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Depression and Sleep Quality: A Network Analysis

Kathy Chen

Agnes Irwin High School, Rosemont, Pennsylvania, USA
kachen@agnesirwin.org

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Abstract: Multiple studies have supported the bi-directional relationship between sleep and depression. However, by adopting the latent constructs of depression and sleep quality, previous studies failed to map relationships among individual symptoms. To address the limitation, this study applied network analysis to investigate the relationships among individual nodes of sleep quality and depression. In specific, this study identified the most central node and bridges across these two conditions. Gaussian graphical models (GGM) of depression symptoms and aspects of sleep quality were calculated using the R package qgraph. By using the bridge functions in the networktools, this study found little relationship among individual items of sleep quality and depression. Moreover, sleep quality nodes served as the main bridges between sleep and depression. The network approach offered insights regarding the link between sleep and depression, which provided a more nuanced understanding of how depression and sleep quality are related.

1. Introduction

Major Depressive Disorder, or MDD, is a prevalent, debilitating, and chronic condition that usually involves sadness, sleep disturbance, fatigue, and worthlessness according to the Diagnostic and Statistical Manual of Mental Disorder-Fifth Edition[1]. As one of the symptoms, sleep disturbance is prevalent among depressed patients, and there is a relatively robust relation between the two. More than 90% of the depressed patients complain about sleep impairments; In contrast, 25% of the patients who complain about chronic insomnia suffered from depression[2-3]. Thus, insomnia and depression are likely to have a bi-directional relationship.

1.1. Sleep and Depression

Multiple studies have been conducted on the link between depression and sleep. Several epidemiological studies identified insomnia as an essential risk factor for subsequent development of depressive episodes[4-6]. As a result of their fruitless efforts combating insomnia, patients with sleep problems may experience helplessness and despair, which is considered to be a valid model to induce depression. Hence, the conclusion that adequate early treatment for sleep disorders might create opportunities for the prevention of psychiatric disorders was concluded by Ford and Kamerow[7] and others[8-9]. Several critical methodological issues have been mentioned to outline the limitations and problems of polysomnographic research in psychiatry, especially in depression. Changes of sleep relating to age in healthy humans are well documented[10-11], including the increasing number of nocturnal awakenings and decreasing number in slow-wave sleep. The changes in elderly are

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comparable to typical features of sleep in adult depression. Early morning awakening and a shortening of Rapid Eye Movement (REM) latency occur in some elderly healthy participants as well. Moreover, sleep disability and difficulty may impair cognitive control, thereby increasing the risk for depression[12].

Although researchers identified the different aspects of sleep difficulties, for instance, patients suffer from frequent nocturnal awakenings, difficulties falling asleep, and early morning awakening, the relationship between the individual symptoms of MDD such as sadness, anhedonia, and fatigue and the different aspects of sleep quality is an essential yet unexamined question.

1.2. Network Approach to Psychopathology

Psychiatric disorders are highly and often comorbid, making it difficult to conduct differential diagnosis. In addition, according to DSM-5 (2013), one only needs to meet a few criteria to be diagnosed with a disorder[1]. This results in various ways in which one may experience a specific disorder. For example, there are 636,120 ways to have Posttraumatic Stress Disorder (PTSD)[13]. And for depression, there are up to 1,030 unique symptom profiles[14]. As a result, it is extremely important to identify the mutually interacting entities between Sleep and Depression. Network analysis is being developed at the crossroads of science fields[15], which provides a way of to think about disorders that does justice to their complex organizations. It is a set of powerful empirical research methods, offering a novel flexible, data-driven methodology to help with understanding of the relationship between each entitle of sleep and depression. By using network analysis, disorders are conceptualized as systems of randomly connected symptoms, which can be represented, analyzed, and studied in their all-inclusive complexity[16].

In a Latent Variable Model, observables or clinical symptoms are interpreted using a small set of latent variables, just like disorders explain symptoms[16]. However, while the Latent Variable Model interprets symptoms as measurements and latent variables determine a set of symptoms, Network analysis conceptualizes symptoms as mutually interacting and views symptoms as a part of the causal system[17]. Using network analysis, it is plausible to map relations between individual symptoms and identify the most core factors, and it also provides visual clarification of psychiatric comorbidities, which shows specific symptoms that bridge across different disorders[17-19].

A number of empirical studies have underscored the promise of network approach to understand the comorbidity among different psychiatric disorders. For instance, a study was conducted using Network Analysis to map the relationship between symptoms of the persistent complex bereavement disorder (PCBD) and common comorbid conditions beyond depression[20]. They discovered that the majority of depression symptoms clustered independently of PCBD, with the only exceptions, suicidality and worthlessness in their MDD comorbidity. In addition to MDD comorbidity, symptoms formed communities without clear boundaries between two diagnoses. Another study was made to investigate the relationship among the symptoms of Obsessive-compulsive disorder (OCD) and depression using network analysis[21]. The result shows that the degree of interference and distress associated with obsessions, and the degree of interference associated with compulsions are the main cause of cor-morbidity.

1.3. The Current Investigation

Even though a generous amount of study has been conducted using Network analysis to determine the correlation between certain psychological disorders and its comorbid condition.

Yet hardly any studies have been conducted on the correlation between individual entities between depression and sleep. The aim of this study is to investigate the link between individual symptoms of depression and different aspects of sleep quality using network analysis.

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1.4. Hypothesis

If it is likely for depression and sleep to have a bi-directional relationship and insomnia is a prominent risk factor for subsequent developments of depressive episodes, the boundary in the network of each depressive symptoms and sleep quality may be unclear. In other words, the nodes of depression and sleep will form one coherent community. By forming one community, sleep quality and depression symptoms are closely related in the network, making similar quantities of sleep and depression items as bridges. Given the great variability in sleep latency, efficiency, and time and that they do not necessarily cause significant dysfunctions, this study hypothesized that subjective sleep quality and dysfunctions both during the day and at nights would serve as the bridges between sleep and depression. Considering the high possibility of crying being the cause of day or night dysfunctions, and its robust connection with other depression symptoms such as feeling depressed and sad, we anticipated I had crying spells (CESD 17) to act as the bridge between sleep and depression. In addition, patients with day dysfunction are likely to have symptoms such as losing appetite or having trouble focusing on what they are doing. Thus, on the whole, this study suppose that sleep quality, day dysfunction, night dysfunction, I had crying spells (CESD 17), I did not feel like eating; my appetite was poor (CESD 2), and I felt I had trouble keeping my mind on what I was doing (CESD 5) were items that mostly likely acts as bridges between sleep and depression. In addition, nodes that were not bridges could still confer impact on other nodes given the strong relationship among items within one entire community.

2. Methods

2.1. Participants and Data

A total of 4,981 Chinese adults, working in a nationwide company that demands intense work labor and rotates their employers to take night shifts, participated in the study prior providing informed consent. The sample is predominantly male (1,293 female, 3,688 male) and relatively young (M = 32.43, SD = 9.08). They completed a wide range of questionnaires that measured their occupational satisfaction, physical health, sleep, and psychological well-being. The study used measures of depression and sleep quality. Other measures were thus not reported here.

2.2. Measures

Depression was assessed with the 20-item Center for Epidemiologic Studies Depression Scale (CESD) [22]. For each item (e.g., I felt depressed), participants rated on a four-point scale for 0 (Rarely or none of the time) to 3 (Most or all of the time). Item 11(My sleep is restless) is excluded from this analysis to avoid confusion between the symptoms of depression and aspects of sleep quality.

Sleep Quality was assessed with the Pittsburgh Sleep Quality Index (PSQI), which consisted of 19 items, creating 7 components that produce one global score[23-24]. For each item in components , participants rated on a four-point scale, 0 (very good) to 3 (very bad).

2.3. Data Analytic Plan

R is used to estimate a series of networks, which are graphical models consisting of nodes and edges. In analysis, nodes represent individual symptoms, and edges represent relationships between the two nodes after conditioning on all other nodes. And thicker edges represent stronger associations between the symptoms in graphical models.

Gaussian graphical models (GGM)[25-26] of depression symptoms and sleep quality aspects were calculated by the R package qgraph[27]. GGM are undirected networks in which edges represent

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partial correlation coefficients. The estimation combines the application of graphical LASSO penalties[28] and model selection based on extended Bayesian information criterion (EBIC)[29], causing small edges to shrink and remove false connections between the nodes based on the indirect relationship with a third node. Thus, it results in more parsimonious networks[30-31].

Since the approach relies heavily on the visual inspection of networks for identification of bridges, it is untenable for large, complex networks. Thus, four statistics of the bridge—strength, betweenness, closeness, and expected influence— are implemented in R package networktools to identify nodes high on bridge centrality[32]. For statistics, communities, a network consisting of multiple predefined disorders, is considered. Besides, a highly simplified network consisting of two communities, depression and sleep quality, is considered to illustrate each statistic[33].

3. Results

Mean and standard deviation of each depressive symptom and sleep quality item are presented in Table 1. The most prevalent depression symptoms were item 13 (I talked less than usual) and item 6 (I felt depressed); most prevalent sleep quality deficits were day dysfunction and sleep quality. The least prevalent depression symptom was item 17 (I had crying spells), and for sleep quality, the least prevalent was sleep efficiency.

By using the bridge functions in the networktools, this study was able to analyze how depression and sleep quality were related and which depression symptoms and sleep quality items may serve as bridges between the two. Likely bridges were colored and presented in a network graph (Figure 1).

Bridge centralities of each node were then visualized and presented in the order of their relative importance. Four statistics of bridge centrality- Strength, Expected Influence, Closeness, Betweenness- were presented in Figure 2. Day dysfunction, night dysfunction, and sleep quality have the strongest bridge strength and bridge expected influence (2-step) among all the nodes. In addition, sleep quality, day dysfunction, and I felt sad (CESD 18) had the strongest bridge betweenness; I felt sad (CESD 18), I had crying spells (CESD 17), and day dysfunction had the strongest bridge closeness.

The primary observation was that there was little relationship between sleep and depression if we were to exclude My sleep was restless (CESD 11). According to Figure 1, there was a profound distance between the symptoms of depression and sleep quality. The symptoms were mostly connected and compressed together with their own community. In fact, if My sleep was restless (CESD 11) was included in the network, it would become the only bridge between sleep and depression. Thus, the relationships observed between depression and sleep in existing literature were mainly driven by the fact that depression includes a symptom (i.e., insomnia or hypersomnia) that is highly related to sleep quality.

Table 1: Descriptive Statistics of Depression and Sleep Quality.

Depression		*M* (*SD*)	Sleep Quality	*M* (*SD*)
CESD1	Bothered by trivial things	1.73 (0.80)	Sleep Time	1.26 (0.87)
CESD2	Loss of appetite	1.64 (0.80)	Day Dysfunction	1.75 (0.94)
CESD3	Could not shake off the blues	1.67 (0.84)	Night Dysfunction	1.24 (0.69)
CESD4R	As good as other people	2.87 (0.98)	Sleep Latency	1.13 (0.60)
CESD5	Hard to concentrate	1.61 (0.78)	Sleep Efficiency	0.47 (0.79)

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CESD6	Felt depressed	1.81 (0.92)	Sleep Quality	1.47 (0.81)
CESD7	Everything was an effort	1.58 (0.79)		
CESD8R	Hopeful about the future	2.54 (1.08)		
CESD9	Life had been a failure	1.50 (0.78)		
CESD10	Felt fearful	1.47 (0.76)		
CESD11	Sleep was restless	2.00 (1.02)		
CESD12R	Felt Happy	2.67 (1.09)		
CESD13	Talked less than usual	1.90 (0.93)		
CESD14	Felt Lonely	1.82 (0.96)		
CESD15	People were unfriendly	1.38 (0.68)		
CESD16R	Enjoyed life	2.56 (1.06)		
CESD17	Crying spells	1.28 (0.63)		
CESD18	Felt sad	1.64 (0.84)		
CESD19	Disliked by people	1.35 (0.66)		
CESD20	Could not get going	1.49 (0.79)		

However, connections between sleep quality and depression were still noticeable. The orange colored nodes indicated that the symptoms are bridges between sleep qualities and depression. From Figure 1, we learnt that night dysfunction, day dysfunction, sleep quality, sleep efficiency, sleep latency, and I had crying spells (CESD 17) were all indices that act as bridges between sleep quality and depression. More items of sleep quality than depressive symptoms served as the bridge, suggesting that almost no depressive symptom is universally related to various indices of sleep quality. Even though only one item of depression was acting as a bridge, nodes that were not bridges could still confer impact on nodes of the other community given the strong relationship among items within the respective community of sleep quality and depression. For instance, from figure 1, we observed that even though sleep time was not acting like a bridge in the network, it had a pronounced impact on all the other items in sleep which acted as bridges. Thus, sleep time was a key factor in determining all the other items in sleep which indirectly influenced items of depression. Another example was I felt that people dislike me (CESD 19), which was not acting as bridges between sleep quality and depression symptoms. Despite its direct connection with night dysfunction, it had a strong correlation with I had crying spells (CESD 17) acting as a bridge that linked with sleep latency, sleep quality, and day dysfunction.

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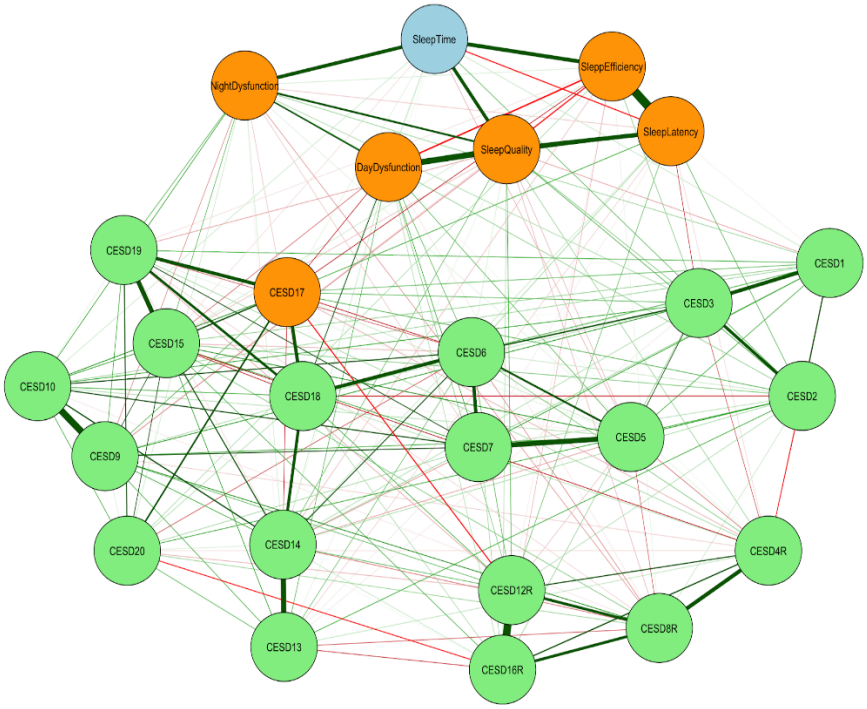

Figure 1: Gaussian Graphical Model (GGM) Networks with Spring Layout of Depressive Symptoms and Sleep Qualities.

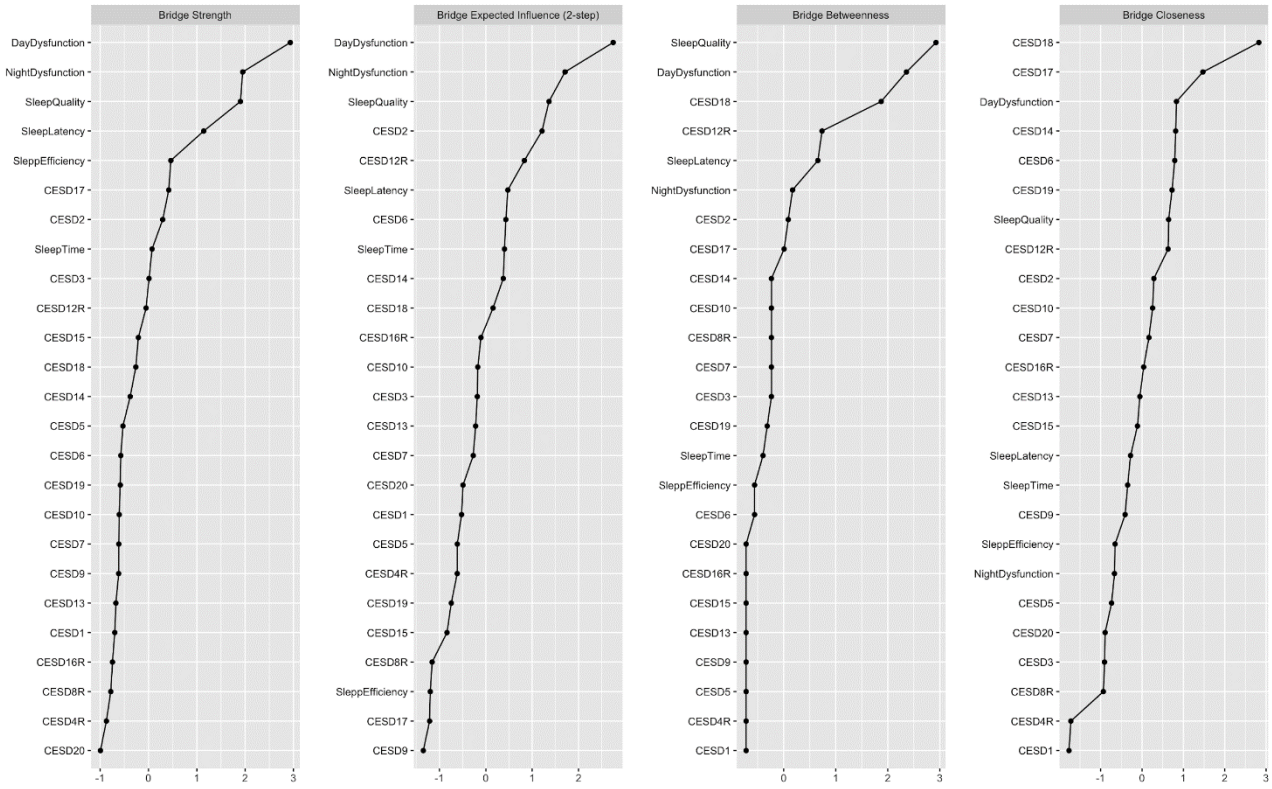

Figure 2: Bridge Strength, Expected Influences (2-step), Betweenness, and Closeness Centrality for Symptoms of Depression and Sleep Quality.

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4. Discussion

From the results, the current study failed to identify pronounced links between depression symptoms and individual sleep quality indexes. Contrary to our hypothesis and what was observed in previous literature, there was a clear boundary between depression and sleep quality, as evidenced by visible distance between the two communities in the network graph as well as the bridge centrality indices. Besides, we noticed two distinct areas with nodes being connected and compressed mostly in its own community. What is also conflicting with our hypothesis was that only sleep qualities mainly acted as the bridge between sleep and depression. Based on Figure 1, all sleep items except sleep time acted as bridges, and only I had crying spells (CESD 17) in depression acted as a bridge. This observation contradicted with what we supposed which more symptoms of depression such as I felt that people disliked me (CESD 19), I felt depressed (CESD 6) will act as bridges.

Within the sleep quality and depression symptoms' community, none of the sleep quality items was closely linked to depression. This result was surprising and contradictory with previous findings, and part of the reasons might be overlapping items in depression that inflated within-community connection and underestimated between-community connection. In addition, without My sleep was restless (CESD 11), there was little relation between depression symptoms and sleep quality. When evaluating the relationship between the two including My sleep was restless (CESD 11), the correlation became stronger. Thus, My sleep was restless (CESD 11) inflated the relationship between sleep quality and depression. In fact, according to other network analyses studies on depression, sleep problem was usually the relatively marginal node in the network[34].

When we examined the network, though there were clear boundaries and distinct communities of sleep and depression emerged, some connections of the nodes within their communities were similar to the connections across the communities. For instance, we noted in the community of depression symptoms, the area made up by item 10 (I felt fearful), item 17 (I had crying spells), and item 19 (I felt that people disliked me) had limited relationships with nodes such as item 1 (I was bothered by things that usually don't bother me) and item 3 (I felt that I could not shake off the blues even with help from my family or friends). Their relationships were even weaker than the correlation between the area made up by I felt fearful (CESD 10), I had crying spells (CESD 17), I felt that people disliked me (CESD 19) and Day Dysfunction and Night Dysfunction. Accordingly, the correlation between sleep and depression was still considerable, even though it was not as strong as we supposed. Since night dysfunction and day dysfunction were inextricably linked with depression symptoms, it might be the incentive of depression. So, the prevention of day dysfunction and night dysfunction might be an effective way to prevent depression.

The advance of our findings should be understood taking into account a number of limitations. Firstly, as mentioned earlier, the overlapping items in CESD will overestimate the relationship among nodes within the community. For example, item 6 (I felt depressed), item 8 (I felt sad), and item 17 (I had crying spells) are indices that almost express the similar meaning of sadness. Besides that, item 19 (I felt that people dislike me) and item 15 (People were unfriendly) also overlapped in that perception of unfriendliness often co-occur with feeling disliked in social interaction. This will create robust links between them which inflated within-community connections, and possible relationship between sleep qualities and depression symptoms might be pulled away because of the strong links between overlapping items causing the underestimation of the between-community connection. For further studies, the use of diagnostic interviews of depression and sleep quality will assess the relationship between individual nodes of depression and sleep more accurately. In addition, participants may be overwhelmed by the number of questions included in the study, which may raise concerns about non-compliance among respondents, resulting in inaccurate responses as compared with diagnostic interviews. However, to achieve the goal of the study, our questionnaire secures a

large sample size, which is essential for network modeling. For future studies to acquire more accurate results, large amounts of time, workforce, and material resources are needed to achieve large sample sizes of diagnostic interviews.

5. Conclusion

In this work, we observed a clear boundary between depression and sleep quality, as evidenced by the two distinct areas with nodes being connected and compressed mostly within their respective community. Reasons and limitations for this study include overlapping items in depression that may inflate within-community relationships. As a whole, the network approach offered insights regarding how sleep quality and depression are related and provided critical suggestions to advance future studies.

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