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Research paper

Associations between depressive symptoms and quality of life among residents of Wuhan, China during the later stage of the COVID-19 pandemic: A network analysis

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ARTICLE INFO

Keywords:
Depression
Quality of life
Later stage of COVID-19
Network analysis

ABSTRACT

Background: Various populations have experienced significant increases in depression and decreased quality of life (QOL) during the coronavirus disease 2019 (COVID-19) pandemic. This network analysis study was designed to elucidate interconnections between particular depressive symptoms and different aspects of QOL and identify the most clinically important symptoms in this network among adults in Wuhan China, the initial epicenter of the COVID-19 pandemic.

Methods: This cross-sectional, convenience-sampling study (N = 2459) was conducted between May 25 to June 18, 2020, after the lockdown policy had been lifted in Wuhan. Depressive symptoms and QOL were measured with the Patient Health Questionnaire-9 (PHQ-9) and first two items of the World Health Organization Quality of Life Questionnaire - brief version (WHOQOL-BREF), respectively. A network structure was constructed from the extended Bayesian Information Criterion (EBIC) model. Network centrality strength and bridge strength were evaluated along with the stability of the derived network model.

Results: Loss of energy (DEP-4) and Guilt feelings (DEP-6) were the two central symptoms with the highest strength as well as the two most prominent bridge symptoms connecting the clusters of depression and quality of life (QOL) in tandem with the two nodes from the QOL cluster. Network structure and bridge strengths remained stable after randomly dropping 75% of the sample.

Conclusion: Interventions targeting “Loss of energy” and “Guilt feelings” should be evaluated as strategies for reducing depressive symptoms and promoting improved QOL in COVID-19-affected populations.

Abbreviations: COVID-19, coronavirus disease 2019.
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https://doi.org/10.1016/j.jad.2022.08.104
Received 21 December 2021; Received in revised form 23 March 2022; Accepted 26 August 2022
Available online 2 September 2022
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1. Introduction

Coronavirus disease 2019 (COVID-19) was first reported in Wuhan, Hubei province of China at the end of 2019, and was subsequently found in other parts of the world (World Health Organization, 2020a, 2020b). Due to its fast transmission rate, the World Health Organization (WHO) declared the COVID-19 outbreak to be a pandemic on March 11, 2020 (World Health Organization, 2020c). Notwithstanding its impact on health and mortality rates, the COVID-19 pandemic has also had pronounced effects on mental health status and quality of life (QOL) (Gu et al., 2021; Kilincel et al., 2021; Pan et al., 2022). For example, various subpopulations including COVID-19 survivors, healthcare professionals and ordinary residents have experienced significant increases in depressive symptoms (Brooks et al., 2020; Canet-Juric et al., 2020; Hu et al., 2020; Li et al., 2021; Zhao et al., 2021) and decreases in QOL (Genta et al., 2021; Lizana et al., 2021; Moser et al., 2020) as a result of the pandemic.

Previous studies have suggested that the relationship between depression and poor QOL is reciprocal and bi-directional, across pandemic (Ferreira et al., 2021; Ma et al., 2020) and non-pandemic eras (Abbey and Andrews, 1985; Chan et al., 2006). Furthermore, individuals who do not meet all diagnostic criteria for major depressive disorder (MDD) but who endorse select severe depressive symptoms also report lowered QOL (Bertha and Balazs, 2013) as well as other adverse consequences, including increased impairment with daily activities (Geiselman and Bauer, 2000) and risk for suicidal behaviors (Balazs et al., 2013; Hegerl, 2016). The severity and impact of depressive symptoms may be magnified as a result of a pandemic. For example, previous research indicated negative effects of severe acute respiratory syndrome (SARS) on mental health status persisted for over one year (Lee et al., 2007; Mak et al., 2009; Maunder et al., 2006). These data underscore how associations between mental health concerns and QOL may become more deeply entrenched in the context of pandemics. Consequently, understanding interactions between depressive symptoms (“depression” hereafter) and QOL during the COVID-19 pandemic may provide foundations for targeted interventions that alleviate depression and its negative impact on functioning.

To date, traditional models of psychopathology have conceptualized depression and other psychiatric syndromes on the basis of latent models wherein individual clinical symptoms (i.e., observable indicators) are equally-weighted manifestations of latent variables (i.e., unobservable factors) (Epskamp and Fried, 2018; Schmittmann et al., 2013). Relatively, a key premise of traditional approaches is that the severity of syndromes such as depression is best measured as the sum of individual symptoms endorsed on interview or questionnaire measures (Eaton, 2015; Epskamp and Fried, 2018). Unfortunately, such approaches may obscure meaningful associations between individual symptoms of a syndrome that may vary in strength with one another and with other indicators of functioning such as QOL (Fried and Nesse, 2014).

Network analysis is an alternative approach designed to elucidate syndromes, comorbidity, and associations with correlates at the level of individual symptoms or attributes (Borsboom and Cramer, 2013). For example, network analysis can provide a visual depiction of how depressive symptoms and different aspects of QOL are interconnected as well as specific symptoms that are more central or clinically important within the overall symptom network (Borsboom, 2017; Borsboom and Cramer, 2012; Cramer et al., 2016; Cramer et al., 2010). The network approach has been applied recently to explore patterns of psychiatric symptom interactions during the COVID-19 pandemic. For example, two previous network analysis studies investigated core post-traumatic stress symptoms (PTSS) in a region most widely affected by COVID-19 (Jiang et al., 2020; Sun et al., 2021). In other research, Wang et al. (Wang et al., 2020) explored changes in relations between depressive and anxiety symptoms during different phases of the COVID-19 pandemic. This study was designed to extend recent network analysis research by attempting to identify depressive symptoms having the strongest influence in relation to QOL in a sample living at the initial epicenter of Wuhan China shortly after the initial lockdown policy had been lifted on April 8, 2020 (i.e., the later stage of the COVID-19 pandemic) (China Daily Global, 2020). In addition, we examined the impact of select subgroup influences (i.e., gender, age group, residence, status as a close contact of someone infected by COVID-19) on the structure and strength of relations between depressive symptoms and QOL facets in observed network models.

2. Methods

2.1. Study setting and participants

This cross-sectional study was conducted in Wuhan, China between May 25, 2020 and June 18, 2020, after the lockdown policy has been lifted (Xinhua Net, 2020b), based on convenience sampling. The questionnaire was designed using the Questionnaire Star application, and a Quick Response (QR) code linked to the invitation and assessment form was generated and distributed via WeChat, which is the most popular social network application in China with around 1.2 billion active users monthly (China Academy of Information and Communications Technology (CAICT), 2020). To be eligible, participants were required to meet the following selection criteria: 1) aged 18 years or older; 2) able to read Chinese and understand the purpose and contents of the assessments; 3) not infected with COVID-19 during the pandemic; 4) provided online electronic informed consent. Otherwise, there were no exclusion criteria in this study. The study protocol was approved by the ethics committee of Beijing Anding Hospital, Capital Medical University.

2.2. Assessment tools

Severity of depressive symptoms in the past two weeks was assessed using the Chinese version of the Patient Health Questionnaire – 9 (PHQ-9), which consists of 9 depressive symptom items, each scored from 0 (not at all) to 3 (almost every day) (Spitzer et al., 1999). Higher PHQ-9 scores represent more severe depression (Chen et al., 2015). Participants reporting a PHQ-9 total score of 5 or above were considered as having clinically relevant depressive symptoms (depression hereafter) (Chen et al., 2015). Psychometric properties of PHQ-9 Chinese version have been validated in Chinese populations (Wang et al., 2014; Xu et al., 2007). QOL in the past two weeks was assessed with the first two items of the World Health Organization Quality of Life Questionnaire - brief version (WHOQOL-BREF). For these items, participants rated their global life quality and general health status from 1 (very dissatisfied) to 5 (very satisfied) with higher scores representing better QOL (Fang et al., 1999; The WHOQOL GROUP, 1998). The Chinese version of the WHOQOL has been validated in Chinese samples, with good psychometric properties (Fang et al., 1999). Finally, demographic information was sought about participants’ age, gender, residence (Wuhan versus other area), and status as a close contact, i.e., having family members, colleagues, close friends or neighbors who had been infected with COVID-19 (National Health Commission of the People’s Republic of China, 2020a).

2.3. Data analysis

All analyses were conducted using R version 4.0.3 (R Core Team, 2020). Because all scores for each parameter had skewed distributions, the network model in this study was constructed using the extended Bayesian Information Criterion (EBIC) graphical least absolute shrinkage and selection operator (gLASSO) with the non-paranormal transformation (Epskamp and Fried, 2018; Garabiles et al., 2019); thicker edges in the EBIC model indicated stronger relationships between nodes. Estimation and visualization of the network were conducted using the R package bootnet version 1.4.3 (Epskamp et al., 2018).
Network centrality indices of strength and bridge strength were evaluated using the R packages qgraph version 1.6.5 (Epskamp et al., 2012), bootnet version 1.4.3 (Epskamp et al., 2018) and networktools version 1.2.3 (Jones, 2020). Strength was defined as the sum of absolute weights of the edge connecting a certain node to all other nodes (Valente, 2012). Bridge strength was defined as the sum of absolute value of all edges between a node A and all nodes that were not in the same cluster as node A (Jones, 2020).

To assess the robustness of the network, network stability was examined via correlation stability coefficients (CS-C) using a case-dropping 1000-time bootstrap method (Chernick, 2011; Costenbader and Valente, 2003). A CS-C quantifies the maximum proportion of cases that can be dropped at random to retain, with 95% certainty, a correlation coefficient (r) of at least 0.7 between centralities of the original network and the subsample network (Epskamp et al., 2018). The CS-C is preferentially above 0.5, with a minimum requirement of 0.25 (Epskamp et al., 2018). This procedure was performed using R package bootnet version 1.4.3 (Epskamp et al., 2018). Network comparison tests (NCT) with Holm’s correction for multiple comparisons examined whether network characteristics differed within subgroups based on gender, age (two subgroups split by median age), residence, and status as a close contact, using R package NetworkComparisonTest version 2.2.1 (van Borkulo et al., 2022).

3. Results

3.1. Basic demographic characteristics

In total, 2614 adults were invited to participate in this study. Of these, 16 people did not provide informed consent and 139 others had been infected previously with COVID-19 and were, therefore, ineligible for inclusion in data analyses. The remaining participants (N = 2459) fulfilled all eligibility criteria. Of the included respondents, 1169 were close contacts (male ratio: 25.5%; ±10.1 years old) and 1290 were not close contacts (male ratio: 25.7%; ±11.4 years old). A majority of participants (1458/2459) resided in Wuhan, while others (n = 1001) resided in other cities of Hubei province or other provinces. Using a PHQ-9 score of 5 or above as cutoff value (Chen et al., 2015), 46.9% of the sample experienced depression (1153/2459; 95% CI: 44.9%–48.9%).

3.2. Network estimation and centrality measures

Means, standard deviations (SDs), node strengths, bridge strengths, predictability, skewness and kurtosis of all PHQ-9 and QOL items are presented in Table 1. Loss of energy (DEP-4) and Guilt feelings (DEP-6) were the two most prominent central symptoms with the highest strength values. The network of PHQ-9 symptoms and QOL items is displayed in Fig. 1. Together with the two nodes from the QOL cluster, Loss of energy (DEP-4) and Guilt feelings (DEP-6) were the strongest bridge symptoms connecting the cluster of depression and the cluster of QOL. The strengths and bridge strengths of all nodes are shown in Fig. 2. Between the two clusters, global QOL (QOL-1) was strongly associated with Guilt feelings (DEP-6) while General health status (QOL-2) was strongly interconnected with Loss of energy (DEP-4). The mean predictability of all symptoms indicated that an average of 39.29% of the variance in each node could be explained by the neighboring nodes. On average, 25.30% of the QOL variance could be explained by depressive symptoms. The weighted adjacency matrix of all items in this network is shown in Supplementary Table 1.

3.3. Network stability and accuracy

The case-dropping bootstrap procedure showed that values of centrality strength and bridge strength remained stable after dropping large proportions of the sample (Fig. 3). CS-Coefficients for strength and bridge strength were both 0.75, indicating that 75% of the sample could be dropped and the network would remain stable.

Bootstrapped 95% CIs for estimated edge weights were narrow, suggesting that the estimates were reliable (Supplementary Fig. 1). Pairwise edge weight and node strength differences are shown in Supplementary Figs. 2–3.

3.4. Comparison of networks based on subgroups

Comparisons of networks based on gender, younger versus older age groups (split by the median age), living area and status as a close contact are shown in Fig. 4. Network invariance tests, global strength invariance tests, and edge invariance tests revealed that the edge weights and global strength between subgroups based on gender, age group, living area and status as a close contact were similar. Node strengths based on these subgroups are shown in Supplementary Fig. 4 while results of network invariance tests and global strength invariance tests are shown in Supplementary Figs. 5–8. The exact p values in edge invariance tests for subgroups by gender, age, living area, and being a close contact are shown in Supplementary Table 2.

4. Discussion

To the best of our knowledge, this study was the first to explore interactions of depressive symptoms with QOL in a COVID-19 affected population. One somatic symptom Loss of energy (DEP-4) and one affective symptom Guilt feelings (DEP-6) emerged as the most central Depressive symptoms in tandem with the two QOL nodes. Loss of energy and Guilt were also the top two bridge symptoms connecting the depressive symptom cluster and the QOL cluster.

Because previous studies have not explored bridge symptoms between depression and QOL, direct comparisons with other studies could not be made. However, our results for depression are in line with Hartung et al. (2019) who recently observed Guilt feelings (DEP-6) and Loss

Table 1

| Items          | Mean | SD  | Strength | Bridge strength | Predictability | Skewness | Kurtosis |
|---------------|------|-----|----------|-----------------|----------------|----------|----------|
| DEP-1: anhedonia | 0.79 | 0.80 | 0.41     | −0.63           | 50.7%          | 0.93     | 0.56     |
| DEP-2: sad mood     | 0.62 | 0.70 | 0.93     | −0.42           | 49.4%          | 1.06     | 1.20     |
| DEP-3: sleep problems | 0.77 | 0.85 | −0.65    | −0.50           | 36.0%          | 0.98     | 0.37     |
| DEP-4: loss of energy       | 0.90 | 0.81 | 1.47     | 0.68            | 52.3%          | 0.81     | 0.40     |
| DEP-5: appetite change    | 0.57 | 0.79 | 0.03     | −0.69           | 41.6%          | 1.35     | 1.26     |
| DEP-6: guilt feelings     | 0.54 | 0.77 | 1.08     | 0.21            | 39.2%          | 1.44     | 1.59     |
| DEP-7: difficulty in concentration | 0.53 | 0.77 | 0.20     | −0.92           | 39.1%          | 1.47     | 1.64     |
| DEP-8: psychomotor signs   | 0.34 | 0.64 | 0.37     | −0.44           | 37.2%          | 2.11     | 4.44     |
| DEP-9: suicidal ideation    | 0.13 | 0.42 | −1.56    | −0.80           | 36.1%          | 4.08     | 19.40    |
| QOL-1: global QOL         | 3.20 | 0.73 | −0.94    | 2.17            | 26.5%          | −0.43    | 0.08     |
| QOL-2: general health status | 3.30 | 0.83 | −1.32    | 1.34            | 24.1%          | −0.33    | −0.42    |

SD: standard deviation. The values of strength and bridge strength were transformed into z-scores.

458
of energy (DEP-4) had the highest centrality completion strength in the depressive symptom community within the general population (Hartung et al., 2019). The mean predictability of QOL (25.3%) was lower than the average predictability of all nodes (39.3%). Hence, although the nine depressive symptoms combined to explain some variance in QOL, substantial variance was unexplained. This finding might be attributable...
to evidence that QOL can be influenced by many factors aside from depression including anxiety levels, socio-environmental support, and stressors (Chen et al., 2020; Liu et al., 2021; Lizana et al., 2021).

The central somatic symptom, Loss of energy (DEP-4), has the highest interconnection with General health status (QOL-2) in depression-QOL network model generated for Wuhan residents. Loss of energy, which refers to feelings of tiredness, fatigue and reduced energy (Billones et al., 2020), is a common symptom of depression (Angst and Dobler-Mikola, 1984; Buchwald and Rudick-Davis, 1993; Corfield et al., 2016; Pae et al., 2007; Reyes-Gibby et al., 2006), especially among people who tend to somatize their depressive symptoms (Stahl, 2002). The relationship between loss of energy and poor general health status has been supported in several respects. First, fatigue or loss of energy is very common in people experiencing chronic physical illnesses (Swain, 2000; Winters et al., 2010) because chronic medical conditions may cause oxidative stress and excessive inflammatory responses that contribute to fatigue or loss of energy (Menting et al., 2018; Morris and Maes, 2014). Second, in relation to the COVID-19 pandemic, the manifestation of “Loss of energy” might be attributed, in part, to a less physically active lifestyle imposed by the lockdown experience (McIlvenny et al., 2000; Stewart et al., 1998) and lack of physical exercise might contribute to declines in general health status (Biddle et al., 2004; Booth et al., 2012; Buchner et al., 1992). It has been broadly verified that participating in exercise can elevate physical energy (Gebhart et al., 2011; Jakobsen et al., 2017; Witard et al., 2016) and improve QOL (Courtney and Friedenreich, 1999; Dauwan et al., 2021; Mehnert et al., 2011; Pacheco et al., 2012).

A key implication of this finding is that interventions designed to address Loss of energy (DEP-4), whether via lifestyle changes or physical exercise, may be useful in improving QOL facets related to perceptions of one’s general health status. Policymakers who wish to promote infection control measures and quarantine policies should also attend to developing creative strategies to promoting physical activity and dynamic lifestyles as means of protecting the mental health status and QOL of general populations living in pandemic conditions.

The central affective symptom, Guilt feelings (DEP-6), was strongly associated with Global QOL (QOL-1) and had the second highest strength in the network model. Guilt is defined as an aversive conscious emotion that involves self-criticism, remorse for one’s thoughts, feelings or actions and a sense of wrongdoing, as if one has violated a moral principle or caused harm to others (Berrios et al., 1992; Tangney and Dearing, 2003). In some cases, guilt can be adaptive because it prompts proactive actions such as confessing, apologizing, or improving interpersonal relationships to remedy distress (Cavalera, 2020; Tangney, 1995). However, guilt can also be maladaptive when it becomes excessive and overwhelming (Căndera and Szentagotai-Tatar, 2018). During the COVID-19 pandemic, sources of guilt feelings may vary between populations. Confirmed cases might experience guilt for being infected or transmitting the virus to family or friends (Aliakbari Dehkordi et al., 2020; Yuan et al., 2021b). Healthcare workers can experience guilt because of medical resource shortages or rationing that interferes with optimal care and increases the likelihood that there will be more victims (Chan and Huak, 2004; Chong et al., 2004; Yuan et al., 2021a). Excessive guilt could result in problematic outcomes such as impaired motivation and maladaptive behaviors that perpetuate depression and reduced QOL (Luck and Luck-Sikorski, 2020; Tilghman-Osborne et al., 2010, 2012). The emergence of guilt as a bridge symptom to QOL in this research aligns with previous studies of other stressors linking lower levels of guilt with higher QOL in various populations including women in menopause (Zivdir and Sohbet, 2017) and male spouses of women with breast cancer (Duggleby et al., 2014; Duggleby et al., 2015).

The centrality of guilt in this research suggests that interventions targeting these feelings may have utility in reducing depression and facilitating mental health during the COVID-19-pandemic. Several post-pandemic psychological recovery interventions emphasize efforts to reduce feelings of guilt in the prevention of adverse psychological functioning in the COVID-19 pandemic (Dodgen-Magee, 2021; Foster, 2021; Minihan et al., 2020). For example, cognitive-behavioral interventions targeting maladaptive thoughts that contribute to feelings of guilt may be useful in reducing depression and associated impairments in functioning, facilitating recovery and improving QOL among people living through the COVID-19 pandemic.
Fig. 4. Network model for depressive symptoms and QOL based on subgroups by gender, age, living area, and whether being a close contact.

Figure legend: DEP-1: anhedonia; DEP-2: sad mood; DEP-3: sleep problems; DEP-4: loss of energy; DEP-5: appetite change; DEP-6: guilt feelings; DEP-7: difficulty in concentration; DEP-8: psychomotor signs; DEP-9: suicidal ideation; QOL-1: global QOL; QOL-2: general health status.

Young participants were defined as aged 34 years old or below, and elder participants were defined as aged 35 years old or above by age-median-split method.
Other analyses indicated that depressive symptom-QOL network structures were similar between close-contacts and non-close-contacts, as well as between participants living in the initial epicenter (Wuhan) versus other areas. Similarities in network structures between these subgroups may be due, in part, to enhanced control of the virus during data collection. That is, this study was conducted after the lockdown policy in Wuhan was lifted on April 8, 2020, and there had been no new cases reported for 19 days (China Daily Global, 2020; DX Doctor, 2021). As such, the data collection period occurred after the most urgent and intensive phase of COVID-19 had passed and life in Wuhan was returning to normal for various subgroups (Xinhua Net, 2020a, 2020b).

Second, health administrative agencies in China had released considerable health education information and resources for mental health and counseling support to the general public in early stages of the pandemic (Li et al., 2020; National Health Commission of the People’s Republic of China, 2020b). Such efforts may have ensured that more widespread segments of the population had accurate knowledge about COVID-19 and strategies to reduce personal risk. A possible consequence of far-reaching public health education may have been increased similarity in the nature of links between depressive symptoms and QOL among groups at risk for COVID-19-related distress such as close contacts and those living near the epicenter compared to groups with lower overall risk.

Strengths of this study included its relatively large sample size, use of network analysis to elucidate depression-QOL relations at a symptom level, and the assessment of a group living at the initial epicenter of the COVID-19 outbreak. Regarding limitations, due to the cross-sectional study design, causal relationships and dynamic changes between depression symptoms and QOL experiences could not be examined. Second, because the assessment was limited to a sample in the Wuhan region, it is not clear whether the depressive symptom-QOL network documented in this research is applicable to different subpopulations in other regions (Marchetti, 2018; Mullarkey et al., 2019). Third, the network structure in this study was limited to the 9 canonical symptoms of depression and 2 brief items about QOL. Hence, including other depressive symptoms and facets of QOL or other forms of distress (e.g., anxiety and insomnia) in the assessment might produce different patterns of relation between depressive symptoms and QOL. Finally, because a random sampling method was not used in this study, the representativeness of the study sample for the population of Wuhan is not known.

In conclusion, Loss of energy and Guilt emerged as critical central symptoms and bridge symptoms in a network model of depression and QOL examined among residents of Wuhan during the COVID-19 pandemic. Public health education, physical activity and psychological interventions targeting these central symptoms, including cognitive behavioral therapy (CBT) and regular physical exercise, have promise as approaches to improving the mental health status and QOL of COVID-19-affected populations including those living in Wuhan.

Sources of funding

The study was supported by the National Science and Technology Major Project for investigational new drug (2018ZX09201-014), the Beijing Municipal Science & Technology Commission (No. Z181100001518005), the University of Macau (MYRG2019-00066-FHS), and the Fundamental Research Funds for the Central Universities (2020JY065).

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Conflict of interest

The authors have no conflicts of interest to declare.

Acknowledgements

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2022.08.104.

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