 time per week =1," "more than one time per week =2"). The PSQI questionnaire has been validated in the Korean population, for which Cronbach's alpha of the whole scale was 0.84.[84]

After building on the comorbidity network models, according to our findings of comorbid symptoms, sleep problems were consistently identified as the most influential bridge symptom of all the time-points after the COVID-19 outbreak (refer to the Results section below for additional details). Therefore, in the application of the comorbid bridge symptom for LTA as a targeted intervention, we utilized sleep problems as the variables of LTA to estimate the changing patterns of the comorbid symptom and its effect on comorbid structures over time.

D. Assessing for additional analysis: resilience

For additional analysis to estimate the antagonism between psychological symptoms in comorbidity network, resilience score utilizing Connor-Davidson Resilience Scale (CD-RISC) was included. In the CMERC online mental health survey, the self-reported CD-RISC questionnaire is able to measure the ability of bounce back in both patients and general population.[85] The CD-RISC has 25 items and is scored on 5-point Likert scale (0 = *not at all*, 1 = *almost never*, 2 = *sometimes*, 3 = *often*, and 4 = *almost always*), where a higher score suggested better resilience status.[85] This questionnaire has been adequately demonstrated which internal consistency and test-retest reliability were 0.93 and 0.93, respectively.[86]

E. Assessing demographic status

Demographic status (covariates) included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake at baseline data. These variables were utilized as demographic status for network analysis, and as covariates for LTA. Baseline socioeconomic status consisted of marital status, educational year, and household income. Marital status was categorized as the following: never married, living with a partner, living alone, and separated by the death of a partner. The educational year was grouped into elementary (6 years), middle school (9 years), high school (12 years), and college (over 12 years), according to the years of educational attainment and the education system in Korea. Information on household income was divided into quartiles (<24.5, 24.5 to <34.5, 34.5 to <48.3, and ≥48.3 million Korean Won/year). Lifestyle variables were comprised of alcohol use, cigarette use, and physical activity. Alcohol use and cigarette use were categorized into "never," "past," and "current" drinking or smoking. Physical activity was evaluated using the Korean version of the International Physical Activity Questionnaire-Short Form.[87] The amount and intensity of physical activity per week were categorized as "low," "middle," and "high" for those who, on average, never exercised, exercised less than 150 minutes, and exercised moderately to vigorously for more than 150 minutes, respectively. Comorbidity was inferred via a self-administered questionnaire about the history of diagnoses by physicians during one's lifetime with any of the following diseases: hypertension, diabetes, cancer, stroke, and transient ischemic stroke, myocardial infarction and angina, heart failure, chronic renal failure, dyslipidemia, liver disease, chronic hepatitis,

liver cirrhosis, thyroid disorders, asthma, chronic obstructive pulmonary disease, osteoporosis, arthritis, and autoimmune disease. Each of the comorbid conditions was marked with “yes” or “no” if the respondents indicated they had or had not been diagnosed as having the disease, respectively. Current medication intake was investigated by surveying the intake of medication prescribed by physicians due to comorbid diseases; respondents who took medication or did not respond with “yes” or “no,” respectively.

3. Statistical analysis

A. Network approach

In this study, we estimated three distinct comorbidity networks of PTSS and depressive symptoms based on data from the following: 1) the 2020 survey (right after the first outbreak), 2) the 2021 survey (approximately 1 year after the first outbreak), and 3) 2022 survey (approximately 2 years after the first outbreak). We conducted the analysis in four steps: i) network estimation, ii) network inference, iii) network robustness, and iv) network comparison. The Schematic representation of the network approach is depicted in Figure 5. All analyses were presented by R (version 4.0.4) via R studio software (version 1.4.1106).

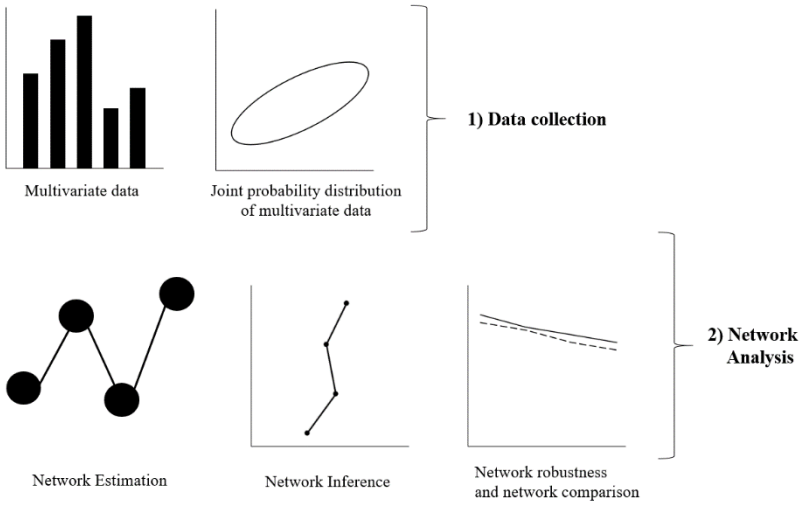


Figure 5. Schematic representation of the network approach

a) Network Estimation

Network models estimating the associations between symptoms are usually constructed using the Gaussian Graphical Model, through the R-package *qgraph*.[88] A network refers to various structures comprising variables, which are represented by nodes and edges.[26] We utilized the term "communities" to define a conceptual group, such as PTSS and depressive symptoms, rather than a statistical group. In the network structure, nodes represent each symptom. Edges depict the association between two nodes and represent some associations, such as correlations between symptoms or comorbid communities.[88,89] The edges are presented as color and thickness: i) color of the edges: positive associations are colored blue and negative associations are colored red,[88] and ii) thickness of the edges: the weighted edges are represented by line thickness, which reflects the strength of the association between nodes, and a thicker line indicates stronger relationships.[88]

Least absolute shrinkage and selection operator (known as L1-regularization method or LASSO) was applied using the Extended Bayesian Information Criterion *EBICglasso* function in the R-package *qgraph* to the estimation of the partial correlation networks to plot the network structure incorporating both the PCL-5 items and the PHQ-9 items.[90,91] Simulation studies suggested that the LASSO has a low likelihood of false positives and provides confidence that an observed association is indeed present in the network.[92] In addition, since both the PCL-5 and PHQ-9 items share several similar questions, such as

those items related to sleep and concentration problems, a redundancy test utilizing the *goldbricker* function from the *networktools* in R-package was considered.[89]

b) Network Inference

We assessed centrality and bridge centrality for identifying central and bridge symptoms in the comorbidity network structure. One-step expected influence was the metrics for centrality used to examine the relative importance of a symptom in the network structure, computed via the R-package *qgraph*.[89] The expected influence considers positive as well as negative edge weight values of all intercommunity edges extending from a given node, which was recently deemed more suitable as measures of node strength in psychopathological networks rather than node strength, betweenness, and closeness.[40] Further, one-step bridge expected influence was depicted for identifying the bridge centrality in connecting the PCL-5 and PHQ-9 communities.[40,89] The *bridge* function from the *networktools* in R-package was implemented to calculate bridge expected influence and identify potential bridge nodes.[89] The bridge expected influence is defined as the sum of the positive as well as negative values of all edges that exist between a specific node, X, which is a part of one community, and all nodes that are not in the same community as the specific node X. This metric is useful between comorbid communities, similar to the expected influence metrics above.[89,93] The centrality indices for network inference were plotted by applying standardized z-scores to facilitate interpretation.

c) Network Robustness

After estimating the comorbidity network structure, we determined network robustness by utilizing the *bootnet* R-package in three steps: 1) network accuracy, 2) network stability, and 3) bootstrapped difference tests.[94] We assessed network accuracy to test for significant differences between edge weights, which was estimated at nonparametric bootstrapped 95% confidence intervals (CIs) by sampling the bootstrap data 1,000 times, thereby presenting a distribution of edge weight and suggesting that networks were accurately estimated. Network stability was estimated utilizing a case-dropped bootstrapping procedure for testing the stability of the centrality, such as both expected influence and bridge expected influence. To this end, progressively case-dropped subsets from the original data set estimated the centrality metrics which repeatedly correlated with those estimated for the original sample, thereby yielding the correlation stability (CS)-coefficient for quantifying stability of the network centrality.[95] A CS-coefficient estimates the maximum proportion of cases that can be dropped from the original data set to maintain a correlation ≥ 0.7 (default value) with a 95% probability between the centrality indices in the original network and the centrality indices with a case-dropped subset.[94] A CS-coefficient ≥ 0.5 is preferably needed to interpret stability for centrality.[94] Lastly, we conducted a bootstrapped difference test to determine whether a node/edge is significantly different from another node/edge within each of the networks. Each of these bootstrapped difference tests were performed 1,000 times for each network. The results from applying these methods, along with those presented below, are detailed in the accompanying Appendix materials.

d) Network Comparison

To test network replicability, a set of network comparison tests was conducted to examine similarities and differences between the network from the first survey (right after the outbreak of COVID-19) and the following surveys (1-2 years after the break out of the COVID-19). Because the network comparison test was designed to compare two networks, our study performed a series of three comparisons to evaluate the differences between the network structure across each phase. The network comparison test is a statistical omnibus test that compares two network structures on several types of characteristics. By utilizing network comparison tests for quantifying differences between networks, we were able to test whether network structures differ quantitatively rather than determining differences through visual inspection alone. To this end, the R-package *network comparison test* was applied to present a permutation-based network comparison that evaluates the null hypothesis of equal connectivity between different networks by randomly shuffling orders of original data individuals.[96] In our study, invariance measures in two factors of the network structures were tested across the networks in all surveys: i) network structure invariance and ii) global expected influence invariance between the networks. The results suggested a *p* value for *M*, which is the difference between the network structures, and for *S*, which is the difference in global expected influence. And we performed a set of 1,000 permutations, which was the least recommended value, to obtain reliable comparison results.[96]

B. Latent Transition Approach

From the findings of the network analysis, sleep problems were consistently found to be the most significant bridge symptom for the PTSS/depressive symptoms networks during the COVID-19 phases. To evaluate the change in sleep problem patterns and whether sleep problems could predict the PTSS/depressive symptoms during the COVID-19 phases, respectively, we conducted additional longitudinal analysis by applying the latent transition approach (Figure 6). All analyses were conducted utilizing SAS 9.4 (SAS Institute, Inc., New York, NY).

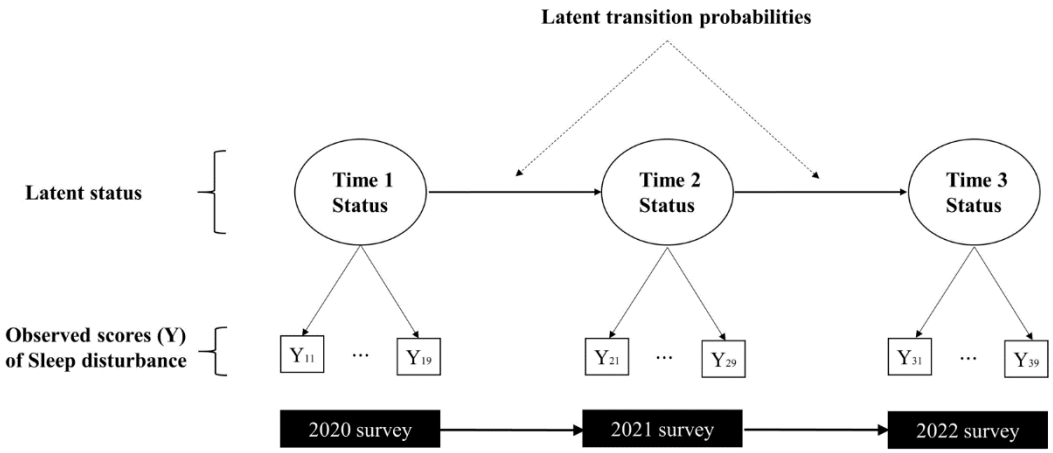


Figure 6. Conceptual diagram of a three time-point LTA

a) Conducting LCA

We first used LCA to determine patterns of latent class for each COVID-19 phase cross-sectionally using the responses to the nine items of the sleep disturbance component of the PSQI [82]. The LCA is a probabilistic method that allows clustering and statistical inference. Utilizing maximum likelihood estimates, the LCA models infer class profiles that best characterize these latent statuses of a set of observed variables, where the response of observed variables has the same pattern. Therefore, the latent classes are homogeneous within, but distinct from each other.

To compare competing class profiles, LCA models with k vs. k+1 classes were tested iteratively until the best model fit was identified. Model fit was estimated with log-likelihood (LL), likelihood ratio statistics (G^2), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), adjusted Bayesian Information Criterion (ABIC), which were the most frequently used measures, and entropy. Generally, low information criterion (IC) values and a high entropy value (ranging from 0 to 1) indicate a better fit.[97] However, when assessing the best model fit particularly in a large population with many indicators, additional classes (k+1 classes) can often lead to a consistent decrease in the IC, and it is helpful to plot the IC to seek a point of inflection or plateauing.[98] Finally, LCA provides the number of classes and the probability of being assigned to each class. In this analysis, from the below, the term latent “status” was used in place of latent “class” to denote the possibility of temporary membership in a class and the possibility of congregations changing statuses over time.

b) Conducting LTA

After building off of the LCA model, we conducted LTA to identify the longitudinal change of repeated measures of the nine items of sleep disturbances during the COVID-19 phases. The LTA model is a longitudinal extension of the LCA, utilizing longitudinal data.[72] The LTA also utilizes maximum likelihood estimation to regress the latent status for follow-up phases on the latent status for the initial phase. Then, the prevalence of latent status in each phase and a transition probability that shows the patterns of change between latent statuses over time are estimated. In our study, a matrix of transition probabilities described how the participant's transition during COVID-19 phases in sleep disturbance profiles. These transition probabilities indicated the likelihood that congregations starting in one status in 2020 would change to another status in 2021, and then change to another status in 2022.

We first tested the fit and measurement invariance across time points by comparing latent transition models in which parameters were freely estimated with models in which parameters were constrained to be equal across the time points.[99] Considering the same with the LCA model, LTA model fit indices, such as ICs (AIC, BIC, and ABIC), G^2, and entropy were used to assess model fit.[100] After confirming the LTA model fit, several measurement parameters were confirmed such as: latent status membership probabilities at the 2020 survey (delta parameters), probabilities of transitions between latent statuses over time (tau parameters), and item-response probabilities conditional on latent status membership and time (rho parameters).

c) Conducting LTA including Covariates and Distal Outcomes

After identifying the latent transition model using fit statistics, additional analyses were conducted for estimating the influence of latent status and its change in PTSS and depressive symptoms over time. First, by utilizing the latent status generated by the LTA, the generalized estimating equation was used to analyze how changes in latent status of sleep disturbance (e.g., changes from status 1 to status 2 during the survey) influenced PTSS and depressive symptoms, during the COVID-19 phases. This analysis yielded estimate effects and their standard errors (SEs), after adjusting for all covariates with the P-value. A P-value of <0.05 was considered significant.

Further, we estimated the effect of latent status of sleep disturbance on distal outcomes, such as PTSS and depressive symptoms in our analysis, over time adjusting for potential confounders. Mean estimates with CI express the effect of distal outcomes given latent status membership. Being able to predict a distal outcome from latent status membership provides etiological information about how the confluence of latent status and/or covariates predicts an outcome of interest; potential application abounds.[101]

For covariates, we included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake at baseline data, in the same manner as was previously mentioned. In addition, PTSS and depressive symptoms were taken into account as distal outcomes. The PCL-5 and PHQ-9 scores assessed PTSS and depressive symptoms as continuous variables, respectively, in the same manner as was previously mentioned.

III. RESULTS

1. Network approach

A. Estimation and inference of the comorbidity network throughout COVID-19 phases

Of the 1,970 respondents at baseline, the mean age was 55.49 years and 64.8% of the respondents were women. Overall, the sample was comprised mostly of current drinker, married, education over 12 years, household income levels in the second quartile, having no disease history, and no current medication intake. Men were primarily past smokers and performed high regular exercise, whereas women were never smokers and performed low regular exercise. In addition, in the 2020 survey, there were no significant differences in the PHQ-9 and PCL-5 scores by sex; however, women had higher PHQ-9 and PCL-5 scores than men in the 2021 and 2022 surveys (Table 1). For the network approach, we estimated three cross-sectional comorbidity networks utilizing data from 2020, 2021, and 2022 surveys, respectively. Figures represent the network structures among the PTSS and depressive symptoms of the CMERC online mental health surveys. In all results, the PCL-5 and PHQ-9 nodes formed two separate communities within the comorbidity network. Most of the node connections presented positive edges, whereas there existed some negative edges. The detailed network structure according to 2020, 2021, and 2022 surveys are described below.

Table 1. Demographic characteristics at baseline by sex

	Total (N=1,970)		Men (N=693)		Women (N=1,277)		p-value
	N	%	N	%	N	%	
Age, Mean (SD)	55.49	(9.2)	55.20	(9.9)	55.65	(8.8)	< 0.01
Smoking							< 0.01
never	1383	(70.2)	187	(27.0)	1196	(93.7)	
past	363	(18.4)	315	(45.5)	48	(3.8)	
current	224	(11.4)	191	(27.6)	33	(2.6)	
Drinking							< 0.01
never	412	(20.9)	60	(8.7)	352	(27.6)	
past	91	(4.6)	45	(6.5)	46	(3.6)	
current	1467	(74.5)	588	(84.9)	879	(68.8)	
Regular exercise							< 0.01
low (0 min/per week)	914	(46.4)	276	(39.8)	638	(50.0)	
middle (less 150 min/per week)	251	(12.7)	88	(12.7)	163	(12.8)	
high (over 150 min/ per week)	805	(40.9)	329	(47.5)	476	(37.3)	
Marital status							< 0.01
never married	117	(5.9)	54	(7.8)	63	(4.9)	
living together	1705	(86.6)	627	(90.5)	1078	(84.4)	
living alone	18	(0.9)	4	(0.6)	14	(1.1)	
divorced or widowed	130	(6.6)	8	(1.2)	122	(9.6)	
Educational year							< 0.01
≤ 6 years	54	(2.7)	9	(1.3)	45	(3.5)	
≤ 9 years	121	(6.1)	26	(3.8)	95	(7.4)	
≤ 12 years	691	(35.1)	190	(27.4)	501	(39.2)	
> 12 years	1104	(56.0)	468	(67.5)	636	(49.8)	
Household income							< 0.01
Q1	403	(20.5)	105	(15.2)	298	(23.3)	
Q2	643	(32.6)	231	(33.3)	412	(32.3)	
Q3	372	(18.9)	142	(20.5)	230	(18.0)	
Q4	552	(28.0)	215	(31.0)	337	(26.4)	

Table 1. Demographic characteristics at baseline by sex (N=1,970) *(continued)*

	Total (N=1,970)		Men (N=693)		Women (N=1,277)		p-value
	N	%	N	%	N	%	
Disease history							0.41
no	1116	(56.7)	384	(55.4)	732	(57.3)	
yes	854	(43.4)	309	(44.6)	545	(42.7)	
Current medication intake							0.05
no	1288	(65.4)	433	(62.5)	855	(67.0)	
yes	682	(34.6)	260	(37.5)	422	(33.1)	
PHQ-9 scores, Mean (SD)							
2020 survey	2.72	(3.7)	2.83	(3.8)	2.66	(3.7)	0.34
2021 survey	4.92	(5.0)	4.08	(4.8)	5.35	(5.0)	< 0.01
2022 survey	4.52	(4.9)	3.49	(4.4)	5.06	(5.0)	< 0.01
PCL-5 scores, Mean (SD)							
2020 survey	10.29	(10.2)	10.25	(10.0)	10.31	(10.4)	0.21
2021 survey	9.68	(11.7)	8.68	(11.4)	10.20	(11.9)	0.02
2022 survey	10.42	(12.6)	9.06	(11.9)	11.16	(12.9)	0.01

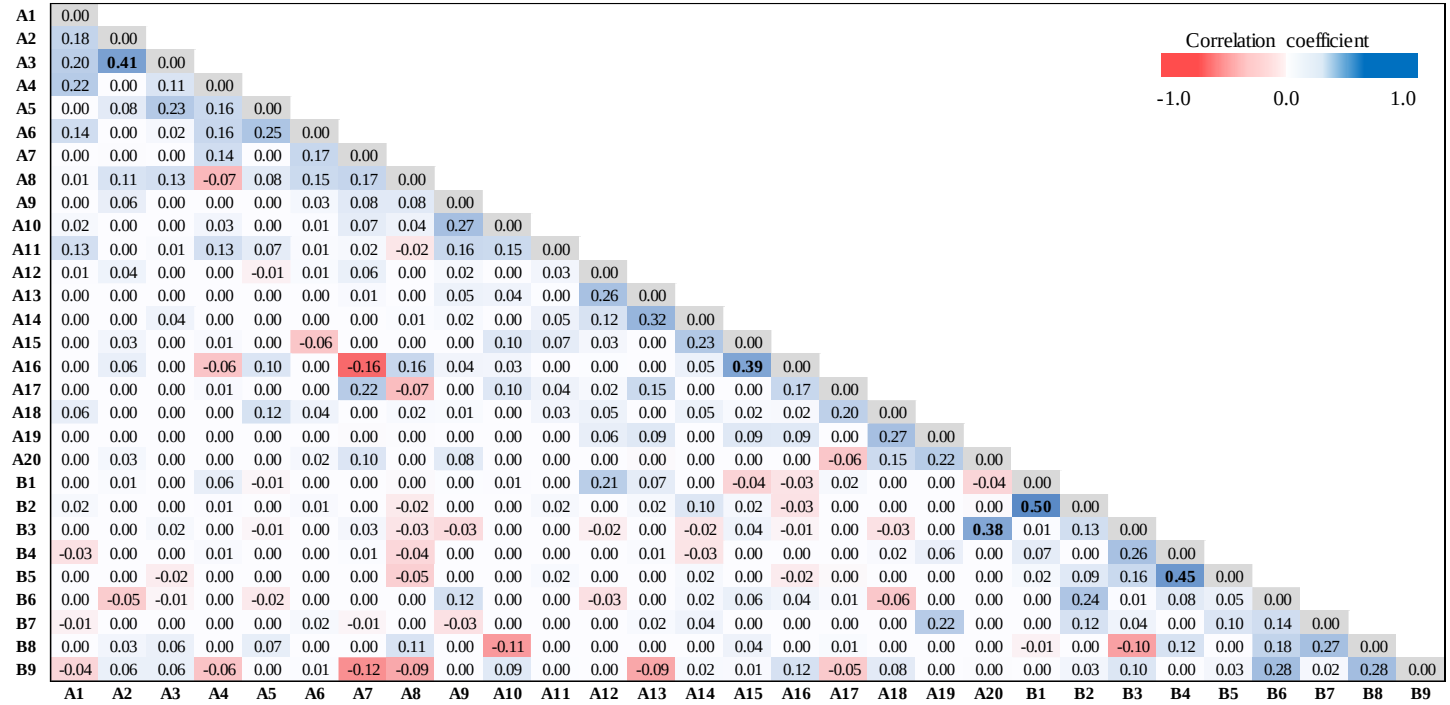
Notes. Sum of numbers may not reflect the total number in group due to missing values.

a) The network of the 2020 survey

The 2020 survey was conducted subacute phase of COVID-19 (right after the outbreak of COVID-19) (Figure 1). Figure 7 and Figure 8a represent the comorbidity network structure at the first detection of the CMERC online mental health survey. The strongest edge across the communities of PCL-5 and PHQ-9 was between sleep disturbance and sleeping problems (A20 and B3, edge weight=0.38). Among the PCL-5 community, the largest edge weight was nightmares and flashbacks (A2 and A3, 0.41), following irritability/anger and reckless and self-destructive behavior (A15 and A16, 0.39). Among the PHQ-9 community, anhedonia and depressed mood had the strongest edge weight (B1 and B2, 0.50), followed between fatigability and appetite problems (B4 and B5, 0.45). The centrality index (expected influence) is shown in Figure 8b. The results showed that depressed mood (B2, standardized EI = 2.35) and flashback symptom (A3, 2.24) had a high node expected influence. Trauma-related amnesia (A8, -1.85) and suicidal ideation (B9, -1.64) showed a relatively lower node expected influence. Figure 8c shows bridge node centrality of the combined PTSS and depressive symptom network. The nodes with relatively high bridge centrality were sleeping disturbance (A20, standardized bridge expected influence=2.04) and sleeping problems (B3, 1.97).

The results of the sensitivity analysis conducted on respondents who participated in all three surveys were similar to the above (Appendix 5-6). Further, by adding the resilience score, which is considered a symptom that could control the psychological symptoms, in a

combined network model of PTSS and depressive symptoms, we estimated the antagonism between psychological symptoms; the resilience was inversely correlated with all other PTSS and depressive symptoms (Appendix 7-8).

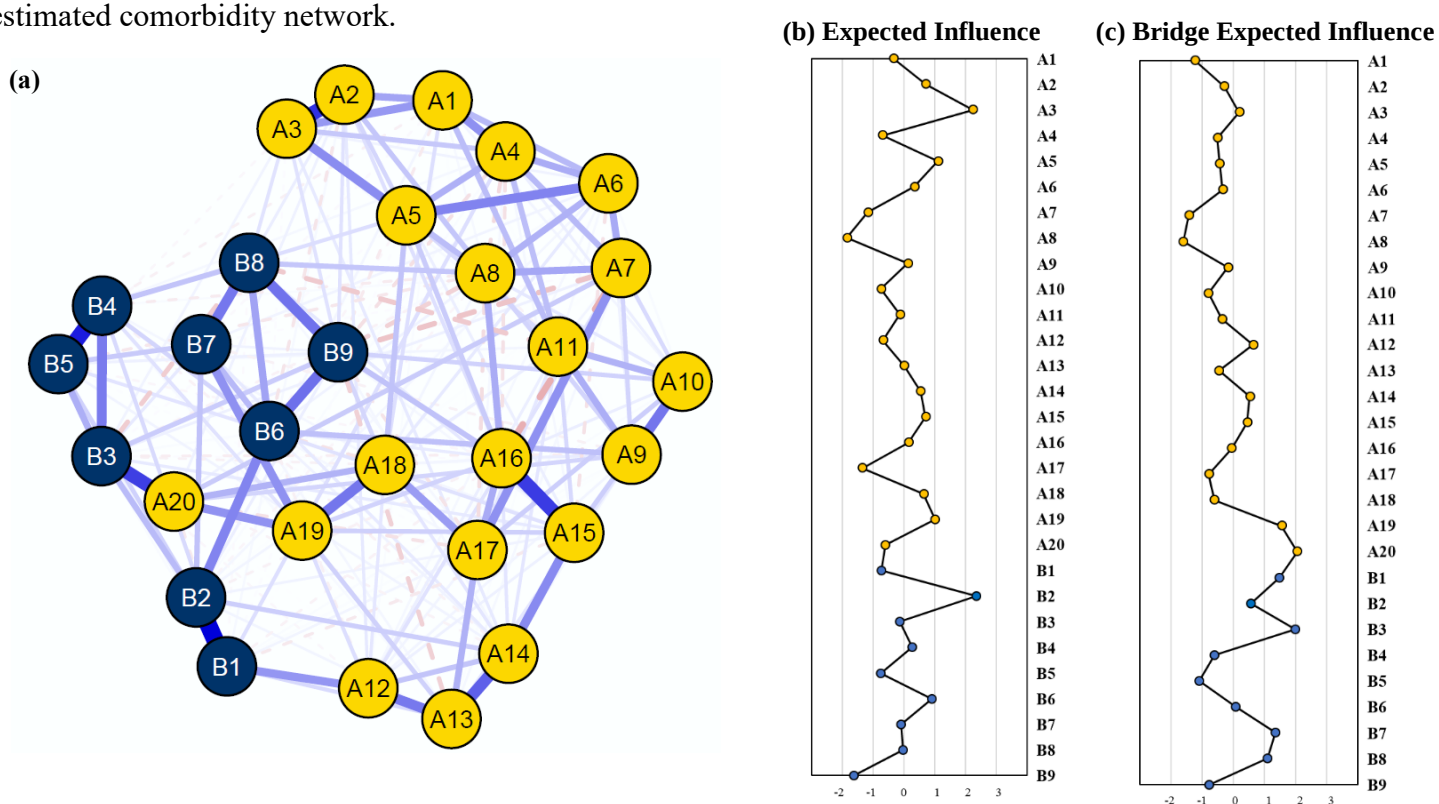


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1	0.00																												
A2	0.18	0.00																											
A3	0.20	**0.41**	0.00																										
A4	0.22	0.00	0.11	0.00																									
A5	0.00	0.08	0.23	0.16	0.00																								
A6	0.14	0.00	0.02	0.16	0.25	0.00																							
A7	0.00	0.00	0.00	0.14	0.00	0.17	0.00																						
A8	0.01	0.11	0.13	-0.07	0.08	0.15	0.17	0.00																					
A9	0.00	0.06	0.00	0.00	0.00	0.03	0.08	0.08	0.00																				
A10	0.02	0.00	0.00	0.03	0.00	0.01	0.07	0.04	0.27	0.00																			
A11	0.13	0.00	0.01	0.13	0.07	0.01	0.02	-0.02	0.16	0.15	0.00																		
A12	0.01	0.04	0.00	0.00	-0.01	0.01	0.06	0.00	0.02	0.00	0.03	0.00																	
A13	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.04	0.00	0.26	0.00																
A14	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.05	0.12	0.32	0.00															
A15	0.00	0.03	0.00	0.01	0.00	-0.06	0.00	0.00	0.00	0.10	0.07	0.03	0.00	0.23	0.00														
A16	0.00	0.06	0.00	-0.06	0.10	0.00	-0.16	0.16	0.04	0.03	0.00	0.00	0.00	0.05	**0.39**	0.00													
A17	0.00	0.00	0.00	0.01	0.00	0.00	0.22	-0.07	0.00	0.10	0.04	0.02	0.15	0.00	0.00	0.17	0.00												
A18	0.06	0.00	0.00	0.00	0.12	0.04	0.00	0.02	0.01	0.00	0.03	0.05	0.00	0.05	0.02	0.02	0.20	0.00											
A19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.09	0.00	0.09	0.09	0.00	0.27	0.00										
A20	0.00	0.03	0.00	0.00	0.00	0.02	0.10	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	0.15	0.22	0.00									
B1	0.00	0.01	0.00	0.06	-0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.21	0.07	0.00	-0.04	-0.03	0.02	0.00	0.00	-0.04	0.00								
B2	0.02	0.00	0.00	0.01	0.00	0.01	0.00	-0.02	0.00	0.00	0.02	0.00	0.02	0.10	0.02	-0.03	0.00	0.00	0.00	0.00	**0.50**	0.00							
B3	0.00	0.00	0.02	0.00	-0.01	0.00	0.03	-0.03	-0.03	0.00	0.00	-0.02	0.00	-0.02	0.04	-0.01	0.00	-0.03	0.00	**0.38**	0.01	0.13	0.00						
B4	-0.03	0.00	0.00	0.01	0.00	0.00	0.01	-0.04	0.00	0.00	0.00	0.00	0.01	-0.03	0.00	0.00	0.00	0.02	0.06	0.00	0.07	0.00	0.26	0.00					
B5	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	0.02	0.00	0.00	0.02	0.00	-0.02	0.00	0.00	0.00	0.00	0.02	0.09	0.16	**0.45**	0.00				
B6	0.00	-0.05	-0.01	0.00	-0.02	0.00	0.00	0.00	0.12	0.00	0.00	-0.03	0.00	0.02	0.06	0.04	0.01	-0.06	0.00	0.00	0.00	0.24	0.01	0.08	0.05	0.00			
B7	-0.01	0.00	0.00	0.00	0.00	0.02	-0.01	0.00	-0.03	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.12	0.04	0.00	0.10	0.14	0.00		
B8	0.00	0.03	0.06	0.00	0.07	0.00	0.00	0.11	0.00	-0.11	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.00	-0.01	0.00	-0.10	0.12	0.00	0.18	0.27	0.00	
B9	-0.04	0.06	0.06	-0.06	0.00	0.01	-0.12	-0.09	0.00	0.09	0.00	0.00	-0.09	0.02	0.01	0.12	-0.05	0.08	0.00	0.00	0.00	0.03	0.10	0.00	0.03	0.28	0.02	0.28	0.00

Figure 7. Correlation matrix of edge weight in a comorbidity network of the 2020 survey.

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

Figure 8. Comorbidity network structures of the 2020 survey. (a) Estimated network of PCL-5 and PHQ-9 symptoms, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network.



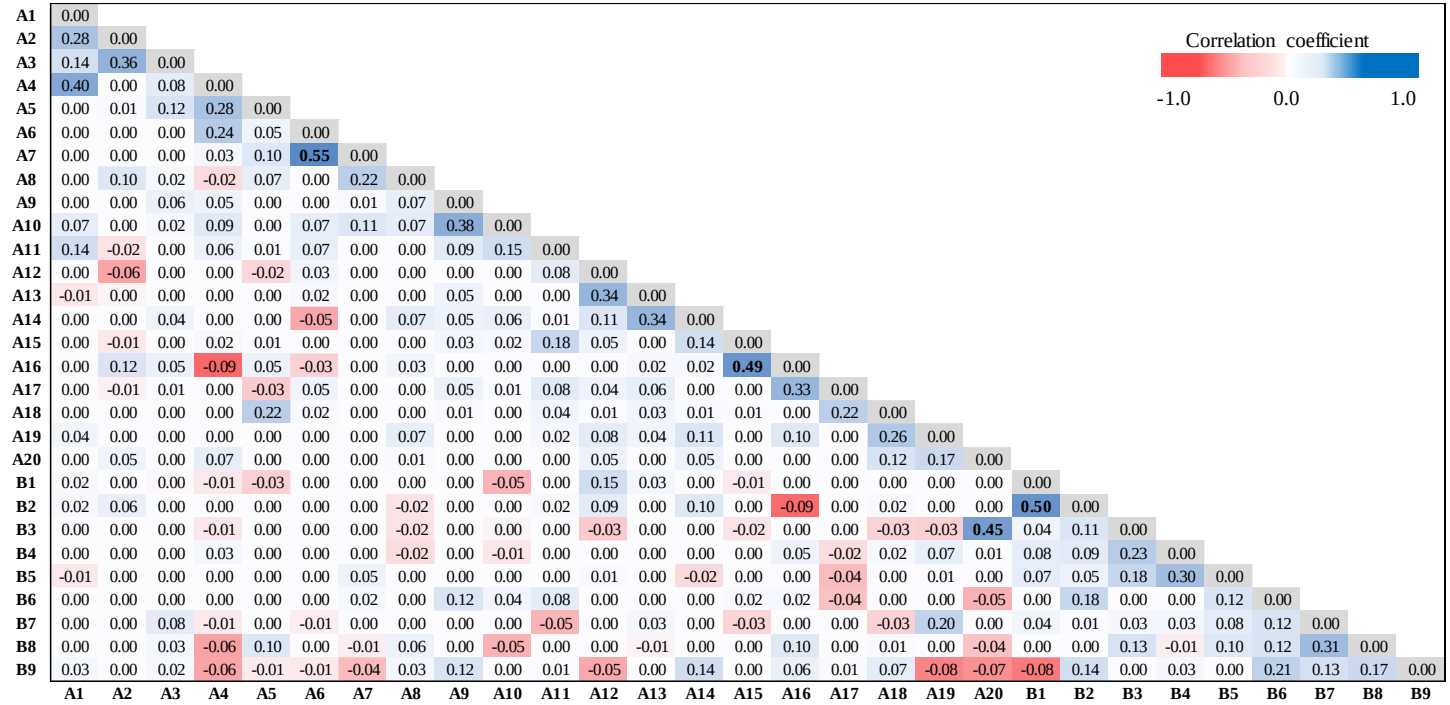
Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

b) The network of the 2021 survey

The next survey was carried out in the year 2021, chronic phase of COVID-19 (approximately 1 year after the outbreak of COVID-19) (Figure 1). The PTSS and depressive symptom network structure at the follow-up detection is shown in Figure 9 and Figure 10a. In this comorbidity network, the largest edge weight was between sleep disturbance and sleeping problems, as was the result of the first survey (A20 and B3, edge weight=0.45). Among the PCL-5 community, the strongest edge weight was between avoidance of thoughts and avoidance of reminders (A6 and A7, 0.55), followed by irritability/anger and reckless self-destructive behavior (A15 and A16, 0.49). Among the PHQ-9 community, the highest edge weight was between anhedonia and depressed mood (B1 and B2, 0.50), which was the same as the results of the first survey. Figure 10b shows the highest expected influence as depressed mood (B2, standardized EI=2.22) and reckless behavior (A16, 1.88); whereas hypervigilance (A17, -1.73) and anhedonia (B1, -1.62) was the lowest node, followed by trauma-related amnesia (A8, -1.49). Figure 10c shows bridge symptom centrality of the comorbid PTSS and depressive symptom network in the 2021 survey. The result showed that most bridge central nodes were sleeping problems (B3, standardized bridge expected influence=1.96) and sleeping disturbance (A20, 1.87), as with the first survey.

Similar findings were obtained from a sensitivity analysis performed on participants who completed all three surveys (Appendix 9-10). Further, by adding the resilience score, which

is considered a symptom that could control the psychological symptoms, in a combined network model of PTSS and depressive symptoms, we estimated the antagonism between psychological symptoms; the resilience was inversely correlated with all other PTSS and depressive symptoms (Appendix 11-12).

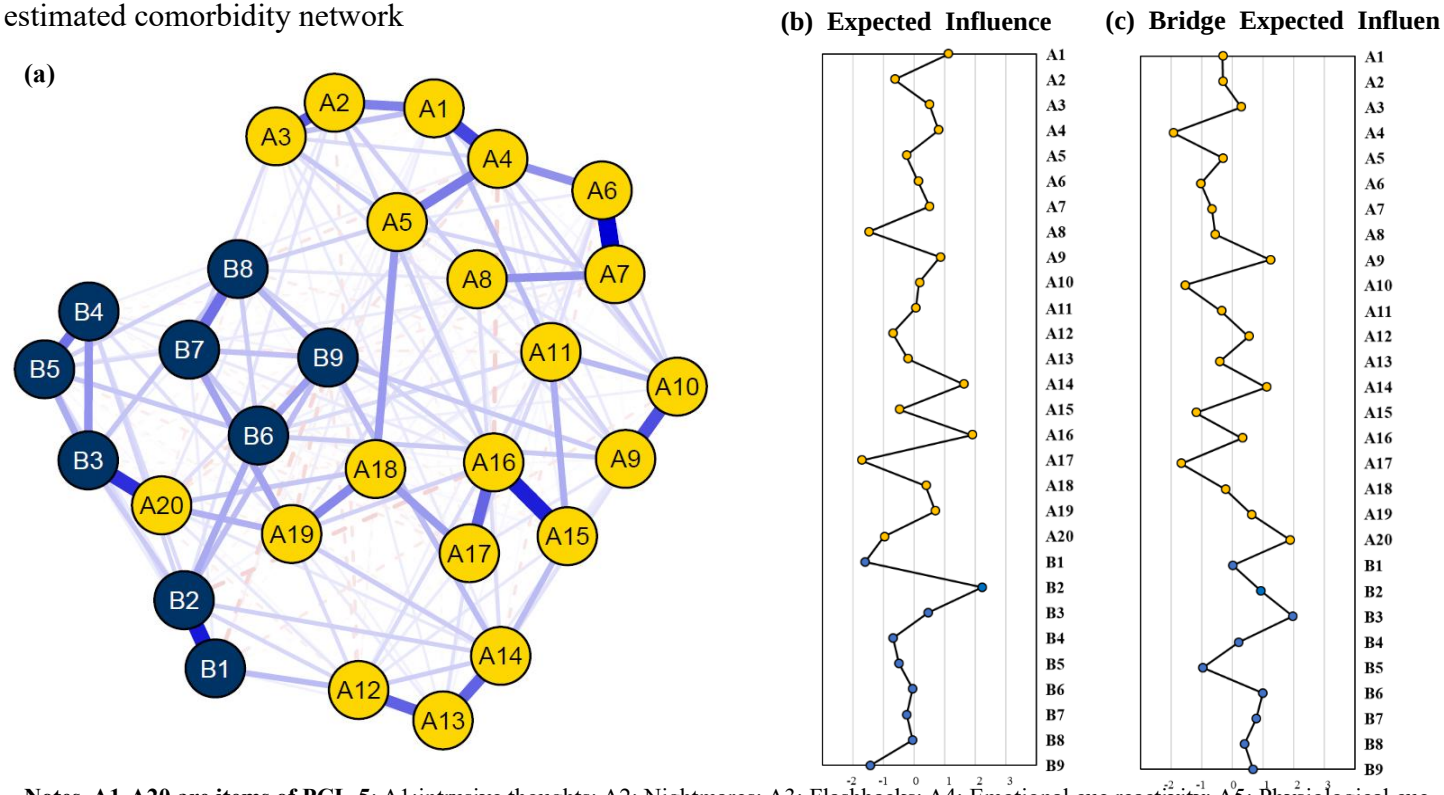


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1	0.00																												
A2	0.28	0.00																											
A3	0.14	0.36	0.00																										
A4	0.40	0.00	0.08	0.00																									
A5	0.00	0.01	0.12	0.28	0.00																								
A6	0.00	0.00	0.00	0.24	0.05	0.00																							
A7	0.00	0.00	0.00	0.03	0.10	**0.55**	0.00																						
A8	0.00	0.10	0.02	-0.02	0.07	0.00	0.22	0.00																					
A9	0.00	0.00	0.06	0.05	0.00	0.00	0.01	0.07	0.00																				
A10	0.07	0.00	0.02	0.09	0.00	0.07	0.11	0.07	0.38	0.00																			
A11	0.14	-0.02	0.00	0.06	0.01	0.07	0.00	0.00	0.09	0.15	0.00																		
A12	0.00	-0.06	0.00	0.00	-0.02	0.03	0.00	0.00	0.00	0.00	0.08	0.00																	
A13	-0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.05	0.00	0.00	0.34	0.00																
A14	0.00	0.00	0.04	0.00	0.00	-0.05	0.00	0.07	0.05	0.06	0.01	0.11	0.34	0.00															
A15	0.00	-0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.03	0.02	0.18	0.05	0.00	0.14	0.00														
A16	0.00	0.12	0.05	-0.09	0.05	-0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.02	**0.49**	0.00													
A17	0.00	-0.01	0.01	0.00	-0.03	0.05	0.00	0.00	0.05	0.01	0.08	0.04	0.06	0.00	0.00	0.33	0.00												
A18	0.00	0.00	0.00	0.00	0.22	0.02	0.00	0.00	0.01	0.00	0.04	0.01	0.03	0.01	0.01	0.00	0.22	0.00											
A19	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.02	0.08	0.04	0.11	0.00	0.10	0.00	0.26	0.00										
A20	0.00	0.05	0.00	0.07	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.00	0.05	0.00	0.00	0.00	0.12	0.17	0.00									
B1	0.02	0.00	0.00	-0.01	-0.03	0.00	0.00	0.00	0.00	-0.05	0.00	0.15	0.03	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00								
B2	0.02	0.06	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.02	0.09	0.00	0.10	0.00	-0.09	0.00	0.02	0.00	0.00	**0.50**	0.00							
B3	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	-0.03	0.00	0.00	-0.02	0.00	0.00	-0.03	-0.03	**0.45**	0.04	0.11	0.00						
B4	0.00	0.00	0.00	0.03	0.00	0.00	0.00	-0.02	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.05	-0.02	0.02	0.07	0.01	0.08	0.09	0.23	0.00					
B5	-0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.00	-0.02	0.00	0.00	-0.04	0.00	0.01	0.00	0.07	0.05	0.18	0.30	0.00				
B6	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.12	0.04	0.08	0.00	0.00	0.00	0.02	0.02	-0.04	0.00	0.00	-0.05	0.00	0.18	0.00	0.00	0.12	0.00			
B7	0.00	0.00	0.08	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	-0.05	0.00	0.03	0.00	-0.03	0.00	0.00	-0.03	0.20	0.00	0.04	0.01	0.03	0.03	0.08	0.12	0.00		
B8	0.00	0.00	0.03	-0.06	0.10	0.00	-0.01	0.06	0.00	-0.05	0.00	0.00	-0.01	0.00	0.00	0.10	0.00	0.01	0.00	-0.04	0.00	0.00	0.13	-0.01	0.10	0.12	0.31	0.00	
B9	0.03	0.00	0.02	-0.06	-0.01	-0.01	-0.04	0.03	0.12	0.00	0.01	-0.05	0.00	0.14	0.00	0.06	0.01	0.07	-0.08	-0.07	-0.08	0.14	0.00	0.03	0.00	0.21	0.13	0.17	0.00

Figure 9. Correlation matrix of edge weight in a comorbidity network of the 2021 survey.

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

Figure 10. Comorbidity network structures of the 2021 survey. (a) Estimated network of PCL-5 and PHQ-9 symptoms, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network

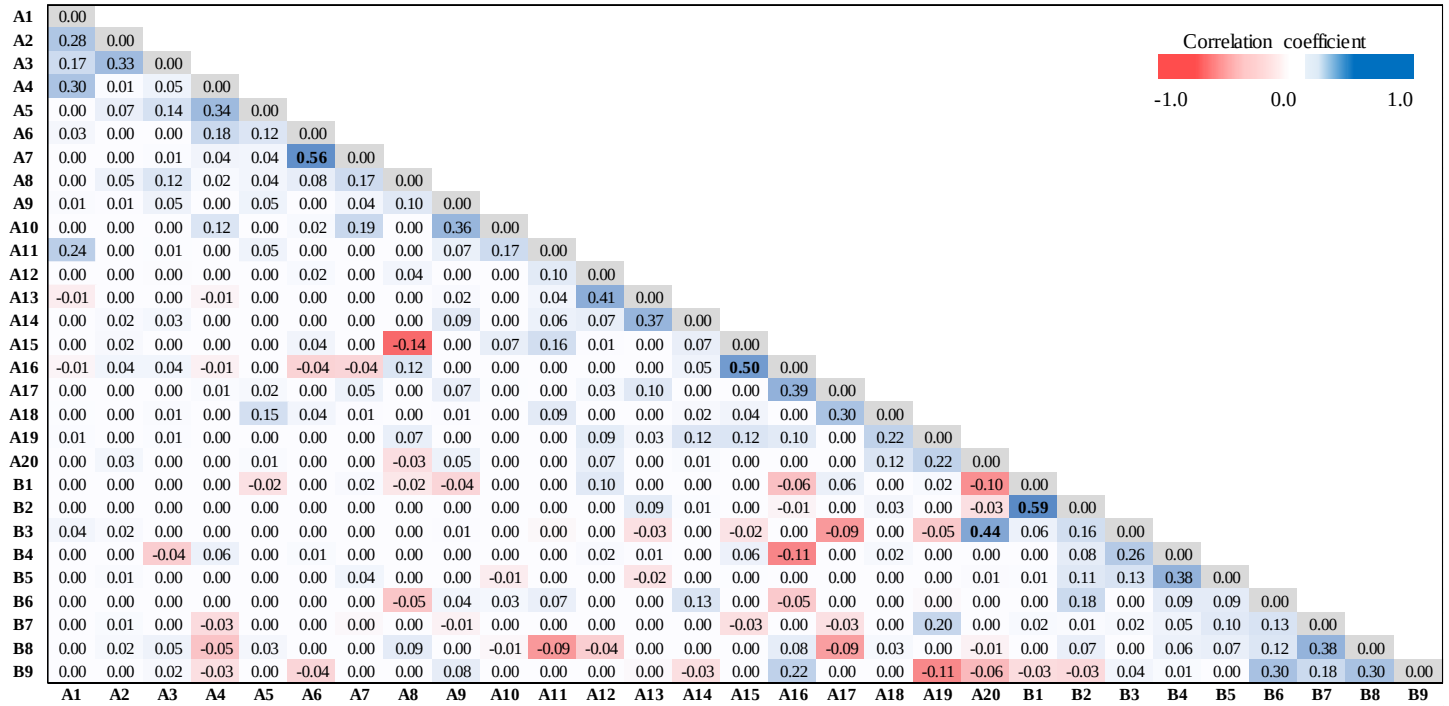


Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

c) The network of the 2022 survey

In the year 2022, the survey was conducted during the chronic phase of COVID-19 (approximately 2 years after the outbreak of COVID-19) (Figure 1). The estimated comorbidity network of the final survey is shown in Figure 11 and Figure 12a. Overall, the results of this final survey were similar to those of the 2021 survey. The comorbidity network featured consistent edges, showing the strongest connection between sleep disturbance and sleeping problems (A20 and B3, edge weight=0.44). Among the PCL-5 community, avoidance of thoughts and avoidance of reminders was strongly interconnected (A6 and A7, 0.56), followed by irritability/anger and reckless self-destructive behavior (A15 and A16, 0.50). Within the PHQ-9 community, the strongest edge weight was between anhedonia and depressed mood (B1 and B2, 0.59). In the network structure of the 2022 survey, depressed mood (B2, standardized EI=1.98) and reckless behavior (A16, 1.79) emerged as the nodes with the highest node expected influence, with the same results as in the prior network that emerged as the strongest node (Figure 12b). Anhedonia (B1, -2.60) and trauma-related amnesia (A8, -2.25) had a relatively lower node expected influence (Figure 12b). Considering only bridge centrality, the results suggested that the most influential bridge symptoms were sleeping problems (B3, standardized bridge expected influence=2.97) and sleep disturbance (A20, 2.32), which was the same as all the previous surveys (Figure 12c).

The findings of the sensitivity analysis on the network structures were similar to the above (Appendix 13-14). Further, by adding the resilience score, which is considered a symptom that could control the psychological symptoms, in a combined network model of PTSS and depressive symptoms, we estimated the antagonism between psychological symptoms; the resilience was inversely correlated with all other PTSS and depressive symptoms (Appendix 15-16).

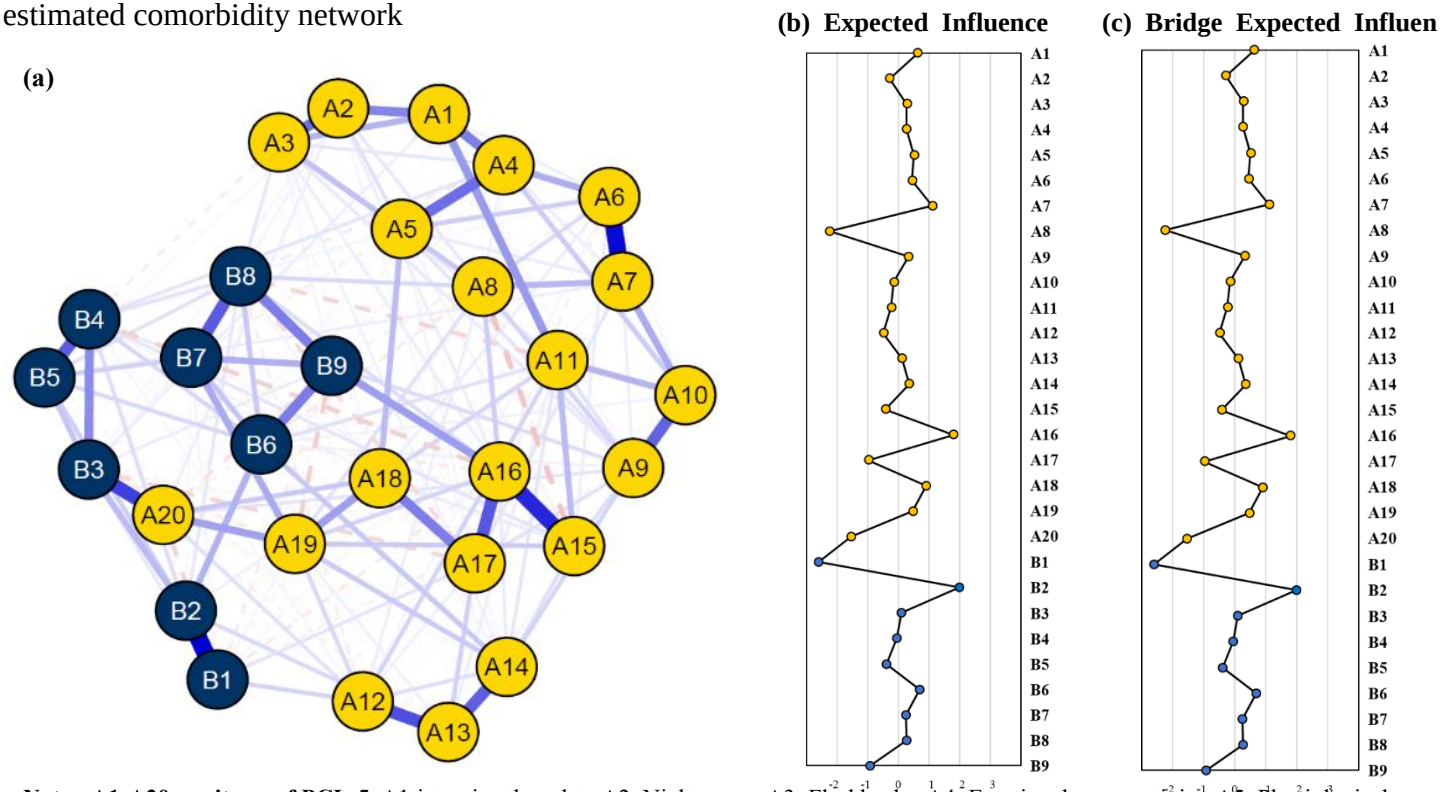


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1	0.00																												
A2	0.28	0.00																											
A3	0.17	0.33	0.00																										
A4	0.30	0.01	0.05	0.00																									
A5	0.00	0.07	0.14	0.34	0.00																								
A6	0.03	0.00	0.00	0.18	0.12	0.00																							
A7	0.00	0.00	0.01	0.04	0.04	**0.56**	0.00																						
A8	0.00	0.05	0.12	0.02	0.04	0.08	0.17	0.00																					
A9	0.01	0.01	0.05	0.00	0.05	0.00	0.04	0.10	0.00																				
A10	0.00	0.00	0.00	0.12	0.00	0.02	0.19	0.00	0.36	0.00																			
A11	0.24	0.00	0.01	0.00	0.05	0.00	0.00	0.00	0.07	0.17	0.00																		
A12	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.00	0.00	0.10	0.00																	
A13	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.41	0.00																
A14	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.06	0.07	0.37	0.00															
A15	0.00	0.02	0.00	0.00	0.00	0.04	0.00	-0.14	0.00	0.07	0.16	0.01	0.00	0.07	0.00														
A16	-0.01	0.04	0.04	-0.01	0.00	-0.04	-0.04	0.12	0.00	0.00	0.00	0.00	0.00	0.05	**0.50**	0.00													
A17	0.00	0.00	0.00	0.01	0.02	0.00	0.05	0.00	0.07	0.00	0.00	0.03	0.10	0.00	0.00	0.39	0.00												
A18	0.00	0.00	0.01	0.00	0.15	0.04	0.01	0.00	0.01	0.00	0.09	0.00	0.00	0.02	0.04	0.00	0.30	0.00											
A19	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.09	0.03	0.12	0.12	0.10	0.00	0.22	0.00										
A20	0.00	0.03	0.00	0.00	0.01	0.00	0.00	-0.03	0.05	0.00	0.00	0.07	0.00	0.01	0.00	0.00	0.00	0.12	0.22	0.00									
B1	0.00	0.00	0.00	0.00	-0.02	0.00	0.02	-0.02	-0.04	0.00	0.00	0.10	0.00	0.00	0.00	-0.06	0.06	0.00	0.02	-0.10	0.00								
B2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.00	-0.01	0.00	0.03	0.00	-0.03	**0.59**	0.00							
B3	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	-0.03	0.00	-0.02	0.00	-0.09	0.00	-0.05	**0.44**	0.06	0.16	0.00						
B4	0.00	0.00	-0.04	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.06	-0.11	0.00	0.02	0.00	0.00	0.00	0.08	0.26	0.00					
B5	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.00	-0.01	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.13	0.38	0.00				
B6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	0.04	0.03	0.07	0.00	0.00	0.13	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.09	0.09	0.00			
B7	0.00	0.01	0.00	-0.03	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	-0.03	0.00	0.20	0.00	0.02	0.01	0.02	0.05	0.10	0.13	0.00		
B8	0.00	0.02	0.05	-0.05	0.03	0.00	0.00	0.09	0.00	-0.01	-0.09	-0.04	0.00	0.00	0.00	0.08	-0.09	0.03	0.00	-0.01	0.00	0.07	0.00	0.06	0.07	0.12	0.38	0.00	
B9	0.00	0.00	0.02	-0.03	0.00	-0.04	0.00	0.00	0.08	0.00	0.00	0.00	0.00	-0.03	0.00	0.22	0.00	0.00	-0.11	-0.06	-0.03	-0.03	0.04	0.01	0.00	0.30	0.18	0.30	0.00

Figure 11. Correlation matrix of edge weight in a comorbidity network of the 2022 survey.

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

Figure 12. Comorbidity network structures of the 2022 survey. (a) Estimated network of PCL-5 and PHQ-9 symptoms, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network



Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

d) Network Robustness

Accuracy tests indicated that all three networks were stably estimated, with small to moderate CIs around the edge weights (Appendix 17). These results presented the accurate distribution of edge weight, suggesting accurate estimations for all networks. Furthermore, for the stability test utilizing a case-dropped bootstrapping, the CS-coefficients for expected influence were 0.75 across all networks. The CS-coefficients for bridge expected influence at each time point were as follows: 2020 survey, CS-coefficients=0.67; in 2021 and 2022 surveys, 0. 75 (Appendix 18). These results exceed the recommended threshold for stability of the network centrality (A CS-coefficient $\geq$ 0.50).

e) Network comparison across time points

The network comparison test indicated that network structures were different across surveys between the 2020 survey and 2021/2022 surveys (2020 vs. 2021: M=0.38, p=<0.01; 2020 vs. 2022: M=0.40, p<0.01), whereas global strengths were in variance (2020 vs. 2021: s=0.40, p=0.85; 2020 vs. 2022: s=0.10, p=0.97). In addition, between the 2021 and 2022 surveys, network structure invariance (2021 vs. 2022: M=0.17, p=0.37) and global strength invariance (2021 vs. 2022: s=0.30, p=0.85) tests indicated that the network structures did not significantly vary across surveys. For now, these results indicate that the networks across surveys did not significantly different in global strength; however, significantly differ in network structures between the subacute phase of COVID-19 (2020 survey) and the chronic phase of COVID-19 (2021 and 2022 survey).

2. Latent transition approach

A. LTA of sleep disturbances during the COVID-19 phases

To explore whether latent status underlying sleep disturbance could infer a meaningful status transition at each measurement occasion and possible causal association with PTSS and depressive symptoms, we conducted LTA in four steps: 1) selecting a latent status profile, 2) interpreting latent status, 3) estimating transition probability, and 4) inferring potential causal association.

a) Selecting a latent status profile

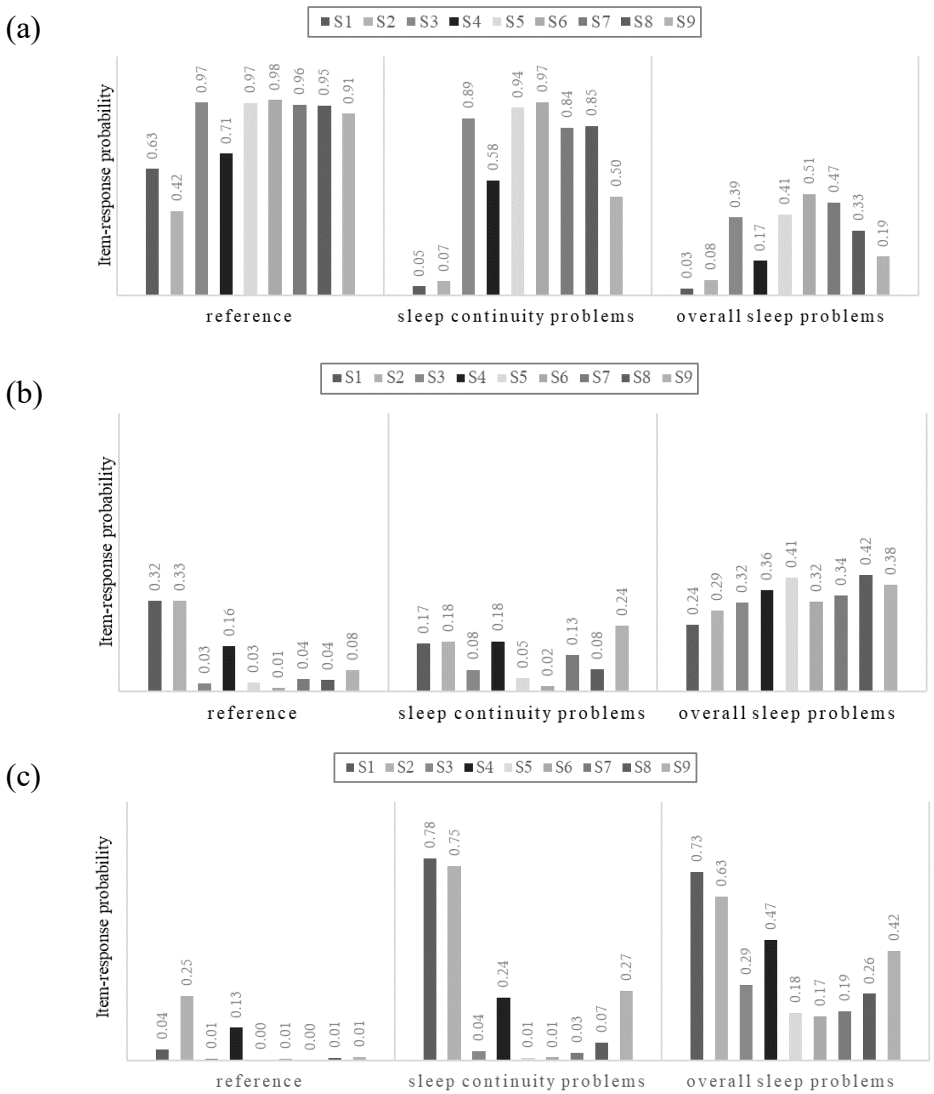
First, exploratory cross-sectional LCA was performed across time points (2020 to 2022 survey). The model fit criteria indicated that the 3-status model fit our data, at every time point, most appropriately (Table 2). The AIC, BIC, and ABIC assessed that the model fit would be best at the 3-status profile (i.e., number of statuses was 3), because that was the point of reflection across the time points (Appendix 19). After building off the number of statuses, we estimated each sleep disturbance items' response probability of being assigned in each separated status to interpret those statuses easily. Figure 13a-c plots each item-response probabilities for the 3-status profile. As a result, each status was characterized as follows: *reference* (status 1, n=918), *sleep continuity problems* (status 2, n=767), and *overall sleep problems* (status 3, n=245). The sample characteristics by latent status are presented in Table 3. Similar findings were obtained from a sensitivity analysis performed on participants who completed all three surveys (Appendix 20).

Table 2. Fit statistics for latent models of sleep disturbances with different number statuses

No. of status	LL	G^2	AIC	BIC	ABIC	Entropy
2020 survey						
2	-11393.4	3392.14	3466.14	3672.06	3554.51	0.74
3	-11161	2927.42	3039.42	3351.07	3173.16	0.74
4	-11041.5	2688.34	2838.34	3255.74	3017.46	0.73
5	-10943.9	2493.14	2681.14	3204.27	2905.63	0.74
2021 survey						
2	-8009.47	2581.6	2655.6	2848.43	2730.9	0.77
3	-7861.43	2285.52	2397.52	2689.37	2511.48	0.70
4	-7783.08	2128.83	2278.83	2669.69	2431.45	0.74
5	-7754.94	2072.54	2260.54	2750.43	2451.83	0.75
2022 survey						
2	-7838.92	2909.15	2983.15	3171.6	3054.08	0.78
3	-7637.76	2506.82	2618.82	2904.05	2726.17	0.78
4	-7529.83	2290.97	2440.97	2822.97	2584.74	0.78
5	-7466.35	2164.02	2352.02	2830.8	2532.22	0.79

Notes. LL=Log Likelihood; G^2= likelihood ratio statistics; AIC=Akaike Information Criterion; BIC=Bayesian Information Criterion.

Figure 13. Item-response probabilities from the three-status model of the sleep disturbances. (a) Probability of answering "never" for each item, (b) Probability of answering "less than one time per week" response for each item, (c) Probability of answering "more than one time per week" response for each item.



Notes. S1 -S9 are items of sleep disturbances in PSQI. S1: wake up in the middle of the night or early morning;S2: Have to get up to use the bathroom; S3: Cannot breathe comfortably; S4: Cough or snore loudly; S5: Feel too cold;S6: Feel too hot; S7: Have bad dreams; S8: Have pain; S9: Other reason(s)

Table 3. Demographic characteristics at baseline by latent status of sleep disturbances

	reference (N=918)		sleep continuity prob (N=767)		overall sleep prob (N=245)		p-value
	N	%	N	%	N	%	
Age, Mean (SD)	55.2	(9.35)	55.6	(9.24)	56.3	(8.60)	0.20
Sex							0.26
men	317	(34.53)	267	(34.81)	98	(40.00)	
women	601	(65.47)	500	(65.19)	147	(60.00)	
Smoking							0.97
never	641	(69.83)	537	(70.01)	175	(71.43)	
past	172	(18.74)	140	(18.25)	45	(18.37)	
current	105	(11.44)	90	(11.73)	25	(10.20)	
Drinking							0.16
never	179	(19.50)	163	(21.25)	60	(24.49)	
past	52	(5.66)	28	(3.65)	10	(4.08)	
current	687	(74.84)	576	(75.10)	175	(71.43)	
Regular exercise							0.24
low (0 min/per week)	445	(48.47)	339	(44.20)	109	(44.49)	
middle (less 150 min/per week)	109	(11.87)	99	(12.91)	39	(15.92)	
high (over 150 min/ per week)	634	(39.65)	329	(42.89)	97	(39.59)	
Marital status							0.14
never married	59	(6.43)	49	(6.39)	7	(2.86)	
living together	796	(86.71)	650	(84.75)	224	(91.43)	
living alone	6	(0.65)	9	(1.17)	1	(0.41)	
divorced or widowed	57	(6.21)	59	(7.69)	13	(5.31)	
Educational year							0.11
≤ 6 years	17	(1.85)	30	(3.91)	6	(2.45)	
≤ 9 years	56	(6.10)	49	(6.39)	13	(5.31)	
≤ 12 years	321	(34.97)	279	(36.38)	77	(31.43)	
> 12 years	524	(57.08)	409	(53.32)	149	(60.82)	

Table 3. Demographic characteristics at baseline by latent profiles of sleep disturbance *(continued)*

	reference (N=918)		sleep continuity prob (N=767)		overall sleep prob (N=245)		p-value
	N	%	N	%	N	%	
Household income							0.93
Q1	185	(20.15)	167	(21.77)	44	(17.96)	
Q2	300	(32.68)	244	(31.81)	83	(33.88)	
Q3	175	(19.06)	142	(18.51)	47	(19.18)	
Q4	258	(28.10)	214	(27.90)	71	(28.98)	
Disease history							0.67
no	520	(56.64)	438	(57.11)	132	(53.88)	
yes	398	(43.36)	329	(42.89)	113	(46.12)	
Current medication intake							0.63
no	607	(66.12)	500	(65.19)	154	(62.86)	
yes	311	(33.88)	267	(34.81)	91	(37.14)	
PHQ-9 scores, Mean (SD)							
2020 survey	1.2	(1.97)	3.3	(3.69)	6.8	(5.19)	<0.01
2021 survey	5.0	(5.02)	4.9	(5.10)	4.4	(4.40)	0.34
2022 survey	4.4	(4.84)	4.8	(5.08)	3.9	(4.20)	0.12
PCL-5 scores, Mean (SD)							
2020 survey	6.2	(6.43)	11.9	(9.70)	20.6	(14.09)	<0.01
2021 survey	9.8	(11.78)	10.2	(12.17)	7.6	(9.81)	0.04
2022 survey	10.3	(12.45)	11.0	(13.19)	9.1	(11.14)	0.26

Notes. Sum of numbers may not reflect the total number in group due to missing values. Prob=problem

b) Interpretation of latent status

The conditional prevalence of sleep disturbance status across time provided the information about the changing patterns of sleep disturbance across the COVID-19 phases (Figure 14, Table 4). The majority status was *reference* (status 1) at the 2020 survey, composed of approximately 46% participants, and at the 2021 and 2022 surveys was *sleep continuity problems* (status 2), composed of about 45% and 43% of participants, respectively. The *overall sleep problems* (status3) was the minority status at the 2020 survey and comprised approximately 11% of participants; however, it steadily increased in prevalence over time and became the second highest status in the 2022 survey, comprising approximately 32% of participants. On the other hand, *reference* (status 1) was the majority status at the 2020 survey; however, it steadily decreased in prevalence over time and became the minority status in the. 2022 survey. This results indicate that, after the outbreak of COVID-19, overall sleep disturbance might increase over time, and the majority of people might experience *sleep continuity problems*. Similar patterns were shown from a sensitivity analysis performed on the participants who completed all three surveys (Appendix 21).

Figure 14. Prevalence of latent statuses of sleep disturbance across the surveys

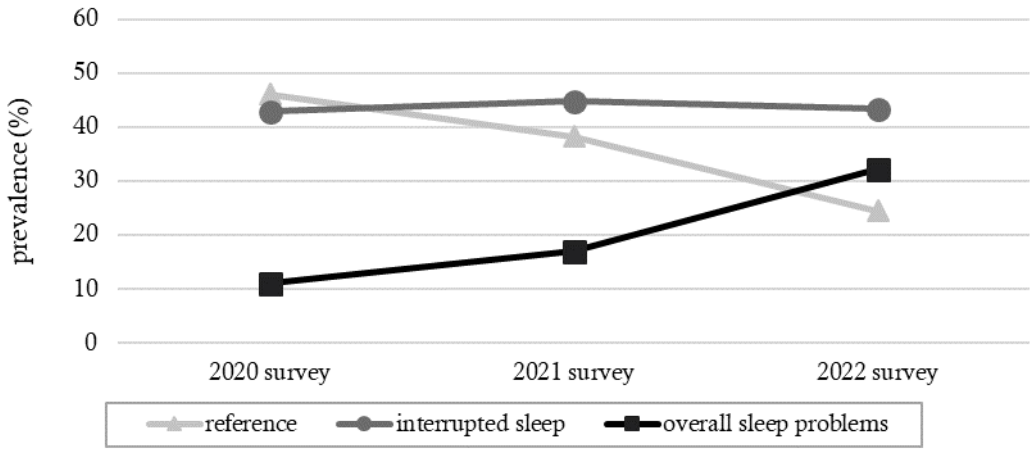


Table 4. Prevalence of latent statuses of sleep disturbance across the surveys

	Latent status		
	reference	sleep continuity prob	overall sleep prob
2020 survey	**46.1**	42.9	11.0
2021 survey	38.3	**44.7**	17.0
2022 survey	24.5	**43.3**	32.2

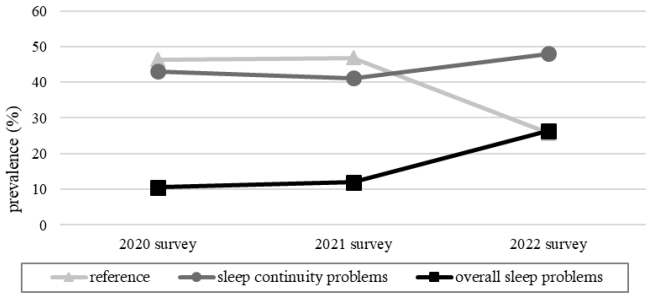
Notes. Covariates included age, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Bolds indicate the highest prevalence among sleep disturbances at each survey. Prob=problem.

In a sex-based stratified analysis, in both men and women, *sleep continuity problems* (status2) and *overall sleep problems* (status3) increased in prevalence over time and took the first and second statuses in the survey conducted in 2022, while *reference* (status 1) had the lowest prevalence at the 2022 survey (Figure 15, Table 5). For men, there was no significant difference in the prevalence of each status in the 2021 survey compared to the 2020 survey, but the prevalence change was greater in the 2022 survey. For women, the prevalence change of each status was shown in the 2021 survey.

In an age-based stratified analysis, *sleep continuity problems* (status 2) showed heterogeneous patterns in prevalence over time, with the *sleep continuity problems* (status 2) consistently decreasing in participants aged 30-40 years and increasing in participants aged 50-60 years (Figure 16, Table 6). In addition, for participants aged 30-40 years, *reference* (status 1) had the highest prevalence throughout all surveys, whereas in the group aged 50-60 years, the prevalence of *reference* (status 1) gradually decreased from the highest to the lowest prevalence from the 2020 survey to the 2022 survey.

Figure 15. Sex-specific prevalence of latent statuses of sleep disturbance across the surveys

(a) Men



(b) Women

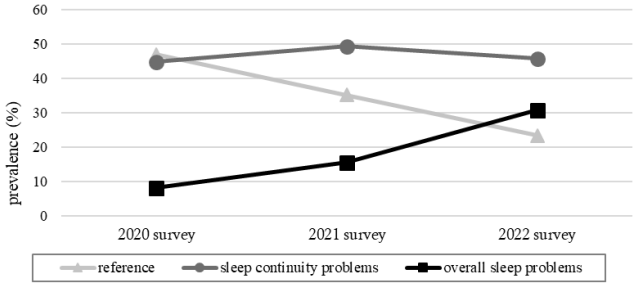


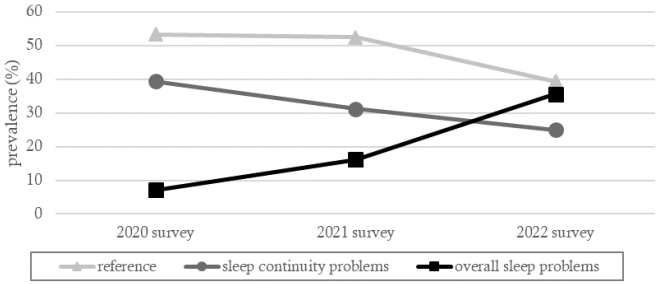
Table 5. Sex-specific prevalence of latent statuses of sleep disturbance across the surveys

	Latent status					
	Men			Women		
	reference	sleep continuity prob	overall sleep prob	reference	sleep continuity prob	overall sleep prob
2020 survey	**46.4**	43.1	10.5	**47.0**	44.8	8.2
2021 survey	**46.8**	41.2	12.0	35.2	**49.3**	15.5
2022 survey	25.7	**48.0**	26.3	23.4	**45.8**	30.8

Notes. Covariates included age, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Bolds indicate the highest prevalence among sleep disturbances at each survey. Prob=problem.

Figure 16. Age-specific prevalence of latent statuses of sleep disturbance across the surveys

(a) 30-40 years



(a) 50-60 years

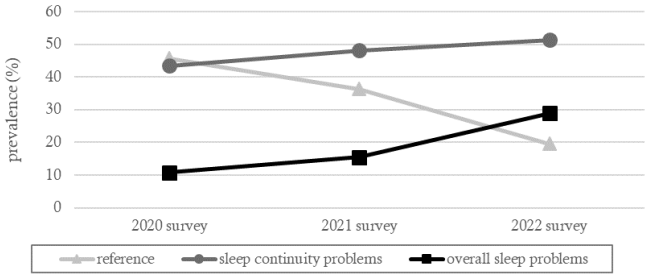


Table 6. Age-specific prevalence of latent statuses of sleep disturbance across the surveys

	Latent status					
	30-40 years			50-60 years		
	reference	Sleep continuity prob	overall sleep prob	reference	Sleep continuity prob	overall sleep prob
2020 survey	**53.4**	39.4	7.2	**45.7**	43.5	10.8
2021 survey	**52.5**	31.3	16.2	36.3	**48.2**	15.5
2022 survey	**39.4**	24.9	35.7	19.6	**51.4**	29.0

Notes. Covariates included age, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Bolds indicate the highest prevalence among sleep disturbances at each survey. Prob=problem.

c) Estimating transition probability

The transition probability represented the patterns that a specific sleep disturbance would be present at the 2021 survey conditional on the 2020 survey and at the 2022 survey conditional on the 2021 survey (Table 7). From the 2020 to 2021 surveys, the transition of participants in *reference* and *overall sleep problems* status into *sleep continuity problems* status was primarily observed. Diagonal elements represented the probability of individuals who had the same status at both times. For instance, a participant in *reference* status at the 2020 survey had a probability of 0.47 that they would be classified as *sleep continuity problems* status at the 2021 survey, while they had a probability of changing to the *overall sleep problems* at the 2021 survey (transition probability=0.13). From the 2021 to 2022 surveys, there was less transition of participants than before, while the majority remained in the same status category. For example, individuals in the *overall sleep problems* status at the 2021 survey had a probability of 0.83 that they would still be classified as *overall sleep problems* status at the 2022 survey. Further, the results of the sensitivity analysis that was conducted on the participants who completed all three surveys had similar patterns to the above results (Appendix 22).

Table 7. Transition probabilities of latent statuses of sleep disturbance across the surveys

	2021 survey				2022 survey		
	reference	sleep continuity prob	overall sleep prob		reference	sleep continuity prob	overall sleep prob
2020 survey				**2021 survey**			
reference	0.40	**0.47**	0.13	reference	**0.59**	0.29	0.12
sleep continuity prob	0.39	**0.45**	0.16	sleep continuity prob	0.01	**0.71**	0.28
overall sleep prob	0.40	**0.47**	0.13	overall sleep prob	0.03	0.15	**0.83**

Notes. Covariates included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake.
Bold indicates the highest transition probabilities among sleep disturbances between surveys. Prob=problem.

According to sex- and age-based stratified analyses of the survey data from 2020 to 2021, women and people in their 50-60s were more likely to transition from the *reference* and *overall sleep problems* statuses to the sleep continuity problems status, whereas men and people in their 30-40s showed a majority transition from the *sleep continuity problems* and *overall sleep problems* statuses into the *reference* status (Table 8-9). From the 2021 to 2022 surveys, similar to the above results, there was less transition of the participants than before, while the majority remained in the same status.

These results suggest that, in the first year after the COVID-19 outbreak, the transition patterns of status to *sleep continuity problems* was high, followed by transition to *reference* status, especially for women and participants aged 50-60 years. On the other hand, after the first year of the COVID-19 outbreak, there was a pattern of maintaining the same status, and the probability that participants had the same status was in order of *overall sleep problems, sleep continuity problems*, and *reference*.

Table 8. Sex-specific transition probabilities of latent statuses of sleep disturbance across the surveys

	2021 survey				2022 survey		
	reference	sleep continuity prob	overall sleep prob		reference	sleep continuity prob	overall sleep prob
Men							
2020 survey				**2021 survey**			
reference	**0.48**	0.37	0.14	reference	**0.54**	0.32	0.13
sleep continuity prob	**0.46**	0.44	0.10	sleep continuity prob	0.00	**0.75**	0.25
overall sleep prob	0.42	**0.46**	0.12	overall sleep prob	0.02	0.17	**0.80**
Women							
2020 survey				**2021 survey**			
reference	0.35	**0.52**	0.13	reference	**0.63**	0.28	0.10
sleep continuity prob	0.35	**0.46**	0.19	sleep continuity prob	0.02	**0.69**	0.29
overall sleep prob	0.38	**0.50**	0.12	overall sleep prob	0.02	0.14	**0.83**

Notes. Covariates included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake.
Bold indicates the highest transition probabilities among sleep disturbances between surveys. Prob=problem.

Table 9. Age-specific transition probabilities of latent statuses of sleep disturbance across the surveys

	2021 survey				2022 survey		
	reference	sleep continuity prob	overall sleep prob		reference	sleep continuity prob	overall sleep prob
30-40 years							
2020 survey				**2021 survey**			
reference	**0.61**	0.27	0.12	reference	**0.72**	0.08	0.19
sleep continuity prob	**0.43**	0.37	0.20	sleep continuity prob	0.00	**0.58**	0.42
overall sleep prob	**0.42**	0.31	0.28	overall sleep prob	0.09	0.14	**0.77**
50-60 years							
2020 survey				**2021 survey**			
reference	0.32	**0.52**	0.16	reference	**0.51**	0.39	0.10
sleep continuity prob	0.39	**0.45**	0.16	sleep continuity prob	0.02	**0.73**	0.25
overall sleep prob	0.42	**0.46**	0.12	overall sleep prob	0.01	0.14	**0.85**

Notes. Covariates included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake.
Bold indicates the highest transition probabilities among sleep disturbances between surveys. Prob=problem.

d) Potential causal association with distal outcomes over time

First, Table 10 shows the estimated PHQ-9 and PCL-5 scores according to changing of each latent status from the 2020 to 2022 surveys. The reference groups were defined as the groups changing from any status (i.e., *reference, sleep continuity problems, or overall sleep problems* status) into *reference* status. These groups were considered as a group that might positively improve the symptom of sleep disturbance during the COVID-19 phases. Among all groups of changing status, the groups changing from any status into *sleep continuity problems* status had significantly higher estimates on both PTSS and depressive symptoms than did the reference groups (*reference* → *sleep continuity problems*: PCL-5 estimate =16.23, PHQ-9 estimate=5.87; *sleep continuity problems* → *sleep continuity problems:* PCL-5 estimate =19.27, PHQ-9 estimate=6.14; *overall sleep problems* → *sleep continuity problems*: PCL-5 estimate =11.60, PHQ-9 estimate=4.36). In particular, among those results, the group that transitioned from *sleep continuity problems* to *sleep continuity problems* status (i.e., that maintained the *sleep continuity problems* status) showed the most significant association with the outcomes, respectively. The groups changing from any status into *overall sleep problems* status presented a significant association with outcomes; however, the estimates were lower than those for the group changing into the *sleep continuity problems* status.

Table 10. Association of changes in the latent statuses of sleep disturbance with PTSS and depressive symptoms during the surveys

Change of status			PCL-5 scores			PHQ-9 scores		
			estimate	SE	p-value	estimate	SE	p-value
reference	→	reference		ref			ref	
	→	sleep continuity prob	16.23	(1.50)	<0.01	5.87	(0.51)	<0.01
	→	overall sleep prob	4.97	(0.62)	<0.01	1.96	(0.29)	<0.01
sleep continuity prob	→	reference		ref			ref	
	→	sleep continuity prob	19.27	(5.52)	<0.01	6.14	(1.72)	<0.01
	→	overall sleep prob	14.25	(6.33)	0.02	4.72	(2.00)	0.02
overall sleep prob	→	reference		ref			ref	
	→	sleep continuity prob	11.60	(1.30)	<0.01	4.36	(0.52)	<0.01
	→	overall sleep prob	3.26	(0.80)	<0.01	1.39	(0.36)	<0.01

Notes. Covariates included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Prob=problem.

According to sex- and age-based stratified analyses, in the groups of women and participants aged 50-60 years, the majority estimates observed by groups changing from any status into the *sleep continuity problems* status had more significant association with PTSS and depressive symptoms than did the groups of men and participants aged 30-40 years (Table 11-12). However, men who maintained the *sleep continuity problems* status during the COVID-19 phases (i.e., changed from *sleep continuity problems* to *sleep continuity problems)* had slightly higher scores for PTSS and depressive symptoms than did women (men: PCL-5 estimate =20.45, PHQ-9 estimate=10.18; women: 18.79, 6.79). To sum up, these results suggest that changing sleep status to *sleep continuity problems* is a risk factor for PTSS and depressive symptoms especially for women and people aged 50-60 years during the COVID-19 phases. In addition, the maintenance of *sleep continuity problems* status might have more negative association with those symptoms for men and people aged 50-60 years.

Table 11. Sex-specific association of changes in the latent statuses of sleep disturbance with PTSS and depressive symptoms during the surveys

Change of status			PCL-5 scores			PHQ-9 scores		
			estimate	SE	p-value	estimate	SE	p-value
Men								
reference	→	reference		ref			ref	
	→	sleep continuity prob	12.17	(2.16)	<0.01	4.62	(0.76)	<0.01
	→	overall sleep prob	4.14	(1.21)	<0.01	1.50	(0.49)	<0.01
sleep continuity prob	→	reference		ref			ref	
	→	sleep continuity prob	20.45	(4.58)	<0.01	10.18	(0.75)	<0.01
	→	overall sleep prob	20.83	(6.27)	<0.01	2.10	(0.55)	<0.01
overall sleep prob	→	reference		ref			ref	
	→	sleep continuity prob	4.02	(7.11)	0.57	0.34	(0.86)	0.69
	→	overall sleep prob	-1.99	(4.02)	0.62	1.00	(0.81)	0.22
Women								
reference	→	reference		ref			ref	
	→	sleep continuity prob	18.59	(1.99)	<0.01	6.52	(0.67)	<0.01
	→	overall sleep prob	5.39	(0.71)	<0.01	2.22	(0.35)	<0.01
sleep continuity prob	→	reference		ref			ref	
	→	sleep continuity prob	18.79	(7.50)	0.01	6.79	(2.24)	<0.01
	→	overall sleep prob	11.53	(8.42)	0.17	5.96	(2.42)	0.01
overall sleep problems	→	reference		ref			ref	
	→	sleep continuity prob	12.35	(1.68)	<0.01	4.57	(0.67)	<0.01
	→	overall sleep prob	3.16	(1.00)	<0.01	1.76	(0.48)	<0.01

Notes. Covariates included age, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Prob=problem.

Table 12. Age-specific association of changes in the latent statuses of sleep disturbance with PTSS and depressive symptoms during the surveys

Change of status			PCL-5 scores			PHQ-9 scores		
			estimate	SE	p-value	estimate	SE	p-value
30-40 years								
reference	→	reference		ref			ref	
	→	sleep continuity prob	15.54	(3.19)	<0.01	5.68	(0.89)	<0.01
	→	overall sleep prob	6.96	(1.65)	<0.01	2.30	(0.66)	<0.01
sleep continuity prob	→	reference		ref			ref	
	→	sleep continuity prob	15.45	(3.58)	<0.01	5.49	(1.06)	<0.01
	→	overall sleep prob	7.85	(2.18)	<0.01	5.48	(3.67)	0.14
overall sleep prob	→	reference		ref			ref	
	→	sleep continuity prob	9.71	(2.78)	<0.01	4.41	(1.13)	<0.01
	→	overall sleep prob	1.65	(2.11)	0.43	1.17	(0.82)	0.15
50-60 years								
reference	→	reference		ref			ref	
	→	sleep continuity prob	16.40	(1.68)	<0.01	5.79	(0.61)	<0.01
	→	overall sleep prob	4.21	(0.61)	<0.01	1.72	(0.32)	<0.01
sleep continuity prob	→	reference		ref			ref	
	→	sleep continuity prob	20.58	(6.99)	<0.01	6.40	(2.37)	0.01
	→	overall sleep prob	14.70	(7.77)	0.06	4.79	(2.58)	0.06
overall sleep prob	→	reference		ref			ref	
	→	sleep continuity prob	12.34	(1.45)	<0.01	4.45	(0.56)	<0.01
	→	overall sleep prob	3.82	(0.82)	<0.01	1.46	(0.38)	<0.01

Notes. Covariates included sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Prob=problem.

Second, the predicted average estimate of PHQ-9 and PCL-5 scores for each latent status over time is shown in Table 13. For the depressive symptoms, among sleep disturbance, *sleep continuity problems* status predicted the highest PHQ-9 scores of 7.27 significantly, and this estimate could be interpreted to mean that the participant in *sleep continuity problems* status might have a high possibility of mild depression over time. In addition, *overall sleep problems* status significantly predicted the PHQ-9 score of 3.23 over time, whereas a status of *reference* predicted the lowest PHQ-9 score of 0.92 but without significance. For the PTSS symptoms, similar to the results above, *sleep continuity problems* status significantly inferred the highest PCL-5 score of 21.83 over time. This estimate could be considered high even though it might not reach the PTSS cutoff, which was recommended above 31 to 33.[78] Moreover, a status of *overall sleep problems* significantly inferred the PCL-5 score of 11.78 over time, followed by *reference* status of 5.57. Further, the results of the sensitivity analysis conducted on participants who completed all three surveys had similar patterns to the above results (Appendix 23).

Table 13. Possible association of latent statuses of sleep disturbance with distal PTSS and depressive symptoms over time

	PCL-5 scores		PHQ-9 scores	
	estimate	CI	estimate	CI
reference	5.57	(5.10 - 6.04)	0.92	(0.77 - 1.07)
sleep continuity prob	21.83	(19.86 - 23.81)	7.27	(6.54 - 8.00)
overall sleep prob	11.78	(10.95 - 12.61)	3.23	(2.92 - 3.54)

Notes. Covariates included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Prob=problem.

The sex- and age-based stratified results showed associations similar to those above, but there was no significant difference of the estimates between the stratified groups (men vs women, 30-40 years vs. 50-60 years) (Table 14-15). The *sleep continuity problems* status was the factor that significantly predicted the highest PHQ-9/PCL-5 scores over time, followed by the *overall sleep problems* status. These findings might suggest a potential causal association between PTSS/depressive symptoms and particularly interrupted sleep over time, after the overall COVID-19 phase.

Table 14. Sex-specific possible association of latent statuses of sleep disturbance with distal PTSS and depressive symptoms over time

	PCL-5 scores		PHQ-9 scores	
	estimate	CI	estimate	CI
Men				
reference	5.72	(4.92 - 6.52)	1.00	(0.74 - 1.27)
sleep continuity prob	19.50	(16.61 - 22.40)	7.31	(6.25 - 8.37)
overall sleep prob	12.07	(10.66 - 13.49)	3.24	(2.71 - 3.78)
Women				
reference	5.48	(4.90 - 6.05)	0.88	(0.71 - 1.06)
sleep continuity prob	23.24	(20.60 - 25.88)	7.18	(6.19 - 8.16)
overall sleep prob	11.75	(10.72 - 12.79)	3.27	(2.88 - 3.67)

Notes. Covariates included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Prob=problem.

Table 15. Age-specific possible association of latent statuses of sleep disturbance with distal PTSS and depressive symptoms over time

	PCL-5 scores		PHQ-9 scores	
	estimate	CI	estimate	CI
30-40 years				
reference	5.31	(4.40 - 6.22)	0.97	(0.68 - 1.27)
sleep continuity prob	21.37	(17.14 - 25.59)	6.91	(5.19 - 8.63)
overall sleep prob	13.17	(11.38 - 14.96)	3.44	(2.82 - 4.06)
50-60 years				
reference	5.70	(5.16 - 6.25)	0.90	(0.73 - 1.08)
sleep continuity prob	22.04	(19.86 - 24.22)	7.32	(6.53 - 8.11)
overall sleep prob	11.07	(10.15 - 12.00)	3.11	(2.74 - 3.47)

Notes. Covariates included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Prob=problem.

IV. DISCUSSION

1. Summary of findings

We examined the comorbidity network structure of PTSS and depressive symptoms in the general population of South Korea, throughout the COVID-19 pandemic. The results of our study offer new insights regarding how the comorbidity network between PTSS and depressive symptoms was constructed after the outbreak of COVID-19. In the majority of the results, depressed mood was the central symptom and sleep problems was the bridge symptom. In particular, sleep problems were consistently identified as the most influential bridge symptom for the comorbidity networks of all time-points throughout the pandemic, whereas the central symptoms varied. Also, network robustness tests revealed that the results for the centrality indices were stable, which is crucial because a stable network means the interpretation of the centrality might be accurate. However, by comparing networks across time-points for testing invariance, network structure was significantly different between the subacute (2020 survey) and chronic (2021 and 2022 surveys) phases of COVID-19. For the network approach, our results suggest there might exist a change in comorbidity network structure throughout the COVID-19 phases; however, with the bridge symptom as a constant.

In addition, in the LTA, the changing time-point from the subacute to chronic phases occurred during the most transition to the sleep continuity problems status among any sleep disturbances. During the COVID-19 phases, changing patterns of sleep status to sleep

continuity problems is a risk factor for PTSS and depressive symptoms especially for women and people aged 50-60 years. Furthermore, the sleep continuity problems status significantly inferred the highest subsequent PCL-5 and PHQ-9 scores, especially for women and participants aged 50-60 years. Hence, consideration of sleep continuity problems at the changing time from the subacute into the chronic phase of COVID-19 might have an effect on the subsequent structure of PTSS and/or depressive symptoms. This may result in an in-depth understanding of how the comorbid psychological symptom structures may interact and improve the effectiveness of prevention of comorbidity.

2. Discussion of study findings

In our study, depressed mood was estimated as a central symptom in comorbid PTSS-depressive symptom networks throughout COVID-19. Depressed mood is a main symptom for screening depressive disorder based on the DSM-5.[102,103] These mood-related symptoms might be shared with those of PTSS, because the negative alterations in mood were utilized for clinical PTSD screening in the DSM-5 criteria of PTSD.[43] After the COVID-19 outbreak, depressive symptoms, due to social distancing as a means of shutdown, were more prevalent than other psychological symptoms in the general population; anxiety or depressive symptoms were prevalent in approximately 30% to 48% of people, compared with PTSS, which were prevalent in approximately 4.6% to 26.3% of people.[9,13-18] Taking these facts into account, depressed mood could play a central role in activating and maintaining psychological distress, especially throughout the pandemic; however, not much research has been done on this subject.[43] Therefore, in-depth understanding and

implications are needed for depressed mood and its possible effect on overall psychological distress after the pandemic especially for the general population.

In our study, there were changing patterns of PTSS central symptoms (i.e., flashback symptoms and subsequent reckless behavior and self-destructive behavior, throughout the COVID-19 outbreak); moreover, flashbacks were central in the subacute phase (i.e., 2020 survey), whereas they were no longer a central symptom in the chronic phase (i.e., in the 2021 and 2022 surveys). Similar to our study, previous studies exploring the comorbid PTSS-depressive symptom network support the notion that flashback is the pivotal and most central symptom that shows a specific mechanism.[26,45] In addition, prior literature conducted before COVID-19 indicates that flashbacks were central symptoms even longitudinally.[26,43,45,104-106] During traumatic events, people tend to be focused on the source of trauma-related danger, which generates re-experienced fragmented memories that are hard to control.[75,107] In terms of COVID-19, in our study, these collective or mass traumas may generate intrusive images (including flashbacks) about the infectious danger during the early time of the traumatic events; however the strength of such images may subsequently weaken. This may be due to numerous distressing features of the early phase of COVID-19 for the public, such as uncertainty about official information on the unexpected pandemic, lack of information about disease-specific treatments and protective effects of COVID-19-related vaccines, and further misinformation spread indiscriminately through mass media.[108] According to previous literatures, these intrusive features could voluntarily control the possibility of flashback occurrence by the avoidance of trauma-

related triggers.[75] In line with this view, in our study, the changing patterns of flashbacks after 1 year of the outbreak may be because of the avoidance of the triggers; for example, the provision of reliable announcement of COVID-19 by the World Health Organization (WHO) and government quarantine guidelines, and even adaption to the pandemic among the public.

In our study, the reckless and self-destructive behavior symptom was one of the most central symptoms of the comorbidity network structure at the chronic phases of COVID-19. Recently, the reckless and self-destructive behavior symptom, including self-injurious or suicidal behavior, was added to the DSM-5 criteria for PTSD diagnosis to account for this role.[103] The reckless and self-destructive behavior symptom is frequently comorbid with PTSS and/or depressive symptoms, which is associated with psychosocial functional impairment and poorer treatment.[109,110] Such reckless and self-destructive behavior may commonly arise in response to traumatic events, and occurrence of reckless behaviors might increase the risk of subsequent traumatic events.[109,111] Furthermore, a network analysis on DSM-5 revision of the PTSD nosology, conducted in the USA before COVID-19, suggests the existence of close relations between a reckless and self-destructive behavior and PTSS clusters.[110] Similar to our study, a network analysis conducted for US healthy participants during the pandemic, reported that COVID-19-related reckless and self-destructive behavior was the most central symptom, even after including the depressive symptoms in the network; however, there exists some discrepancy about when the reckless and self-destructive behavior was the most central symptom; the reckless and

self-destructive behavior was the most central at only the chronic phase in our study.[42] Given that these disagreements in the timing of activating reckless and self-destructive behavior after the pandemic could be an important target point of intervention that may produce great benefits for the public, further studies are needed to tailor interventions to treat these comorbid statuses concurrently.

In terms of the least central symptom in the comorbidity network, amnesia was loosely related to other symptoms. This suggestion is in accordance with previous research exploring both PTSD only and the comorbid PTSD-depressive symptom network.[46,104,106,112,113] This is in line with a systematic review of network approach on PTSS, which suggests that for most trauma-exposed individuals, amnesia is not a core symptom.[112] Also, in a meta-analysis, amnesia was found to be among the least central symptoms in the network.[106] Furthermore, a study about the latent structure of PTSS showed some factor-analytic results, most notably the consideration of weak loading of amnesia onto the corresponding clusters.[114]

We also estimated a metric of combined symptoms between PTSS and depressive disorder and found that their shared symptoms acted as bridge symptoms. There was much heterogeneity in bridge symptoms across studies.[26,43,45] In our study, examining bridge nodes revealed that sleep disturbance in PCL-5 and sleeping problems in PHQ-9 emerged as major bridge symptoms, replicating previous studies.[26,43,45] Sleep is an important contributor to mental health. Many psychiatric diagnoses, based on the DSM-5, entail sleep problems as one of their potential and non-specific symptoms.[103] In general, individuals

with psychiatric disorders suffer sleep difficulties at a rate of approximately 50-80%.[115] Likewise, PTSS and depression share non-specific psychiatric symptoms for diagnostic criteria, such as sleep disturbance and difficulty concentrating.[103] In terms of combined symptoms between PTSS and depression, sleep problems is observed at high rates and closely linked to the progression of these disorders.[116,117] Therefore, the high level of comorbid symptoms of sleep problems might point to mechanisms that activate between disorders. Thus, this point suggests the need for further consideration about effective sleep interventions for comorbid PTSD and depression.

Recently, researchers have highlighted the relevance of repeated measurement in the estimation of psychological networks due to the limitations of cross-sectional data.[60] Therefore, with the network approach, several prior studies have attempted to apply a person-centered analytic approach.[118,119] One study of Dutch patients with traumatic events first used LCA to identify subgroups of patients sharing the same symptoms, and second, did network analysis by the subgroups.[118] In another study, across four time points, the authors estimated a four cross-sectional network, similar to our study, and applied latent growth curve models, which was a kind of CFA model used specifically to model trajectories over time for estimating network structure fit.[119,120]

In our study, after building off the network structure, sleep problems were utilized as variables of a person-centered approach for targeted intervention. The person-centered approach revealed considerable individual differences in the general population with sleep problems prospectively with greater variability during COVID-19. The three profiles

identified at the 2020 to 2022 surveys (reference, sleep continuity problems, overall sleep problems) indicate unique sleep problems that could have varying implications for the general population and inform effective interventions for mental health. In addition, we suggested that the extent and transition, especially into sleep continuity problems status, over time occurred at the subacute phase of COVID-19. These profiles were more stable over time compared with the other profile; when transitions were make, there was little change between profiles, especially in reference status. These facts are linked with the outcomes of PTSS/depressive symptoms. Moreover, these findings might infer the potential causal association between PTSS/depressive symptoms and sleep continuity problems, after the overall COVID-19 phase. The present results share some similarities with those reported in prior studies. First, sleep problems utilizing the PSQI could have several distinct profiles (ranging from two to four), with great variety, while there is no consistency in that naming.[64-68] And second, these latent profiles were also more stable over time compared with prior results.[121] These findings suggest that the early intervention for the general population with specific sleep problems would be preceded.

Many psychological conditions are associated with sleep disturbances. However, the direction of the association between sleep problems and psychological symptoms, and vice versa, has remained a controversial issue. This suggests possible bidirectional associations between sleep problems and psychological symptoms. In the case of anxiety disorders (including PTSD) and mood disorders (including depression), which are addressed in our study, most cases of mood disorders appeared simultaneously with (~22%) or after (~40%)

insomnia; however, insomnia appeared concurrently (~38%) or following (~34%) the onset of the anxiety disorder.[122] In addition, approximately one-fifth (21%) and 13% of people with sleep problems have depression and anxiety disorders, respectively, and prior persistent sleep problems were a significant predictor of both anxiety disorders and depression.[122-124] On the other hand, patients who experienced acute or chronic traumatic events have shorter sleep, and those with PTSS showed longer sleep latency and frequent nocturnal awakenings.[125-127] Additionally, approximately two-thirds of people with depressive symptoms report that they experience sleep problems (sleep-onset insomnia and frequent awakenings, etc.), and further, women or the elderly are more likely to report experiencing sleep problems than males and younger people.[122,128,129] Moreover, younger people more prominently experience sleep-onset problems, while older people are more likely to experience sleep-continuity problems.[128,129] These bidirectional associations may be possible because elevated levels of inflammation and soluble intercellular adhesion molecules in the brain after trauma-related events are associated with biological disposition on sleep difficulties, PTSS, and depressive symptoms; however, more studies are needed to confirm this explanation.[122,130]

3. Implications of the study

From the clinical perspective, a network approach for understanding the psychological symptom-level interplay has value because symptoms do not occur in isolation.[36] However, clinical application of these results, such as central and bridge symptoms, should be done with caution. For example, the central symptoms may or may not be an effective target for

intervention; highly central symptoms are not always viable intervention targets, and the high centrality may not always translate into having clinical meaning.[131,132] According to a recent discussion concerning the validity and appropriateness of central and bridge symptom interpretation, symptoms of low centrality, such as suicidal ideation, could have the most important clinical implications even if it had low centrality in a network meaning.[131,132] Therefore, applying the results of network analysis to clinical practice should be done with great care; we should have considerable knowledge about the characteristics of participants and elements of the network if we intend to choose a clinical implication as an intervention target based on a network approach.

Collectively, the clinical implication of our findings is as follows: Among the general population of adults in South Korea who have experienced the COVID-19 pandemic directly or indirectly, the bridge symptom that simultaneously activates PTSS and depressive symptoms was sleep problems in all phases. Among sleep problems, people who had sleep continuity problems during the pandemic were considered as harbingers of the psychological conditions, which often begin before the PTSS and depressive symptoms. In view of these points, from a public health view, if an infectious epidemic situation (i.e., next pandemic) arises in the future, prompt screening of sleep problems and considering their status is needed, especially focusing on the tilting point from the subacute to chronic phases of the pandemic, in an effort to alleviate both the comorbidity between PTSS and depressive symptoms and adverse psychological effects, especially in the general population.

4. Limitations and Strengths

The current study has several limitations worth mentioning. First, this study applied a repeated cross-sectional design for the network approach, which precludes the ability to draw dynamic changes and causal inferences from the network. Future work is needed to elucidate symptom prognosis utilizing longitudinal and multi-level models. Second, the data regarding PTSS, depressive symptoms, and sleep disturbance assessments were obtained using online self-report measures, rather than clinician-administered interviews. Particularly, in relation to COVID-19 pandemic experiences, the screening tool was unable to identify whether the formal criterion of trauma was satisfied. Third, because sample size influences the power to detect network structures, so the unequal participant number between phases of the COVID-19 network structure potentially affected the results. To address the instability of the network structures when performed on groups of the unequal participant number, we conducted several comparison analyses by utilizing network comparison tests, running with a random subsample balanced in the number of each networks and found the following results: between the 2020 survey and the 2021/2022 surveys, the network structure were statistically different (2020 vs. 2021: $M=0.38$, $p<0.01$; 2020 vs. 2022: $M=0.40$, $p<0.01$), whereas global strengths were not significantly different (2020 vs. 2021: $s=3.53$, $p=0.13$; 2020 vs. 2022: $s=0.72$, $p=0.78$); between the 2021 and 2022 surveys, network structure invariance (2021 vs. 2022: $M=0.17$, $p=0.62$) and global strength invariance (2021 vs. 2022: $s=1.51$, $p=0.41$) tests indicated that the network structures did not significantly vary across surveys. Fourth, our results are difficult to

generalize to clinical PTSD participants. It is necessary to fully consider the severity and type of trauma of the participants. Finally, we utilized a part of the PSQI for measuring sleep disturbance; there need to be further studies for validity.

Notwithstanding these significant limitations, the main strengths of our study may contribute to extant knowledge in the field. First, our research takes into consideration the subacute and chronic stages of the COVID-19 pandemic; therefore, comparisons of symptom patterns across different stages of the pandemic could be conducted. Second, we focused on individual symptoms rather than clusters, which supported us in establishing the specific symptom-level associations between the communities. However, our samples are racially homogenous and are focused on adults; future research should examine the association across more representative samples over the life course. Third, we utilized DSM-5 criteria of PTSS for PTSD assessment, such as the negative alterations in mood known as depressive-like symptoms. As network analysis is data-driven, including the DSM-5 symptoms may provide more considerable vital information on symptom structures. Fourth, we applied longitudinal person-centered analysis, such as LTA, to test the transition of the symptoms for targeted intervention during COVID-19.

V. CONCLUSIONS

Our results suggest that there might exist a changing pattern in the network structure throughout the COVID-19 phases, while the bridge symptom (sleep problems in our study) remains constant. In addition, the transition to sleep continuity problems, primarily from other sleep disturbances occurred during the time flow from the subacute to chronic phases, and this transition has a negative association with PTSS and depressive symptoms. Furthermore, people who have symptoms of sleep continuity problems are inferred to experience a significant possible adverse impact on PTSS and depressive symptoms over time, especially in women and people aged over 50 years.

Collectively, the clinical implication of our findings is as follows. Among general adults in South Korea who have experienced the COVID-19 pandemic directly or indirectly, the bridge symptom that simultaneously activates PTSS and depressive symptoms was sleep problems in all phases. Among sleep problems, people who had sleep continuity problems during the pandemic were considered as harbingers of psychological conditions, which often begins before the PTSS and depressive symptoms. Hence, from a public health point of view, if an infectious epidemic situation (i.e. next pandemic) arises in the future, prompt screening for sleep problems and considering status would be effective as an effort to alleviate both the comorbidity of PTSS and depressive symptoms and adverse psychological effects, especially by focusing on the tilting point from the subacute to chronic phases of the pandemic.

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APPENDIX

Appendix 1. Nine-symptom checklist of the Patient Health Questionnaire (PHQ-9)

Over the *last 2 weeks*, how often have you been bothered by any of the following problems?		Not at all	Several days	More than half the days	Nearly every day
1.	Little interest or pleasure in doing things	0	1	2	3
2.	Feeling down, depressed, or hopeless	0	1	2	3
3.	Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4.	Feeling tired or having little energy	0	1	2	3
5.	Poor appetite or overeating	0	1	2	3
6.	Feeling bad about yourself—or that you are a failure or have let yourself or your family down	0	1	2	3
7.	Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8.	Moving or speaking so slowly that other people could have noticed? Or the opposite—being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9.	Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

Appendix 2. Twenty-symptom post-traumatic checklist for DSM-5 (PCL-5)

In the past month, how much were you bothered by:		Not at all	A little bit	Moderately	Quite a bit	Extremely
1.	Repeated, disturbing, and unwanted memories of the stressful experience?	0	1	2	3	4
2.	Repeated, disturbing dreams of the stressful experience?	0	1	2	3	4
3.	Suddenly feeling or acting as if the stressful experience were actually happening again (as if you were actually back there reliving it)?	0	1	2	3	4
4.	Feeling very upset when something reminded you of the stressful experience?	0	1	2	3	4
5.	Having strong physical reactions when something reminded you of the stressful experience (for example, heart pounding, trouble breathing, sweating)?	0	1	2	3	4
6.	Avoiding memories, thoughts, or feelings related to the stressful experience?	0	1	2	3	4
7.	Avoiding external reminders of the stressful experience (for example, people, places, conversations, activities, objects, or situations)?	0	1	2	3	4
8.	Trouble remembering important parts of the stressful experience?	0	1	2	3	4
9.	Having strong negative beliefs about yourself, other people, or the world (for example, having thoughts such as: l am bad, there is something seriously wrong with me, no one can be trusted, the world is completely dangerous)?	0	1	2	3	4
10.	Blaming yourself or someone else for the stressful experience or what happened after it?	0	1	2	3	4
11.	Having strong negative feelings such as fear, horror, anger, guilt, or shame?	0	1	2	3	4
12.	Loss of interest in activities that you used to enjoy?	0	1	2	3	4
13.	Feeling distant or cut off from other people?	0	1	2	3	4

Appendix 2. Twenty-symptom post-traumatic checklist for DSM-5 (PCL-5) *(continued)*

In the past month, how much were you bothered by:		Not at all	A little bit	Moderately	Quite a bit	Extremely
14.	Trouble experiencing positive feelings (for example, being unable to feel happiness or have loving feelings for people close to you)?	0	1	2	3	4
15.	Irritable behavior, angry outbursts, or acting aggressively?	0	1	2	3	4
16.	Taking too many risks or doing things that could cause you harm?	0	1	2	3	4
17.	Being "superalert" or watchful or on guard?	0	1	2	3	4
18.	Feeling jumpy, or easily startled?	0	1	2	3	4
19.	Having difficulty concentrating?	0	1	2	3	4
20.	Trouble falling or staying asleep?	0	1	2	3	4

Appendix 3. Nineteen items of the Pittsburgh sleep quality index (PSQI)

INSTRUCTIONS:
The following questions relate to your usual sleep habits during the past month only.
Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1.	During the past month, what time have you usually gone to bed at night?	BED TIME _____
2.	During the past month, how long (in minutes) has it	NUMBER OF MINUTES _____
3.	During the past month, what time have you usually gotten up in the morning?	GETTING UP TIME _____
4.	During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)	HOURS OF SLEEP PER NIGHT _____

For each of the remaining questions, check the one best response. Please answer all questions

	5. During the past month, how often have you had trouble sleeping because you . . .	**Not during the past month**	**Less than once a week**	**Once or twice a week**	**Three or more times a week**
a)	Cannot get to sleep within 30 minutes	0	1	2	3
b)	Wake up in the middle of the night or early morning	0	1	2	3
c)	Have to get up to use the bathroom	0	1	2	3
d)	Cannot breathe comfortably	0	1	2	3
e)	Cough or snore loudly	0	1	2	3
f)	Feel too cold	0	1	2	3
g)	Feel too hot	0	1	2	3
h)	Had bad dreams	0	1	2	3
i)	Have pain	0	1	2	3
j)	Other reason(s), please describe : How often during the past month have you had trouble sleeping because of this?	0	1	2	3

Appendix 3. Nineteen items of the Pittsburgh sleep quality index (PSQI) *(continued)*

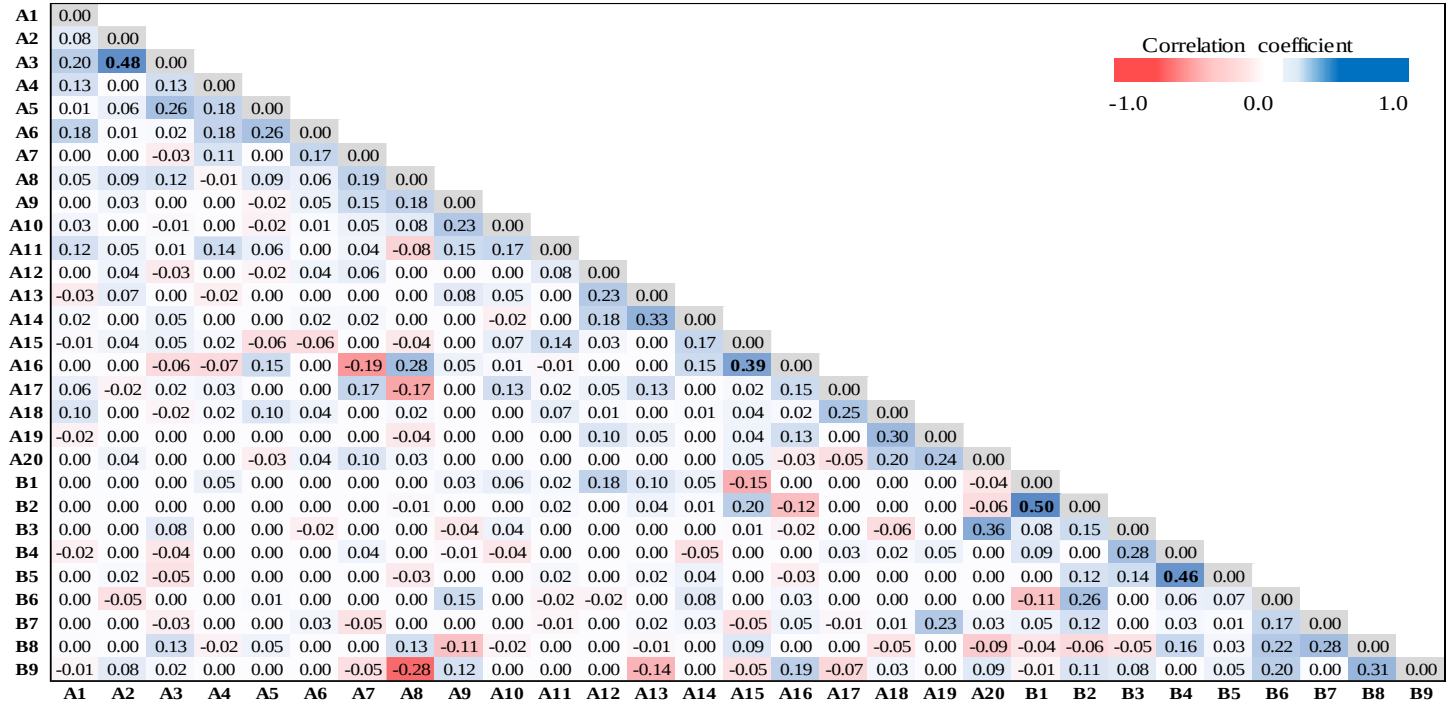
6.	During the past month, how would you rate your sleep quality overall?	Very good _____ Fairly good _____ Fairly bad _____ Very bad _____			
		Not during the past month	**Less than once a week**	**Once or twice a week**	**Three or more times a week**
7.	During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?	0	1	2	3
8.	During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	0	1	2	3
9.	During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	No problem at all _____ Only a very slight problem _____ Somewhat of a problem _____ A very big problem _____			
10.	Do you have a bed partner or roommate?	No bed partner or room mate _____ Partner/roommate in other room _____ Partner in same room, but not same bed _____ Partner in same bed _____			

Appendix 3. Nineteen items of the Pittsburgh sleep quality index (PSQI) *(continued)*

If you have a roommate or bed partner, ask him/her how often in the past month you have had . . .	**Not during the past month**	**Less than once a week**	**Once or twice a week**	**Three or more times a week**
a) Loud snoring	0	1	2	3
b) Long pauses between breaths while asleep	0	1	2	3
c) Legs twitching or jerking while you sleep	0	1	2	3
d) Episodes of disorientation or confusion during sleep	0	1	2	3
e) Other restlessness while you sleep; please describe	0	1	2	3

Appendix 4. Observed indicators and mean scores of sleep disturbance components

Item	Response category	2020 survey (N=1,930)		2021 survey (N=1,355)		2022 survey (N=1,204)	
		Mean	(SD)	Mean	(SD)	Mean	(SD)
1	Wake up in the middle of the night or early morning (0~3)	1.31	(1.11)	1.43	(1.10)	1.84	(1.09)
2	Have to get up to use the bathroom (0~3)	1.52	(1.11)	1.58	(1.12)	1.83	(1.08)
3	Cannot breathe comfortably (0~3)	0.22	(0.59)	0.25	(0.63)	0.31	(0.72)
4	Cough or snore loudly (0~3)	0.73	(1.01)	0.83	(1.06)	0.82	(1.06)
5	Feel too cold (0~3)	0.16	(0.48)	0.22	(0.56)	0.48	(0.79)
6	Feel too hot (0~3)	0.13	(0.44)	0.17	(0.53)	0.43	(0.77)
7	Have bad dreams (0~3)	0.20	(0.52)	0.25	(0.56)	0.57	(0.81)
8	Have pain (0~3)	0.27	(0.68)	0.38	(0.76)	0.48	(0.83)
9	Other reason(s), How often you have had trouble sleeping because of this reasons? (0~3)	0.60	(0.94)	0.71	(1.04)	0.84	(1.13)

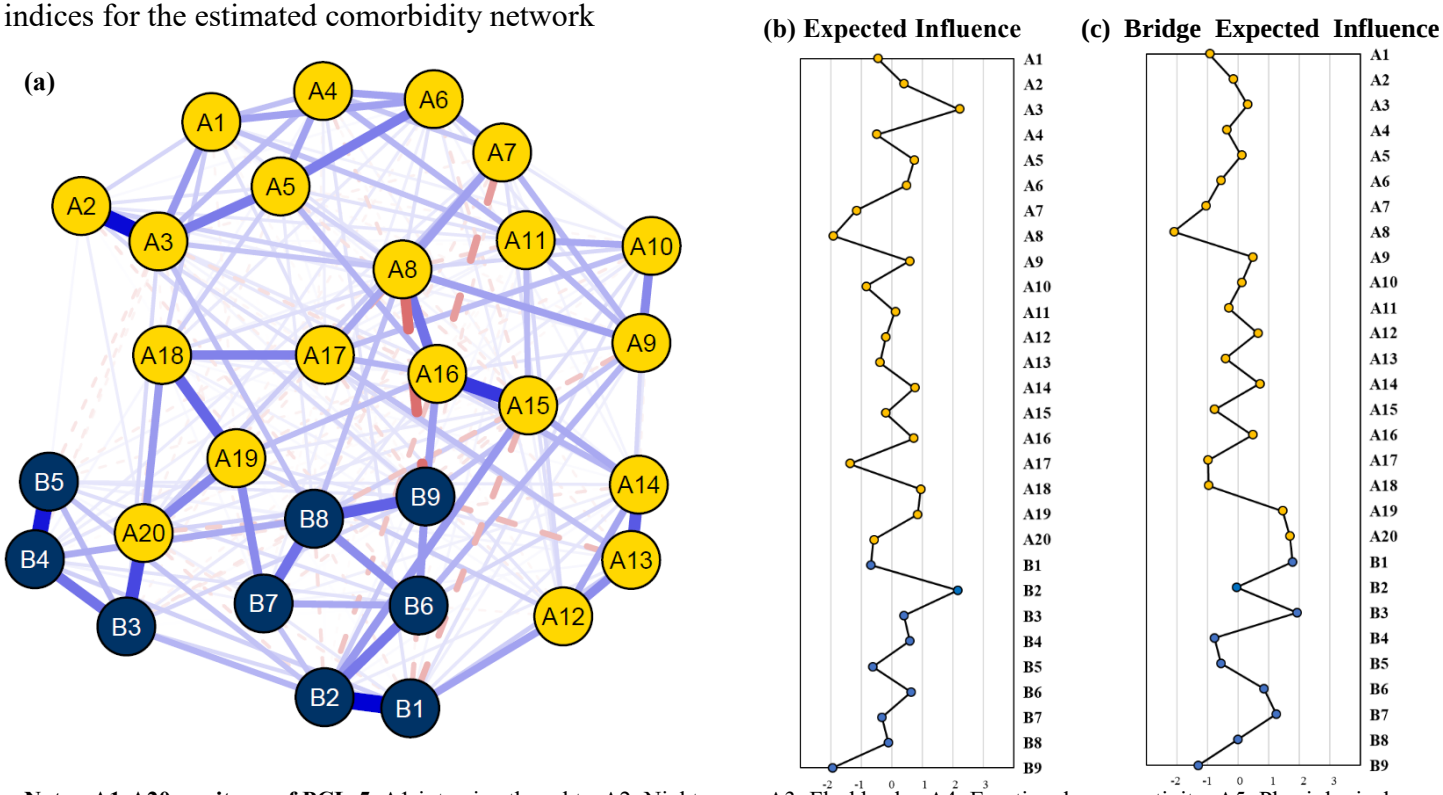


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1	0.00																												
A2	0.08	0.00																											
A3	0.20	**0.48**	0.00																										
A4	0.13	0.00	0.13	0.00																									
A5	0.01	0.06	0.26	0.18	0.00																								
A6	0.18	0.01	0.02	0.18	0.26	0.00																							
A7	0.00	0.00	-0.03	0.11	0.00	0.17	0.00																						
A8	0.05	0.09	0.12	-0.01	0.09	0.06	0.19	0.00																					
A9	0.00	0.03	0.00	0.00	-0.02	0.05	0.15	0.18	0.00																				
A10	0.03	0.00	-0.01	0.00	-0.02	0.01	0.05	0.08	0.23	0.00																			
A11	0.12	0.05	0.01	0.14	0.06	0.00	0.04	-0.08	0.15	0.17	0.00																		
A12	0.00	0.04	-0.03	0.00	-0.02	0.04	0.06	0.00	0.00	0.00	0.08	0.00																	
A13	-0.03	0.07	0.00	-0.02	0.00	0.00	0.00	0.00	0.08	0.05	0.00	0.23	0.00																
A14	0.02	0.00	0.05	0.00	0.00	0.02	0.02	0.00	0.00	-0.02	0.00	0.18	0.33	0.00															
A15	-0.01	0.04	0.05	0.02	-0.06	-0.06	0.00	-0.04	0.00	0.07	0.14	0.03	0.00	0.17	0.00														
A16	0.00	0.00	-0.06	-0.07	0.15	0.00	-0.19	0.28	0.05	0.01	-0.01	0.00	0.00	0.15	**0.39**	0.00													
A17	0.06	-0.02	0.02	0.03	0.00	0.00	0.17	-0.17	0.00	0.13	0.02	0.05	0.13	0.00	0.02	0.15	0.00												
A18	0.10	0.00	-0.02	0.02	0.10	0.04	0.00	0.02	0.00	0.00	0.07	0.01	0.00	0.01	0.04	0.02	0.25	0.00											
A19	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.10	0.05	0.00	0.04	0.13	0.00	0.30	0.00										
A20	0.00	0.04	0.00	0.00	-0.03	0.04	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.05	-0.03	-0.05	0.20	0.24	0.00									
B1	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.03	0.06	0.02	0.18	0.10	0.05	-0.15	0.00	0.00	0.00	0.00	-0.04	0.00								
B2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.02	0.00	0.04	0.01	0.20	-0.12	0.00	0.00	0.00	-0.06	**0.50**	0.00							
B3	0.00	0.00	0.08	0.00	0.00	-0.02	0.00	0.00	-0.04	0.04	0.00	0.00	0.00	0.00	0.01	-0.02	0.00	-0.06	0.00	0.36	0.08	0.15	0.00						
B4	-0.02	0.00	-0.04	0.00	0.00	0.00	0.04	0.00	-0.01	-0.04	0.00	0.00	0.00	-0.05	0.00	0.00	0.03	0.02	0.05	0.00	0.09	0.00	0.28	0.00					
B5	0.00	0.02	-0.05	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.02	0.00	0.02	0.04	0.00	-0.03	0.00	0.00	0.00	0.00	0.00	0.12	0.14	**0.46**	0.00				
B6	0.00	-0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.15	0.00	-0.02	-0.02	0.00	0.08	0.00	0.03	0.00	0.00	0.00	0.00	-0.11	0.26	0.00	0.06	0.07	0.00			
B7	0.00	0.00	-0.03	0.00	0.00	0.03	-0.05	0.00	0.00	0.00	-0.01	0.00	0.02	0.03	-0.05	0.05	-0.01	0.01	0.23	0.03	0.05	0.12	0.00	0.03	0.01	0.17	0.00		
B8	0.00	0.00	0.13	-0.02	0.05	0.00	0.00	0.13	-0.11	-0.02	0.00	0.00	-0.01	0.00	0.09	0.00	0.00	-0.05	0.00	-0.09	-0.04	-0.06	-0.05	0.16	0.03	0.22	0.28	0.00	
B9	-0.01	0.08	0.02	0.00	0.00	0.00	-0.05	-0.28	0.12	0.00	0.00	0.00	-0.14	0.00	-0.05	0.19	-0.07	0.03	0.00	0.09	-0.01	0.11	0.08	0.00	0.05	0.20	0.00	0.31	0.00

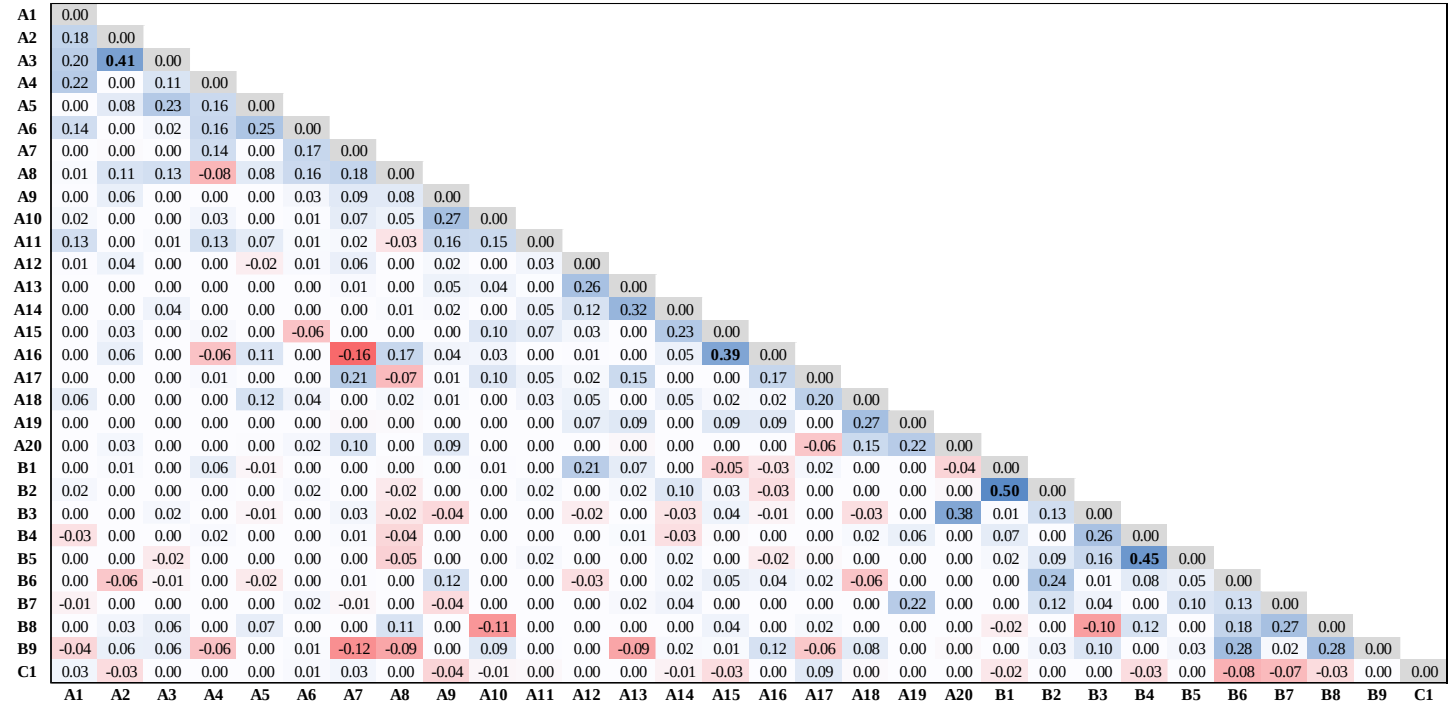
Appendix 5. Correlation matrix of edge weight in a comorbidity network of the complete set of the 2020 survey

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

Appendix 6. Comorbid network structures of the complete set of the 2020 survey. (a) Estimated network of PCL-5 and PHQ-9 symptoms, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network



Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

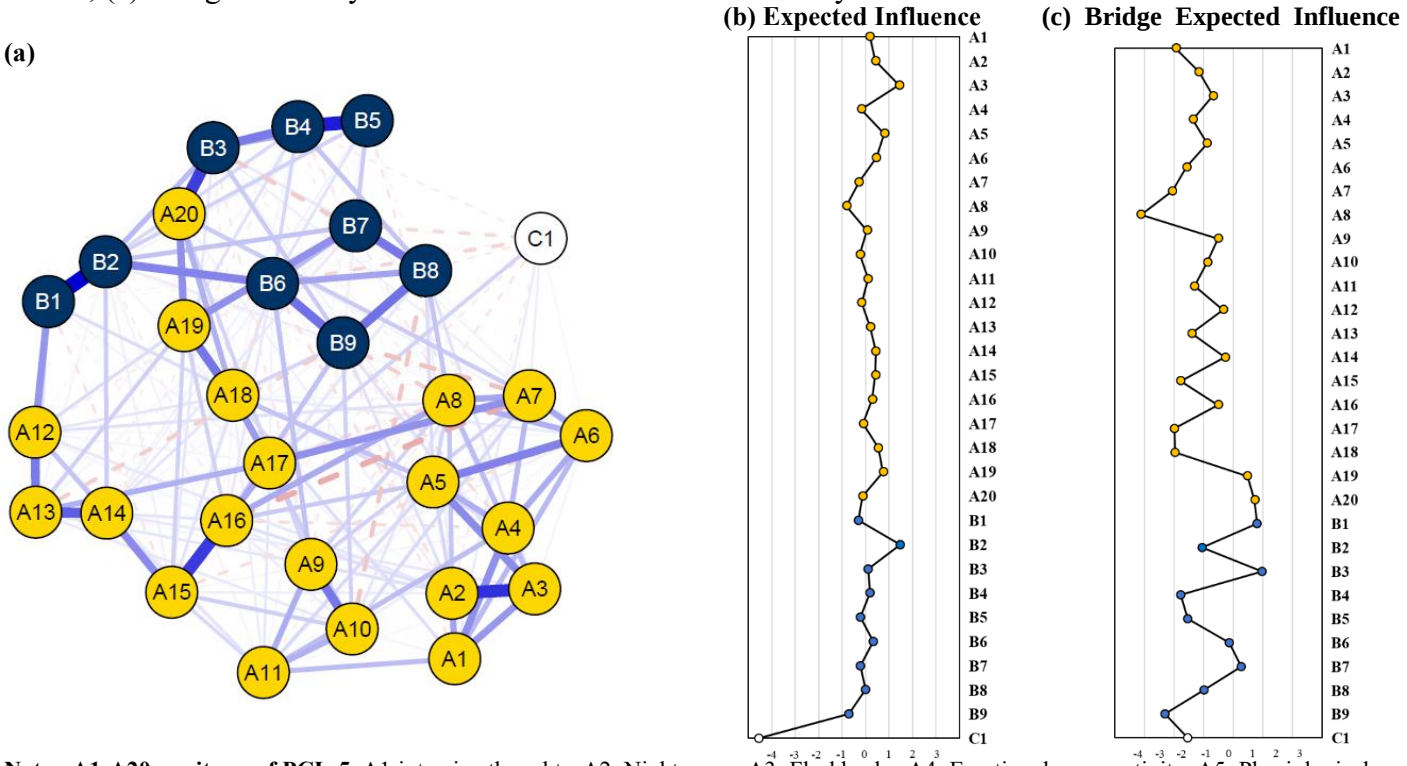


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9	C1
A1	0.00																													
A2	0.18	0.00																												
A3	0.20	**0.41**	0.00																											
A4	0.22	0.00	0.11	0.00																										
A5	0.00	0.08	0.23	0.16	0.00																									
A6	0.14	0.00	0.02	0.16	0.25	0.00																								
A7	0.00	0.00	0.00	0.14	0.00	0.17	0.00																							
A8	0.01	0.11	0.13	-0.08	0.08	0.16	0.18	0.00																						
A9	0.00	0.06	0.00	0.00	0.00	0.03	0.09	0.08	0.00																					
A10	0.02	0.00	0.00	0.03	0.00	0.01	0.07	0.05	0.27	0.00																				
A11	0.13	0.00	0.01	0.13	0.07	0.01	0.02	-0.03	0.16	0.15	0.00																			
A12	0.01	0.04	0.00	0.00	-0.02	0.01	0.06	0.00	0.02	0.00	0.03	0.00																		
A13	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.04	0.00	0.26	0.00																	
A14	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.05	0.12	0.32	0.00																
A15	0.00	0.03	0.00	0.02	0.00	-0.06	0.00	0.00	0.00	0.10	0.07	0.03	0.00	0.23	0.00															
A16	0.00	0.06	0.00	-0.06	0.11	0.00	-0.16	0.17	0.04	0.03	0.00	0.01	0.00	0.05	**0.39**	0.00														
A17	0.00	0.00	0.00	0.01	0.00	0.00	0.21	-0.07	0.01	0.10	0.05	0.02	0.15	0.00	0.00	0.17	0.00													
A18	0.06	0.00	0.00	0.00	0.12	0.04	0.00	0.02	0.01	0.00	0.03	0.05	0.00	0.05	0.02	0.02	0.20	0.00												
A19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.09	0.00	0.09	0.09	0.00	0.27	0.00											
A20	0.00	0.03	0.00	0.00	0.00	0.02	0.10	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	0.15	0.22	0.00										
B1	0.00	0.01	0.00	0.06	-0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.21	0.07	0.00	-0.05	-0.03	0.02	0.00	0.00	-0.04	0.00									
B2	0.02	0.00	0.00	0.00	0.00	0.02	0.00	-0.02	0.00	0.00	0.02	0.00	0.02	0.10	0.03	-0.03	0.00	0.00	0.00	0.00	**0.50**	0.00								
B3	0.00	0.00	0.02	0.00	-0.01	0.00	0.03	-0.02	-0.04	0.00	0.00	-0.02	0.00	-0.03	0.04	-0.01	0.00	-0.03	0.00	0.38	0.01	0.13	0.00							
B4	-0.03	0.00	0.00	0.02	0.00	0.00	0.01	-0.04	0.00	0.00	0.00	0.00	0.01	-0.03	0.00	0.00	0.00	0.02	0.06	0.00	0.07	0.00	0.26	0.00						
B5	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	0.02	0.00	0.00	0.02	0.00	-0.02	0.00	0.00	0.00	0.00	0.02	0.09	0.16	**0.45**	0.00					
B6	0.00	-0.06	-0.01	0.00	-0.02	0.00	0.01	0.00	0.12	0.00	0.00	-0.03	0.00	0.02	0.05	0.04	0.02	-0.06	0.00	0.00	0.00	0.24	0.01	0.08	0.05	0.00				
B7	-0.01	0.00	0.00	0.00	0.00	0.02	-0.01	0.00	-0.04	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.12	0.04	0.00	0.10	0.13	0.00			
B8	0.00	0.03	0.06	0.00	0.07	0.00	0.00	0.11	0.00	-0.11	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.00	-0.02	0.00	-0.10	0.12	0.00	0.18	0.27	0.00		
B9	-0.04	0.06	0.06	-0.06	0.00	0.01	-0.12	-0.09	0.00	0.09	0.00	0.00	-0.09	0.02	0.01	0.12	-0.06	0.08	0.00	0.00	0.00	0.03	0.10	0.00	0.03	0.28	0.02	0.28	0.00	
C1	0.03	-0.03	0.00	0.00	0.00	0.01	0.03	0.00	-0.04	-0.01	0.00	0.00	0.00	-0.01	-0.03	0.00	0.09	0.00	0.00	0.00	-0.02	0.00	0.00	-0.03	0.00	-0.08	-0.07	-0.03	0.00	0.00

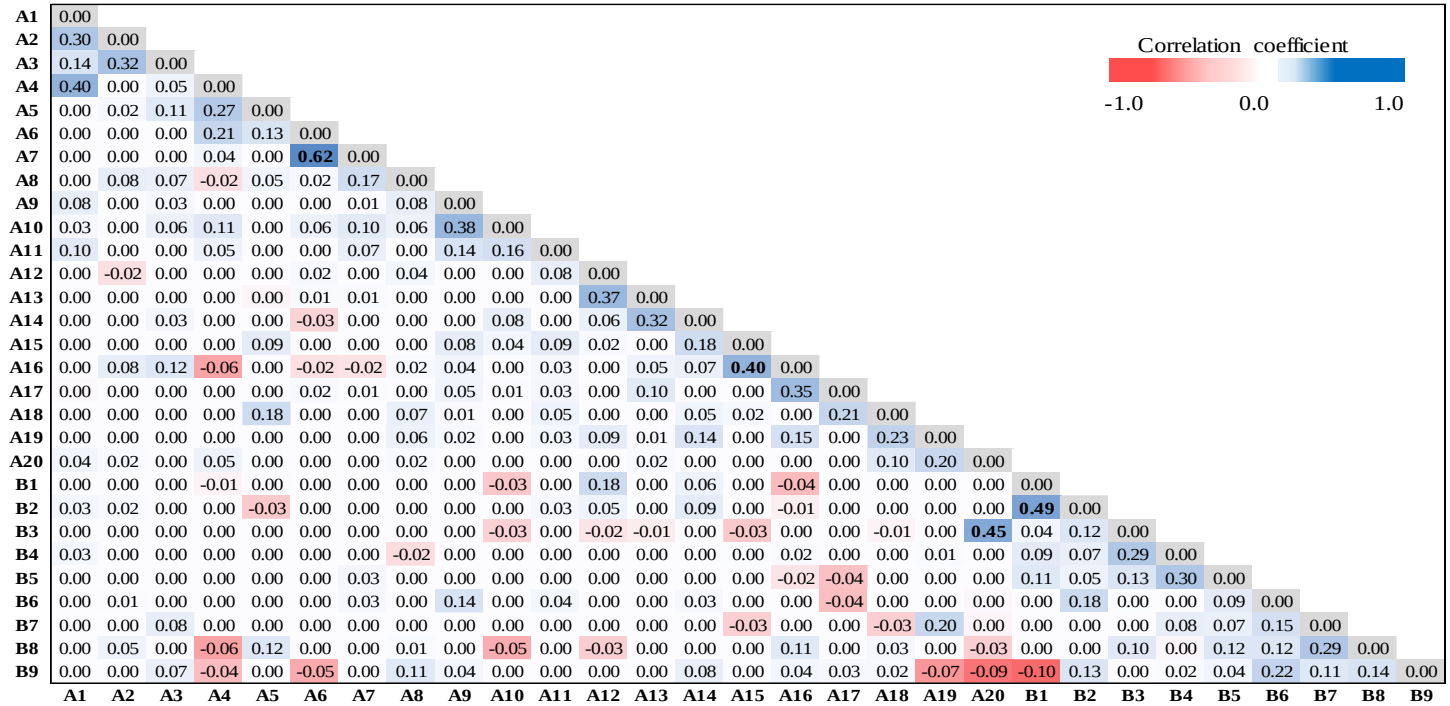
Appendix 7. Correlation matrix of edge weight in a combined network of PTSS, depressive symptoms, and resilience in the 2020 survey

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9**: B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation. **C1 is resilience score** estimated by CD-RISC questionnaires.

Appendix 8. Combined network structures of PTSS, depressive symptoms, and resilience of the 2020 survey. (a) Estimated network of PCL-5, PHQ-9, and CD-RISC, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network



Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation. **C1 is sum of CD-RISC scores**.

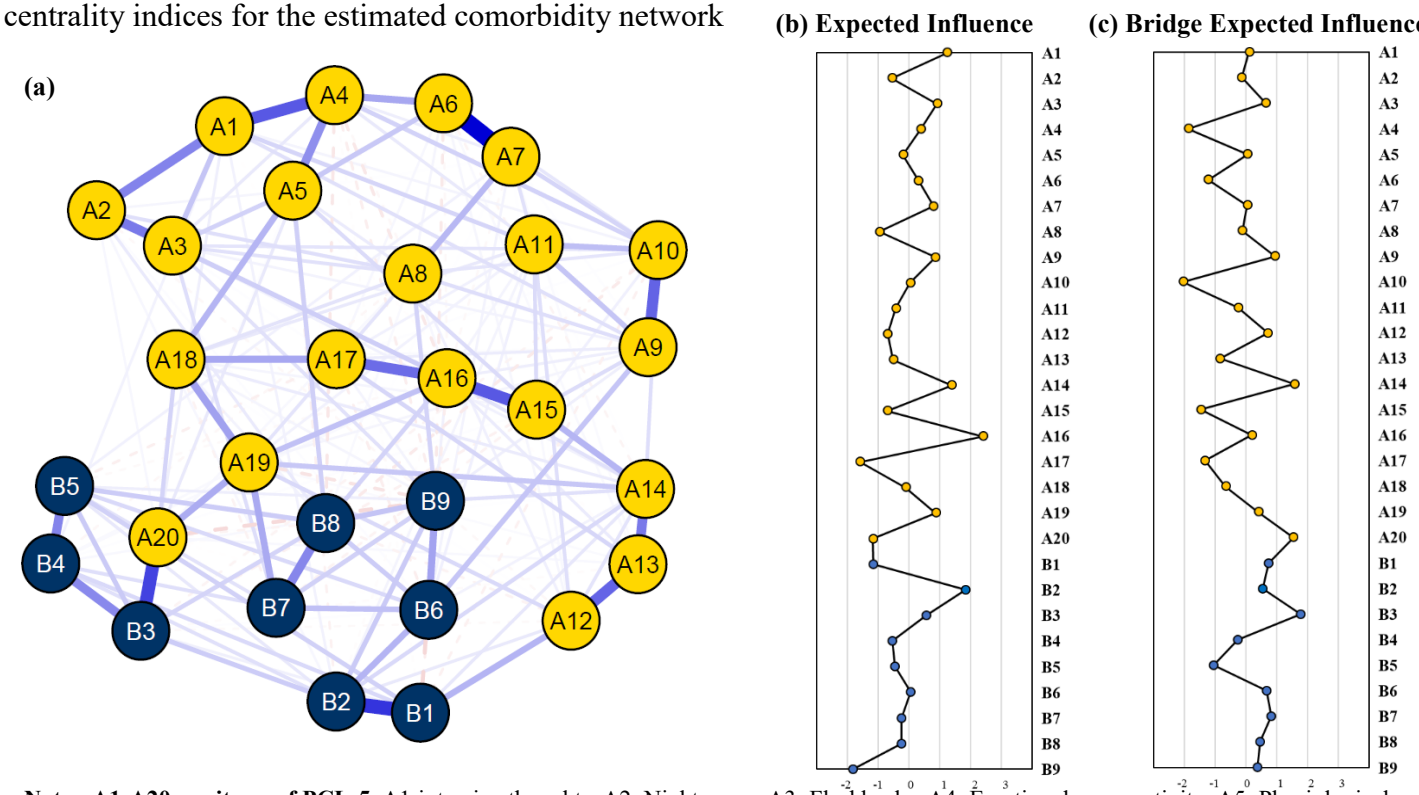


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1	0.00																												
A2	0.30	0.00																											
A3	0.14	0.32	0.00																										
A4	0.40	0.00	0.05	0.00																									
A5	0.00	0.02	0.11	0.27	0.00																								
A6	0.00	0.00	0.00	0.21	0.13	0.00																							
A7	0.00	0.00	0.00	0.04	0.00	**0.62**	0.00																						
A8	0.00	0.08	0.07	-0.02	0.05	0.02	0.17	0.00																					
A9	0.08	0.00	0.03	0.00	0.00	0.00	0.01	0.08	0.00																				
A10	0.03	0.00	0.06	0.11	0.00	0.06	0.10	0.06	0.38	0.00																			
A11	0.10	0.00	0.00	0.05	0.00	0.00	0.07	0.00	0.14	0.16	0.00																		
A12	0.00	-0.02	0.00	0.00	0.00	0.02	0.00	0.04	0.00	0.00	0.08	0.00																	
A13	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.37	0.00																
A14	0.00	0.00	0.03	0.00	0.00	-0.03	0.00	0.00	0.00	0.08	0.00	0.06	0.32	0.00															
A15	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.08	0.04	0.09	0.02	0.00	0.18	0.00														
A16	0.00	0.08	0.12	-0.06	0.00	-0.02	-0.02	0.02	0.04	0.00	0.03	0.00	0.05	0.07	**0.40**	0.00													
A17	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.05	0.01	0.03	0.00	0.10	0.00	0.00	0.35	0.00												
A18	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.07	0.01	0.00	0.05	0.00	0.00	0.05	0.02	0.00	0.21	0.00											
A19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.03	0.09	0.01	0.14	0.00	0.15	0.00	0.23	0.00										
A20	0.04	0.02	0.00	0.05	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.10	0.20	0.00									
B1	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.18	0.00	0.06	0.00	-0.04	0.00	0.00	0.00	0.00	0.00								
B2	0.03	0.02	0.00	0.00	-0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.00	0.09	0.00	-0.01	0.00	0.00	0.00	0.00	**0.49**	0.00							
B3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	-0.02	-0.01	0.00	-0.03	0.00	0.00	-0.01	0.00	**0.45**	0.04	0.12	0.00						
B4	0.03	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.09	0.07	0.29	0.00					
B5	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.04	0.00	0.00	0.00	0.11	0.05	0.13	0.30	0.00				
B6	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.14	0.00	0.04	0.00	0.00	0.03	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.09	0.00			
B7	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	-0.03	0.20	0.00	0.00	0.00	0.00	0.08	0.07	0.15	0.00		
B8	0.00	0.05	0.00	-0.06	0.12	0.00	0.00	0.01	0.00	-0.05	0.00	-0.03	0.00	0.00	0.00	0.11	0.00	0.03	0.00	-0.03	0.00	0.00	0.10	0.00	0.12	0.12	0.29	0.00	
B9	0.00	0.00	0.07	-0.04	0.00	-0.05	0.00	0.11	0.04	0.00	0.00	0.00	0.00	0.08	0.00	0.04	0.03	0.02	-0.07	-0.09	-0.10	0.13	0.00	0.02	0.04	0.22	0.11	0.14	0.00

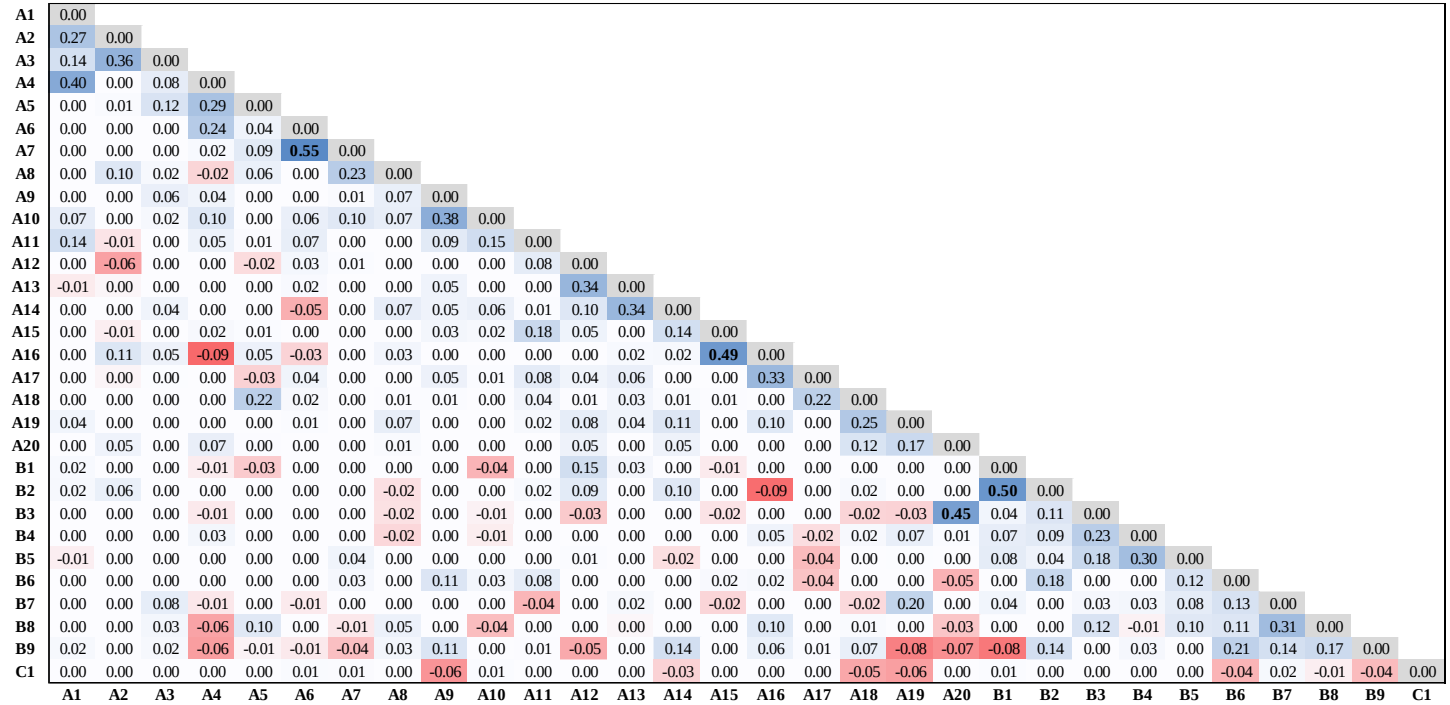
Appendix 9. Correlation matrix of edge weight in a comorbidity network of the complete set of the 2021 survey.

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

Appendix 10. Comorbidity network structures of the complete set of the 2021 survey. (a) Estimated network of PCL-5 and PHQ-9 symptoms, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network



Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

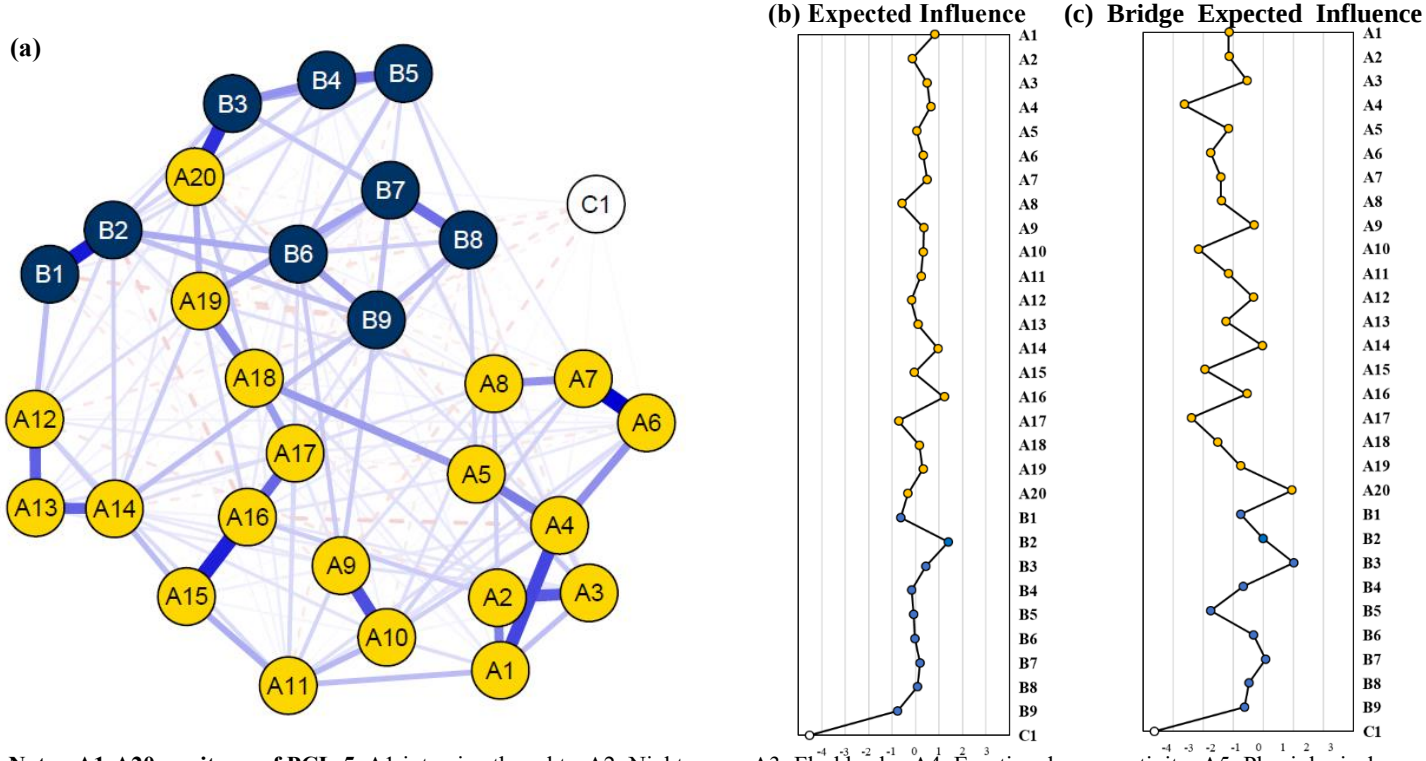


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9	C1
A1	0.00																													
A2	0.27	0.00																												
A3	0.14	0.36	0.00																											
A4	0.40	0.00	0.08	0.00																										
A5	0.00	0.01	0.12	0.29	0.00																									
A6	0.00	0.00	0.00	0.24	0.04	0.00																								
A7	0.00	0.00	0.00	0.02	0.09	**0.55**	0.00																							
A8	0.00	0.10	0.02	-0.02	0.06	0.00	0.23	0.00																						
A9	0.00	0.00	0.06	0.04	0.00	0.00	0.01	0.07	0.00																					
A10	0.07	0.00	0.02	0.10	0.00	0.06	0.10	0.07	0.38	0.00																				
A11	0.14	-0.01	0.00	0.05	0.01	0.07	0.00	0.00	0.09	0.15	0.00																			
A12	0.00	-0.06	0.00	0.00	-0.02	0.03	0.01	0.00	0.00	0.00	0.08	0.00																		
A13	-0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.05	0.00	0.00	0.34	0.00																	
A14	0.00	0.00	0.04	0.00	0.00	-0.05	0.00	0.07	0.05	0.06	0.01	0.10	0.34	0.00																
A15	0.00	-0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.03	0.02	0.18	0.05	0.00	0.14	0.00															
A16	0.00	0.11	0.05	-0.09	0.05	-0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.02	**0.49**	0.00														
A17	0.00	0.00	0.00	0.00	-0.03	0.04	0.00	0.00	0.05	0.01	0.08	0.04	0.06	0.00	0.00	0.33	0.00													
A18	0.00	0.00	0.00	0.00	0.22	0.02	0.00	0.01	0.01	0.00	0.04	0.01	0.03	0.01	0.01	0.00	0.22	0.00												
A19	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.07	0.00	0.00	0.02	0.08	0.04	0.11	0.00	0.10	0.00	0.25	0.00											
A20	0.00	0.05	0.00	0.07	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.00	0.05	0.00	0.00	0.00	0.12	0.17	0.00										
B1	0.02	0.00	0.00	-0.01	-0.03	0.00	0.00	0.00	0.00	-0.04	0.00	0.15	0.03	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00									
B2	0.02	0.06	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.02	0.09	0.00	0.10	0.00	-0.09	0.00	0.02	0.00	0.00	**0.50**	0.00								
B3	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	-0.02	0.00	-0.01	0.00	-0.03	0.00	0.00	-0.02	0.00	0.00	-0.02	-0.03	**0.45**	0.04	0.11	0.00							
B4	0.00	0.00	0.00	0.03	0.00	0.00	0.00	-0.02	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.05	-0.02	0.02	0.07	0.01	0.07	0.09	0.23	0.00						
B5	-0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.00	-0.02	0.00	0.00	-0.04	0.00	0.00	0.00	0.08	0.04	0.18	0.30	0.00					
B6	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.11	0.03	0.08	0.00	0.00	0.00	0.02	0.02	-0.04	0.00	0.00	-0.05	0.00	0.18	0.00	0.00	0.12	0.00				
B7	0.00	0.00	0.08	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	-0.04	0.00	0.02	0.00	-0.02	0.00	0.00	-0.02	0.20	0.00	0.04	0.00	0.03	0.03	0.08	0.13	0.00			
B8	0.00	0.00	0.03	-0.06	0.10	0.00	-0.01	0.05	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01	0.00	-0.03	0.00	0.00	0.12	-0.01	0.10	0.11	0.31	0.00		
B9	0.02	0.00	0.02	-0.06	-0.01	-0.01	-0.04	0.03	0.11	0.00	0.01	-0.05	0.00	0.14	0.00	0.06	0.01	0.07	-0.08	-0.07	-0.08	0.14	0.00	0.03	0.00	0.21	0.14	0.17	0.00	
C1	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	-0.06	0.01	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	-0.05	-0.06	0.00	0.01	0.00	0.00	0.00	0.00	-0.04	0.02	-0.01	-0.04	0.00

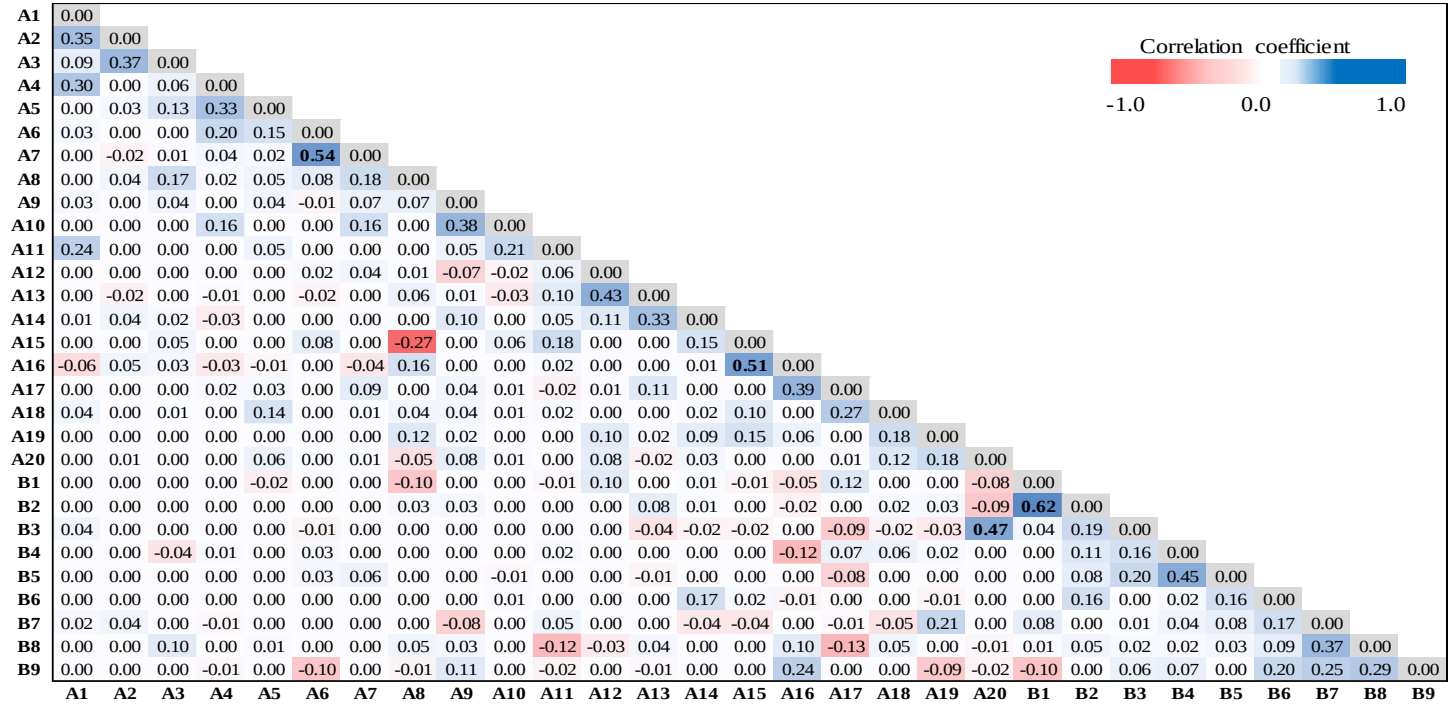
Appendix 11. Correlation matrix of edge weight in a combined network of PTSS, depressive symptoms, and resilience in the 2021 survey.

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9**: B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation. **C1 is resilience score** estimated by CD-RISC questionnaires.

Appendix 12. Combined network structures of PTSS, depressive symptoms, and resilience of the 2021 survey. (a) Estimated network of PCL-5, PHQ-9, and CD-RISC, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network



Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.**C1 is sum of CD-RISC scores**.

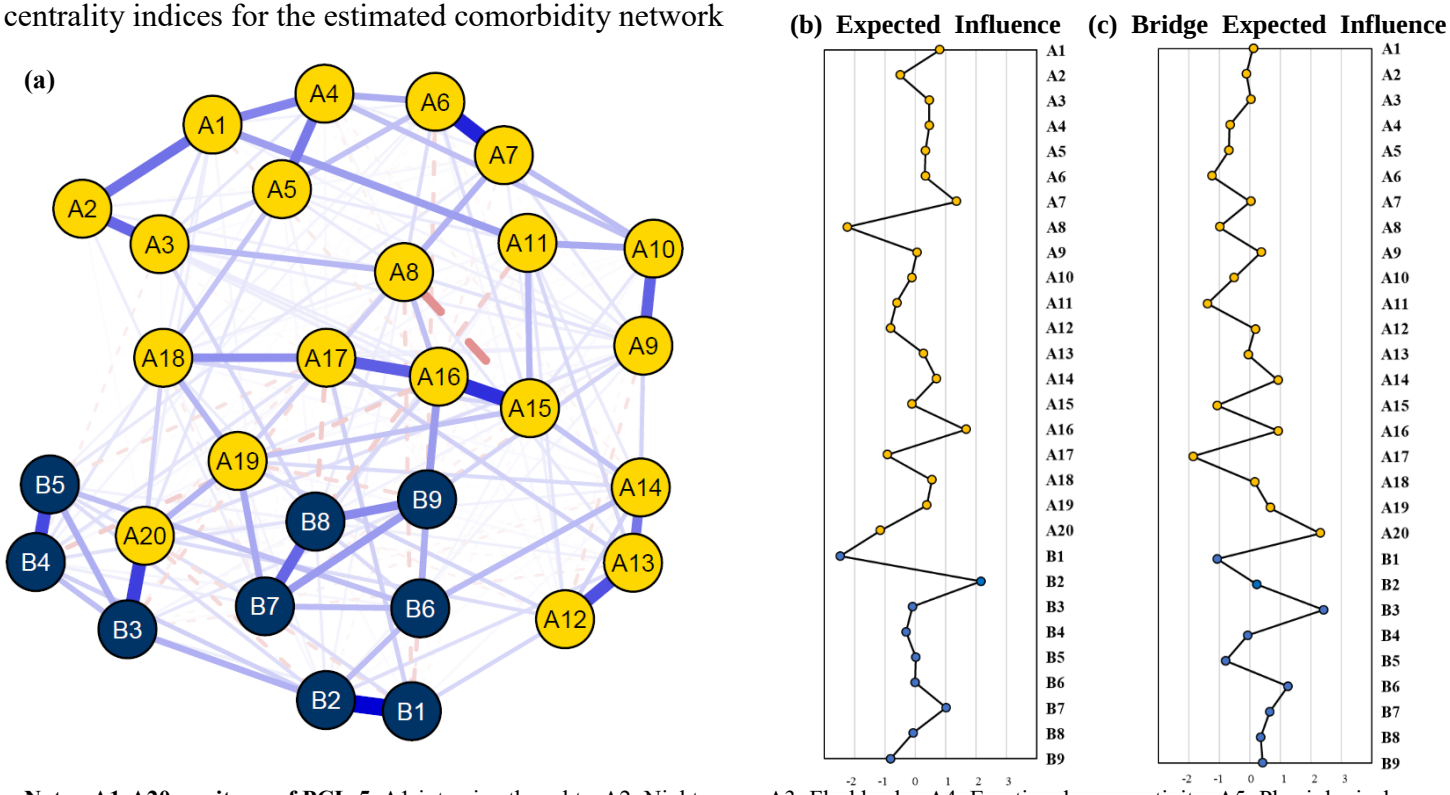


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1	0.00																												
A2	0.35	0.00																											
A3	0.09	0.37	0.00																										
A4	0.30	0.00	0.06	0.00																									
A5	0.00	0.03	0.13	0.33	0.00																								
A6	0.03	0.00	0.00	0.20	0.15	0.00																							
A7	0.00	-0.02	0.01	0.04	0.02	**0.54**	0.00																						
A8	0.00	0.04	0.17	0.02	0.05	0.08	0.18	0.00																					
A9	0.03	0.00	0.04	0.00	0.04	-0.01	0.07	0.07	0.00																				
A10	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.00	0.38	0.00																			
A11	0.24	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05	0.21	0.00																		
A12	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.01	-0.07	-0.02	0.06	0.00																	
A13	0.00	-0.02	0.00	-0.01	0.00	-0.02	0.00	0.06	0.01	-0.03	0.10	0.43	0.00																
A14	0.01	0.04	0.02	-0.03	0.00	0.00	0.00	0.00	0.10	0.00	0.05	0.11	0.33	0.00															
A15	0.00	0.00	0.05	0.00	0.00	0.08	0.00	-0.27	0.00	0.06	0.18	0.00	0.00	0.15	0.00														
A16	-0.06	0.05	0.03	-0.03	-0.01	0.00	-0.04	0.16	0.00	0.00	0.02	0.00	0.00	0.01	**0.51**	0.00													
A17	0.00	0.00	0.00	0.02	0.03	0.00	0.09	0.00	0.04	0.01	-0.02	0.01	0.11	0.00	0.00	0.39	0.00												
A18	0.04	0.00	0.01	0.00	0.14	0.00	0.01	0.04	0.04	0.01	0.02	0.00	0.00	0.02	0.10	0.00	0.27	0.00											
A19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.02	0.00	0.00	0.10	0.02	0.09	0.15	0.06	0.00	0.18	0.00										
A20	0.00	0.01	0.00	0.00	0.06	0.00	0.01	-0.05	0.08	0.01	0.00	0.08	-0.02	0.03	0.00	0.00	0.01	0.12	0.18	0.00									
B1	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	-0.10	0.00	0.00	-0.01	0.10	0.00	0.01	-0.01	-0.05	0.12	0.00	0.00	-0.08	0.00								
B2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.08	0.01	0.00	-0.02	0.00	0.02	0.03	-0.09	**0.62**	0.00							
B3	0.04	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	-0.02	-0.02	0.00	-0.09	-0.02	-0.03	**0.47**	0.04	0.19	0.00						
B4	0.00	0.00	-0.04	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	-0.12	0.07	0.06	0.02	0.00	0.00	0.11	0.16	0.00					
B5	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.00	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	-0.08	0.00	0.00	0.00	0.00	0.08	0.20	0.45	0.00				
B6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.17	0.02	-0.01	0.00	0.00	-0.01	0.00	0.00	0.16	0.00	0.02	0.16	0.00			
B7	0.02	0.04	0.00	-0.01	0.00	0.00	0.00	0.00	-0.08	0.00	0.05	0.00	0.00	-0.04	-0.04	0.00	-0.01	-0.05	0.21	0.00	0.08	0.00	0.01	0.04	0.08	0.17	0.00		
B8	0.00	0.00	0.10	0.00	0.01	0.00	0.00	0.05	0.03	0.00	-0.12	-0.03	0.04	0.00	0.00	0.10	-0.13	0.05	0.00	-0.01	0.01	0.05	0.02	0.02	0.03	0.09	0.37	0.00	
B9	0.00	0.00	0.00	-0.01	0.00	-0.10	0.00	-0.01	0.11	0.00	-0.02	0.00	-0.01	0.00	0.00	0.24	0.00	0.00	-0.09	-0.02	-0.10	0.00	0.06	0.07	0.00	0.20	0.25	0.29	0.00

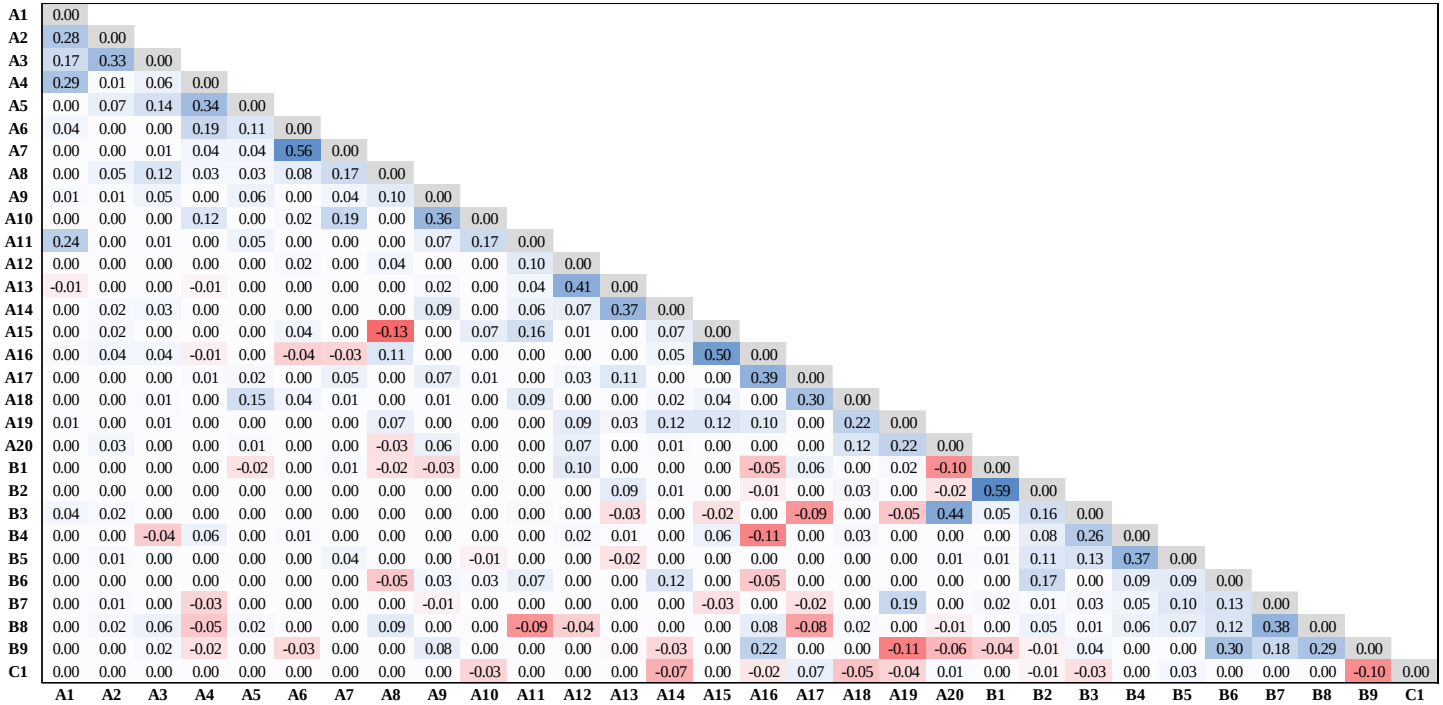
Appendix 13. Correlation matrix of edge weight in a combined network in the complete set of the 2022 survey.

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

Appendix 14. Comorbidity network structures of the complete set of the 2022 survey. (a) Estimated network of PCL-5 and PHQ-9 symptoms, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network



Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation.

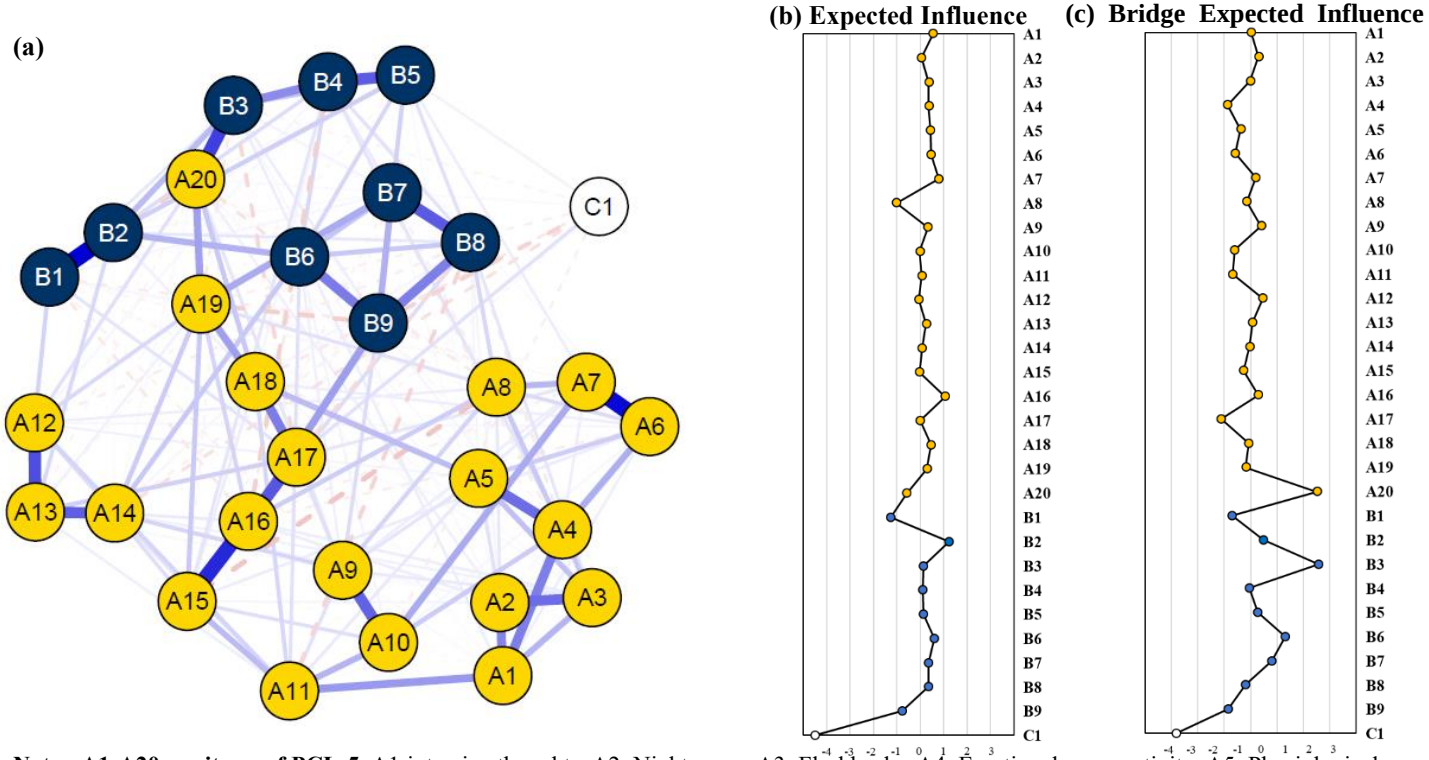


	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	B1	B2	B3	B4	B5	B6	B7	B8	B9	C1
A1	0.00																													
A2	0.28	0.00																												
A3	0.17	0.33	0.00																											
A4	0.29	0.01	0.06	0.00																										
A5	0.00	0.07	0.14	0.34	0.00																									
A6	0.04	0.00	0.00	0.19	0.11	0.00																								
A7	0.00	0.00	0.01	0.04	0.04	0.56	0.00																							
A8	0.00	0.05	0.12	0.03	0.03	0.08	0.17	0.00																						
A9	0.01	0.01	0.05	0.00	0.06	0.00	0.04	0.10	0.00																					
A10	0.00	0.00	0.00	0.12	0.00	0.02	0.19	0.00	0.36	0.00																				
A11	0.24	0.00	0.01	0.00	0.05	0.00	0.00	0.00	0.07	0.17	0.00																			
A12	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.00	0.00	0.10	0.00																		
A13	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.41	0.00																	
A14	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.06	0.07	0.37	0.00																
A15	0.00	0.02	0.00	0.00	0.00	0.04	0.00	-0.13	0.00	0.07	0.16	0.01	0.00	0.07	0.00															
A16	0.00	0.04	0.04	-0.01	0.00	-0.04	-0.03	0.11	0.00	0.00	0.00	0.00	0.00	0.05	0.50	0.00														
A17	0.00	0.00	0.00	0.01	0.02	0.00	0.05	0.00	0.07	0.01	0.00	0.03	0.11	0.00	0.00	0.39	0.00													
A18	0.00	0.00	0.01	0.00	0.15	0.04	0.01	0.00	0.01	0.00	0.09	0.00	0.00	0.02	0.04	0.00	0.30	0.00												
A19	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.09	0.03	0.12	0.12	0.10	0.00	0.22	0.00											
A20	0.00	0.03	0.00	0.00	0.01	0.00	0.00	-0.03	0.06	0.00	0.00	0.07	0.00	0.01	0.00	0.00	0.00	0.12	0.22	0.00										
B1	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	-0.02	-0.03	0.00	0.00	0.10	0.00	0.00	0.00	-0.05	0.06	0.00	0.02	-0.10	0.00									
B2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.00	-0.01	0.00	0.03	0.00	-0.02	0.59	0.00								
B3	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	-0.02	0.00	-0.09	0.00	-0.05	0.44	0.05	0.16	0.00							
B4	0.00	0.00	-0.04	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.06	-0.11	0.00	0.03	0.00	0.00	0.00	0.08	0.26	0.00						
B5	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.00	-0.01	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.11	0.13	0.37	0.00					
B6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	0.03	0.03	0.07	0.00	0.00	0.12	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.09	0.09	0.00				
B7	0.00	0.01	0.00	-0.03	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	-0.02	0.00	0.19	0.00	0.02	0.01	0.03	0.05	0.10	0.13	0.00			
B8	0.00	0.02	0.06	-0.05	0.02	0.00	0.00	0.09	0.00	0.00	-0.09	-0.04	0.00	0.00	0.00	0.08	-0.08	0.02	0.00	-0.01	0.00	0.05	0.01	0.06	0.07	0.12	0.38	0.00		
B9	0.00	0.00	0.02	-0.02	0.00	-0.03	0.00	0.00	0.08	0.00	0.00	0.00	0.00	-0.03	0.00	0.22	0.00	0.00	-0.11	-0.06	-0.04	-0.01	0.04	0.00	0.00	0.30	0.18	0.29	0.00	
C1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	-0.07	0.00	-0.02	0.07	-0.05	-0.04	0.01	0.00	-0.01	-0.03	0.00	0.03	0.00	0.00	0.00	-0.10	0.00

Appendix 15. Correlation matrix of edge weight in a combined network of PTSS, depressive symptoms, and resilience in the 2022 survey.

Notes. The blue-color box shows a positive correlation between symptoms, while the red-color box shows a negative correlation. Bold means a correlation of the highest several of the edge weights. **A1-A20 are items of PCL-5**: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9**: B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation. **C1 is resilience score** estimated by CD-RISC questionnaires.

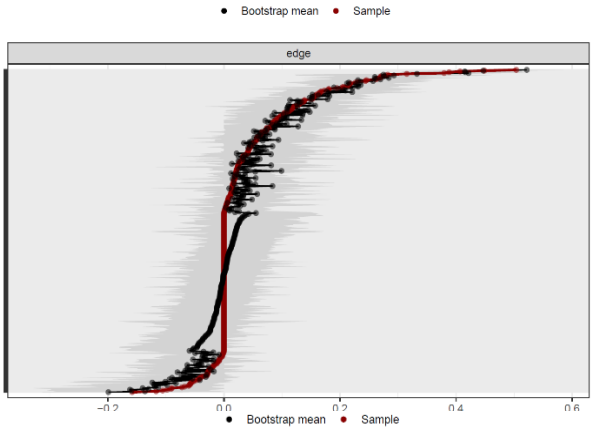
Appendix 16. Combined network structures of PTSS, depressive symptoms, and resilience of the 2022 survey. (a) Estimated network of PCL-5, PHQ-9, and CD-RISC, (b) Centrality indices for the estimated comorbidity network, (c) Bridge centrality indices for the estimated comorbidity network



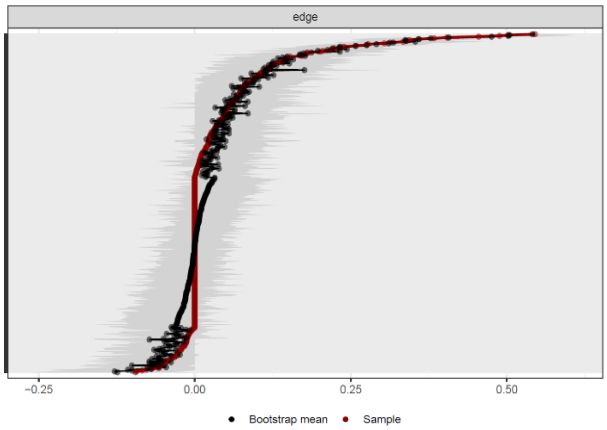
Notes. A1-A20 are items of PCL-5: A1:intrusive thoughts; A2: Nightmares; A3: Flashbacks; A4: Emotional cue reactivity; A5: Physiological cue reactivity; A6: Avoidance of thoughts; A7: Avoidance of reminders; A8: Trauma-related amnesia; A9: Negative beliefs; A10: Blame of self or others; A11: Negative trauma-related emotions; A12: Loss of interest; A13: Detachment; A14: Restricted affect; A15: Irritability/anger; A16: Reckless/self-destructive behavior; A17: Hypervigilance; A18: Exaggerated startle response; A19: Difficulty concentrating; A20: Sleep disturbance. **B1-B9 are items of PHQ-9:** B1: Anhedonia; B2: Depressed mood; B3; Sleeping problems; B4: Fatigability; B5: Appetite problems; B6: Negative feeling by myself; B7: Concentration problems; B8: Agitation/retardation; B9: Suicidal ideation. **C1 is sum of CD-RISC scores**.

Appendix 17. Bootstrapped confidence intervals of estimated edge weights for the comorbidity network. (a) accuracy test right after the outbreak of coronavirus-19, (b) accuracy test 1 year after the outbreak of coronavirus-19, (c) accuracy test 2 years after the outbreak of coronavirus-19.

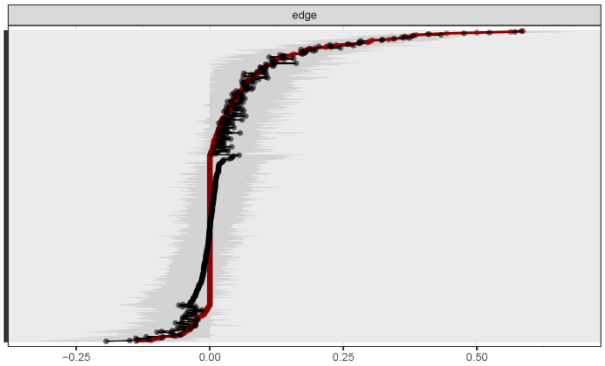
(a)



(b)

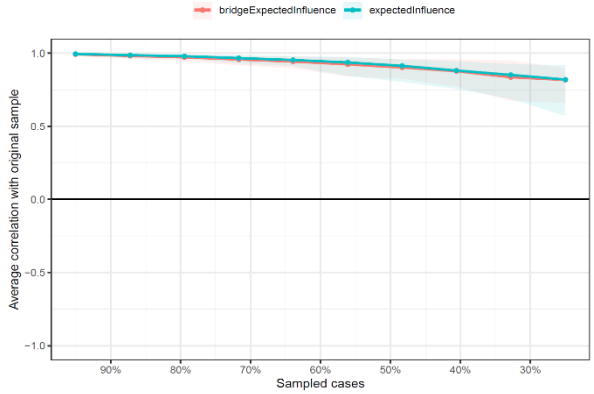


(c)

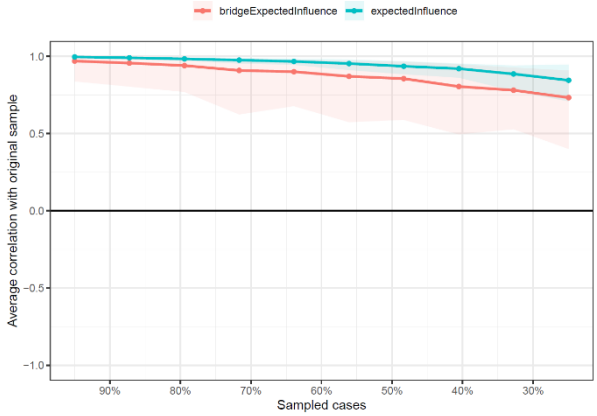


Appendix 18. Stability of both expected influence and bridge expected influence. (a) stability test of the 2020 survey, (b) stability test of the 2021 survey, (c) stability test of the 2022 survey.

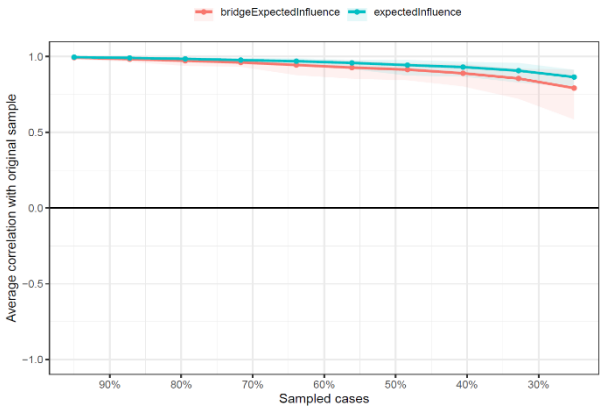
(a)



(b)

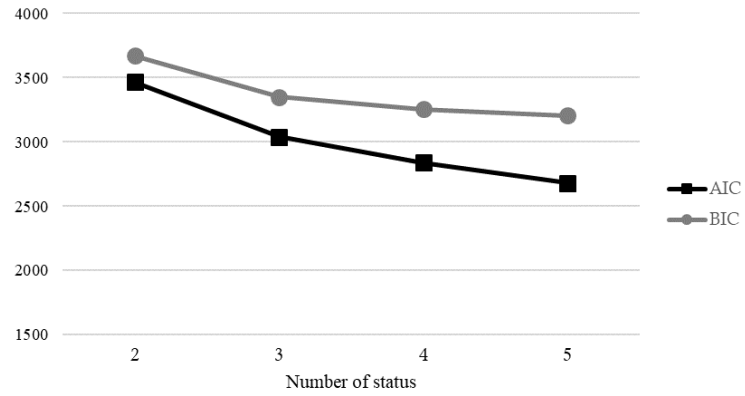


(c)

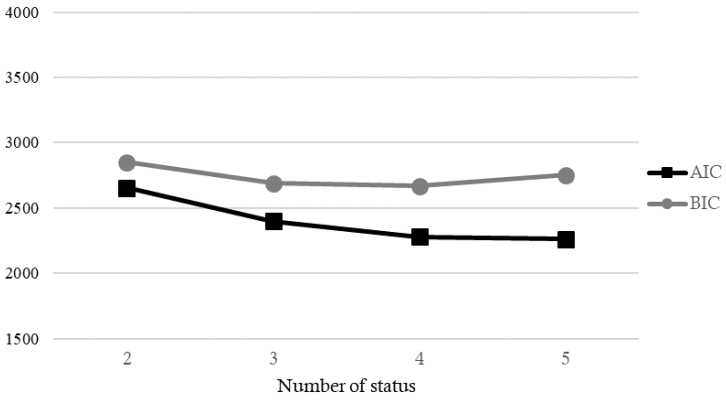


Appendix 19. Elbow plot of information criteria for latent models of sleep disturbances with different number statuses. (a) Elbow plot of the 2020 survey, (b) Elbow plot of the 2021 survey, (c) Elbow plot of the 2022 survey.

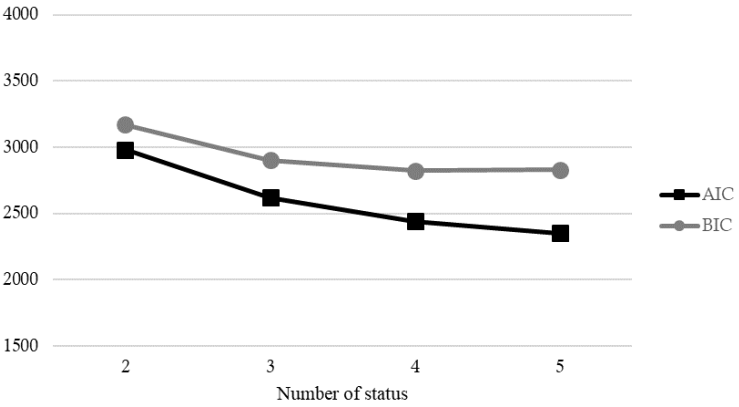
(a)



(b)



(c)



Appendix 20. Fit statistics for latent models of sleep disturbances with different number statuses of the complete set of the surveys

No. of status	LL	G^2	AIC	BIC	ABIC	Entropy
2020 survey						
2	-5784.77	2029.37	2103.37	2285.14	2167.62	0.75
3	-5662.11	1784.04	1896.04	2171.15	1993.29	0.75
4	-5594.46	1648.75	1798.75	2167.2	1929	0.78
5	-5545.64	1551.09	1739.09	2200.89	1902.34	0.77
2021 survey						
2	-5866.39	2040.24	2114.24	2296.01	2178.5	0.77
3	-5752.6	1812.66	1924.66	2199.77	2021.92	0.71
4	-5690.17	1687.79	1837.79	2206.24	1968.04	0.75
5	-5660.6	1628.66	1816.66	2278.46	1979.91	0.78
2022 survey						
2	-6520.55	2551.43	2625.43	2807.2	2689.69	0.77
3	-6351.94	2214.21	2326.21	2601.33	2423.47	0.8
4	-6257.4	2025.12	2175.12	2543.58	2305.37	0.79
5	-6207.27	1924.87	2112.87	2574.67	2276.12	0.78

Notes. LL=Log Likelihood; G^2= likelihood ratio statistics; AIC=Akaike Information Criterion; BIC=Bayesian Information Criterion.

Appendix 21. Prevalence of latent statuses of sleep disturbance across the surveys of the complete set of the surveys

	Latent status		
	reference	sleep continuity prob	overall sleep prob
2020 survey	**47.7**	44.4	7.9
2021 survey	38.5	**48.0**	13.5
2022 survey	24.9	**48.2**	26.9

Notes. Covariates included age, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Bolds indicate the highest prevalence among sleep disturbances at each survey. Prob=problem.

Appendix 22. Transition probabilities of latent statuses of sleep disturbance across the surveys of the complete set of the surveys

	2021 survey				2022 survey		
	reference	Sleep continuity prob	overall sleep prob		reference	Sleep continuity prob	overall sleep prob
2020 survey				**2021 survey**			
reference	0.39	**0.48**	0.13	reference	**0.62**	0.30	0.08
sleep continuity prob	0.38	**0.47**	0.15	sleep continuity prob	0.01	**0.72**	0.27
overall sleep prob	0.39	**0.52**	0.08	overall sleep prob	0.03	0.16	**0.81**

Notes. Covariates included age, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Bolds indicate the highest prevalence among sleep disturbances at each survey. Prob=problem.

Appendix 23. Possible association of latent statuses of sleep disturbance with distal PTSS and depressive symptoms over time of the complete set of the surveys

	PCL-5 scores		PHQ-9 scores	
	estimate	CI	estimate	CI
reference	5.33	(4.61 - 6.05)	0.75	(0.53 - 0.97)
sleep continuity prob	23.73	(20.68 - 26.77)	7.96	(0.69 - 9.02)
overall sleep prob	11.34	(10.26 - 12.42)	3.02	(2.61 - 3.42)

Notes. Covariates included age, sex, socioeconomic status, lifestyle factors, comorbidity, and current medication intake. Prob=problem.

ABSTRACT (KOREAN)

팬데믹 시기의 정신증상: 장기간의 외상 후 스트레스증상, 우울증상, 그리고 수면장애증상에 대한 네트워크분석 및 잠재전이분석

연세대학교 대학원 보건학과

이유진

연구배경: COVID-19이 팬데믹(Pandemic)으로 공식 선언됨으로 인해, COVID-19은 집단 트라우마로서 일반인구의 정신건강에 영향을 끼치고 있다. 팬데믹으로 인한 정신적 영향이 신체적 감염 정도보다 빠르다는 사실과 충격적인 사건의 경험이 다양한 정신적 고통을 유발할 수 있다는 사실을 고려할 때, COVID-19 팬데믹의 장기화는 일반인구에게 외상 후 스트레스증상(Post-traumatic stress symptom, PTSS) 및 우울증상(Depressive symptom)과 같이 빈번하게 함께 발생하는 것으로 알려진 정신증상들의 동반이환(Comorbidity) 유병률을 가속화 시킬 수 있다. 이처럼, 지속되는 팬데믹은 외상 후 스트레스증상과 우울증상 사이의 장기적인 상호 작용을 야기할 수 있으며, 이는 이후의 동반이환 구조 및 패턴을 변화시킬 수 있다. 이러한 관점에서, 팬데믹 기간의 시간 흐름에 따른 외상 후 스트레스증상 및 우울증상의 동반이환 메커니즘을 이해하는 것은 일반인구의 정신 건강을 위한 개입점이 될 수 있다.

연구방법: 연구 대상자는 30세에서 64세로 구성되었으며, COVID-19 기간 동안 진행한 3차례에 걸친 심뇌혈관 및 대사질환 원인연구센터 온라인 정신건강 설문조사의 참여자가 연구에 포함되었다(1차: 1,925명, 2차: 1,754명, 3차: 1,595명). 외상 후 스트레스증상 및 우울증상은 각각 PCL-5 (Post-traumatic stress disorder Checklist for the DSM-5) 및 PHQ-9 (Patient Health Questionnaires-9)으로 측정되었다. 모든 분석은 Goldbricker 테스트를 통해 모든 증상 사이의 연관성 패턴 중복 정도를 테스트 후 네트워크분석(Network analysis)을 수행하였다. 네트워크분석을 통해 외상 후 스트레스증상 및 우울증상 동반이환의 증상 수준 메커니즘(Symptom-level mechanism)을 밝히고자 했으며, 분석은 1) 네트워크추정(Network estimation), 2) 네트워크추론(Network inference), 3) 네트워크 견고성평가(Network Robustness), 그리고 4) 시점 간 네트워크비교(Network comparison) 네 단계로 진행되었다. 네트워크분석을 통해 발견된 외상 후 스트레스증상 및 우울증상을 동시에 유지시키는 동반이환증상(Bridge symptom)은 잠재전이분석(Latent transition analysis, LTA)를 통해 시간에 따른 변화 패턴 및 영향을 고려했다. 잠재전이분석을 통해 팬데믹 기간에 따른 전이 정도와 이후 이의 외상 후 스트레스증상 및 우울증상에의 영향을 연령 및 성별로 계층화 하여 측정하였다.

연구결과: 외상후 스트레스증상 및 우울증상의 동반이환 네트워크(Comorbidity network)는 각 정신증상의 정의에 부합하는 두개의 분리된 증상 커뮤니티를

구성하였다. 팬데믹 전 시점에서 수면문제(Sleep problems and sleep disturbance)는 두개의 증상커뮤니티를 가장 강하게 연결하는 가교증상(Bridge symptom)으로 확인되었지만, 중심증상(Central symptom)은 시점에 따라 변화하는 패턴을 보였다. 동반이환 네트워크는 모든 시점에서 안정적이었지만, 판데믹의 아급성기(Subacute phase) 및 만성기(Chronic phase)의 네트워크 구조 자체는 서로 유의하게 상이하였다. 동반이환 네트워크 모델에 대한 확정 후, 가교증상인 수면문제에 대하여 잠재전이분석을 진행하였다. 수면문제는 PSQI (Pittsburgh Sleep Quality Index) 문항 중 수면장애(Sleep disturbance) 섹션 9개 문항으로 정의하였으며, 잠재계층분석(Latent Class Analysis, LCA)을 통해 기준상태(Reference), 수면 연속성문제가 있는 상태(Sleep continuity problems), 그리고 전반적인 수면문제가 있는 상태(Overall sleep problems)의 세가지 잠재상태로 분류되었다. 잠재전이분석을 적용하여 분석 한 결과, COVID-19이 아급성기에서 만성기로 변환할 때 기준상태 및 전반적인 수면문제가 있는 상태는 수면연속성문제가 있는 상태로 전이되는 패턴을 보였다. 이러한 수면 연속성문제로의 전이는 외상 후 스트레스증상 및 우울증상에 유의한 부정적인 연관성을 도출했으며, 특히 이러한 경향은 여성 및 50-60대에서 두드러졌다. 아울러, 수면 연속성 문제 상태는 팬데믹 이후의 외상 후 스트레스증상 및 우울증상 모두에 부정적인 영향을 끼칠 가능성을 보였다.

결론: 본 연구는 팬데믹이 장기화됨에 따라 변화하는 외상 후 스트레스증상 및 우울증상의 동반이환 메커니즘의 변화하는 패턴을 발견하였으며, 두 정신증상의 동반이환 가교증상은 수면문제였다. 또한, 팬데믹 상황이 아급성기에서 만성기로 전환되는 동안 수면문제 상태들의 수면 연속성문제로의 전이가 두드러졌으며, 이러한 전이는 이후 외상 후 스트레스증상 및 우울증상에 부정적인 연관성을 보였다. 이러한 결과를 공중보건(Public health)의 관점에서 적용한다면, 향후 COVID-19과 유사한 감염성 전염병(Next pandemic)이 발생하였을 경우 일반인구를 대상으로 수면장애가 있는 인구를 신속하게 선별하고 그 잠재적인 수면상태까지 고려하는 것이 일반인구의 정신건강에 도움을 줄 수 있는 개입점이 될 수 있으며, 이는 특히 팬데믹의 아급성기에서 만성기로의 변화 시점에 초점을 맞추어 진행되어야 한다.

키워드: 네트워크분석 (Network analysis), 잠재전이분석 (Latent transition analysis), 외상 후 스트레스증상, 우울증상, 수면장애증상, COVID-19