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A Bayesian network analysis of sleep quality, anxiety, and depression symptoms in Peruvian Adults

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A B S T R A C T

It has been suggested that individuals with sleep disorders tend to experience concurrent mental health disorders, such as anxiety and depression. Therefore, this study aimed to address this gap by utilizing Bayesian network analysis to explore the potential causal relationships between sleep quality, anxiety, and depressive symptoms in a sample of 451 Peruvian adults. The network structures for sleep quality, depression, and anxiety were estimated using the Jenkins Sleep Scale, Patient Health Questionnaire-2, and General Anxiety Disorder-2, respectively. The causal relationships between symptoms were estimated using Bayesian networks from a directed acyclic graph (DAG) model. Nighttime Awakenings and Anhedonia play significant and distinct roles in the symptom network dynamics. Nighttime Awakenings showed directional probabilities of four symptoms: Nervousness, Difficulty Falling, Stay Asleep, and Depressed Mood. Anhedonia also showed directional probabilities toward three symptoms: Tiredness on Awakening, Uncontrollable Worry, and Depressed Mood. Meanwhile, although Nervousness does not have outgoing arrows to other symptoms, it shows conditional dependence with Uncontrollable Worry, Depressed Mood, and Nighttime Awakenings. The findings suggest adopting a comprehensive approach to the treatment of sleep disorders, anxiety, and depression, considering the interconnections among various symptoms and addressing not only the core symptoms but also those that function as mediators or bridges within the symptom network.

Análisis de red bayesiana de la calidad del sueño, ansiedad y depresión

Palabras clave:
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R E S U M E N

Se ha sugerido que las personas con trastornos del sueño tienden a sufrir trastornos mentales concurrentes como ansiedad y depresión. Por lo tanto, el presente estudio tuvo como objetivo llenar esta brecha aplicando el análisis de redes bayesianas para investigar posibles relaciones causales entre síntomas de calidad de sueño, ansiedad y depresión en una muestra de adultos peruanos. La estructura de la red de calidad de sueño, depresión y ansiedad se estimó utilizando la Jenkins Sleep Scale, la Patient Health Questionnaire-2 y la Ge-

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neral Anxiety Disorder-2 respectivamente. Las relaciones causales entre los síntomas se estimaron utilizando redes bayesinas a partir de un modelo directed acyclic graph (DAG). los Nighttime Awakenings y la Anhedonia desempeñan un rol importante y diferente en la dinámica de red de síntomas. Los Nighttime Awakenings mostró probabilidades direccionales hacia cuatro síntomas: Nervousness, Difficulty Falling, Stay Asleep and Depressed Mood. La Anhedonia también mostró probabilidades direccionales hacia tres síntomas: Tiredness on Awakening, Uncontrollable Worry y Depressed Mood. Por otro lado, si bien el Nervousness no presenta flechas salientes a otros síntomas, si evidencia dependencia condicional con la dependencia condicional la Uncontrollable Worry, Depressed Mood y Nighttime Awakenings. Los hallazgos sugieren adoptar un enfoque integral en el tratamiento de los trastornos del sueño, la ansiedad y la depresión, considerando las interconexiones entre los diferentes síntomas y abordando no solo los síntomas principales sino también aquellos que actúan como mediadores o puentes en la red de síntomas.

Introduction

It is estimated that a person spends about 27 years of their life sleeping (Ohayon, 2011). Therefore, sleep quality is an important clinical construct in sleep medicine, encompassing a set of events that disrupt sleep, such as total sleep time, time required to fall asleep, sleep maintenance, wake time, sleep efficiency, spontaneous awakening, and apnea (Krystal & Edinger, 2008). Poor sleep quality has been reported in nearly every country worldwide, and across various clinical patient groups (Ohayon, 2011). More than half of the adult population worldwide has experienced some form of sleep disturbance, with 15–20% reporting chronic sleep problems (Mollayeva et al., 2016). A systematic review and meta-analysis indicated that the pooled prevalence of poor sleep quality among working-age adults was 32.8% (95% CI: 25.9% - 39.7%) (Simonelli et al., 2018). However, it has been estimated that less than 20% of individuals with sleep problems are properly diagnosed and treated, a percentage that decreases to 10% for more specific issues, such as excessive sleepiness (Ohayon, 2011). The presence of variability, which cannot be explained by region, rurality, sex, age group, or sleep assessment method, and biases identified in various studies suggest that sleep prevalence estimates may be erroneous and should be interpreted with caution (Simonelli et al., 2018).

Sleep quality disturbances are among the most common health problems and are of significant importance to public health because of their negative impact on physical and mental health, reducing work performance, social interaction, and quality of life (El-Tantawy et al., 2014; Mollayeva et al., 2016). Poor sleep quality can be considered a significant symptom of other medical and sleep disorders (Fabbri et al., 2021). Studies in the general population have suggested that individuals reporting poor sleep quality tend to use health services more frequently (El-Tantawy et al., 2014), and have a higher risk of coronary disease (Khan et al., 2018; Lao et al., 2018) and death (Gao et al., 2022; Kwok et al., 2018; Pienaar et al., 2021). Additionally, poor sleep quality has been associated with a higher risk of overweight, obesity, and diabetes mellitus (Gao et al., 2022).

Moreover, various epidemiological studies have shown that individuals with sleep disorders tend to suffer from concurrent mental disorders such as anxiety and depression (Dinis & Bragança, 2018; Okun et al., 2018; Scott et al., 2021). It has been reported that individuals with symptoms of poor sleep quality, such as insomnia (problems initiating sleep, waking frequently, waking earlier than desired, and difficulty returning to sleep), are 10–17 times more likely to experience clinically significant levels of depression and anxiety symptoms (Baglioni et al., 2011; Taylor et al., 2005). Many mental health problems do not occur in isolation, but are part of dynamic, interconnected, and complex systems (Fried et al., 2017). However, the nature of the relationship between sleep quality, anxiety, and depression symptoms is not clearly understood (Scott et al., 2021). A better understanding of the functioning and dynamics of the symptom system for sleep quality, anxiety, and depression would allow for a better prediction of their relationships.

Traditional methodologies, including multiple linear regression and hierarchical or multivariate logistic regression, are limited in describing the complex, conditional, linear, or nonlinear relationships among different variables (Peng et al., 2021). The network approach is a promising procedure that provides insights into the dynamic and causal relationships between the symptoms of sleep quality, depression, and anxiety (Borsboom, 2017). Within the network approach, mental disorders are not latent or unobserved pathological entities, but emergent phenomena generated by interactions among the symptoms that constitute them (Epskamp et al., 2018). The network approach allows for a graphical representation, where variables are represented by nodes (or symptoms), whereas connections between pairs of nodes are represented by edges. Multivariate analysis of psychological data using network models applied to various research areas has generated increasing interest (Huth et al., 2023). A subclass of network models is Bayesian networks, which combine the principles of graph theory and probability theory to evaluate the relationships between variables (Larrañaga & Moral, 2011). Bayesian networks have no limitations regarding data distribution, allowing the incorporation of various types of data to assess the influence of different factors associated with mental health and their relationships (Peng et al., 2021). Bayesian network models provide a directed acyclic graph (DAG), where the edges represent the direction of dependencies between nodes and do not form closed loops. Bayesian networks rely on probability distributions, making them valuable tools for risk assessment, especially under conditions of uncertainty (Jensen & Nielsen, 2007), because they provide evidence for observing paths and predicting outcomes (Stallman et al., 2021). Unlike regression models, Bayesian networks have the advantage of comparing relative risks, identifying subtle relationships, quantifying causal relationships in graph structures, and identifying node sensitivities, all of which are useful for identifying intervention targets (Cleophas & Zwinderman, 2019).

Bayesian networks have been increasingly used to analyze the predictions of clinical risks and risk stratification in medicine (Sedighi et al., 2021). However, as mental health syndromes present with related symptoms that influence each other, the network approach seems useful for understanding these syndromes (Turner et al., 2023). To date, no studies have been identified that have used Bayesian networks to investigate the conditional relationships among symptoms of sleep quality, anxiety, and depression in the Peruvian population or in any other Latin American sample. Therefore, this study aimed to understand the interdependencies between the symptoms of sleep quality, anxiety, and depression in a sample of Peruvian adults using a Bayesian network model. According to scientific literature, it is hypothesized that poor sleep quality occurs concurrently with symptoms of anxiety and depression in this sample of Peruvian adults. Thus, this study sought to provide information that can serve as a reference for the development of specific interventions aimed at improving and preventing issues related to sleep quality, anxiety, and depression.

Methods

Procedure and participants

The study was conducted between July and August 2023. An online survey was administered, and participants were invited to respond via social media platforms (e.g., Facebook and Instagram) and email. Snowball sampling was employed to encourage participants to forward the online survey to family, friends, or other contacts who met the specified criteria (Hernández & Carpio, 2019). Online snowball sampling allows gathering information from participants in various locations and achieves higher response rates than other sampling techniques (Baltar & Brunet, 2012). The inclusion criteria for the sample included being of legal age, not having a diagnosis of migraine, sleep disorders, or substance use, and providing informed consent. Therefore, minors who report a diagnosis of migraine, sleep disorders, or substance use and do not provide informed consent will not be included in this study.

The sample consisted of 451 individuals with an average age of 24.9 (SD = 9.3), of which 130 (28.8%) were male and 321 (71.2%) were female. Most participants were single (n = 386; 85.6%), followed by married (n = 33; 7.3%), cohabiting (n = 25; 5.5%), divorced (n = 3; 0.7%), and widowed (n = 4; 0.9%) individuals. The majority reported having some university education (n = 277; 61.4%) and completed university degrees (n = 74; 16.4%), followed by those who completed only secondary education (n = 66; 14.6%), complete technical studies (n = 25; 5.5%), incomplete technical studies (n = 8; 1.8%), and incomplete secondary education (n = 1; 0.2%). About 33.5% of the participants (n = 151) reported having regular bedtime, while 66.5% (n = 300) indicated that they did not. A total of 53.7% (n = 242) reported not being light-sleepers, while 46.3% (n = 209) reported being light-sleepers. Participants slept for an average of 6.6 hours per night (SD = 1.6).

Measures

Sleep Quality Symptoms. Sleep quality symptoms were assessed using the Jenkins Sleep Scale (JSS-4; Jenkins et al., 1988). The JSS-4 assesses the frequency and intensity of a set of sleep problems over the past four weeks (difficulty initiating sleep, waking during the night, waking during sleep, difficulty maintaining sleep, and feeling exhausted in the morning despite sleep). The JSS consists of four items, each with a six-point Likert scale (ranging from "never" = 0 to "22 to 31 days" = 5). The sum of the scores from each item results in a total score ranging from 0 to 20, with higher scores indicating a higher frequency of sleep problems. The Spanish version adapted for Peru by Villarreal-Zegarra et al. (2022) was used in this study. In the current study, JSS-4 showed adequate reliability through internal consistency (ω = .79 [95% CI: .76, .82]).

Anxiety and Depression Symptoms. Symptoms of depression and anxiety were measured using the Patient Health Questionnaire-2 (PHQ-2; Kroenke et al., 2003) and General Anxiety Disorder-2 (GAD-2; Kroenke et al., 2007), respectively. Both the PHQ-2 and the GAD-2 consist of two items considered central symptoms of depression and generalized anxiety as per the DSM-5-TR (PHQ-2: "Feeling down, depressed, or hopeless" and "Little interest or pleasure in doing things"; GAD-2: "Feeling nervous, anxious, or on edge," and "Not being able to stop or control worrying") (American Psychiatric Association, 2022). The items of PHQ-2 and GAD-2 feature a four-point Likert scale rating ranging from "0 = not at all" to "3 = nearly every day," with total scores ranging from 0 to 6. In this study, the Spanish versions of the PHQ-2 and GAD-7 by Caycho-Rodríguez et al. (2019) were used, which showed adequate reliability. In this study, the PHQ-2 (ω = .76 [95% CI: .70, .81]) and GAD-7 (ω = .76 [95% CI: .69, .81]) exhibited adequate reliability through internal consistency.

Data Analysis

Statistical analysis was performed using Rstudio version 4.3.2. Initially, descriptive statistics were analyzed using arithmetic mean, standard deviation, and Pearson correlation matrix. Additionally, before estimating the network structure, the topological overlap of nodes was explored using the networktools package and the goldbricker function, where redundancy greater than 25% with a *p-value* of .05 was determined to ascertain statistical significance (Hittner et al., 2003; Jones, 2021).

Furthermore, a Bayesian network structure was constructed from a directed acyclic graph (DAG) model using the bnlearn package (Scutari, 2010). The DAG model is represented by nodes connected by directional edges (arrows) that establish probabilities of dependence between pairs of nodes (A-B), where A has a direct effect on B, and an indirect chain (A-B-C), where A has an indirect effect on C through B. In other words, the arrows highlight the probability that one variable may cause another, whereas the absence of an arrow assumes independence and no direction (Sonis and Jiang, 2023). For DAG estimation, structure learning was conducted using the Hill-Climbing (HC) algorithm with the hc function. This Bayesian algorithm analyzes the structure by continuously adding, removing, and reversing the direction of edges through an iterative procedure for all possible edges of the network until an adequate fit and optimization of the Bayesian Information Criterion (BIC) are achieved, where the arrows with the lowest negative BIC value have the greatest contribution to the model (Briganti et al., 2023; Scutari, 2010; Sonis and Jiang, 2023). This procedure was conducted with 50 random restarts and 100 perturbations for each restart (Briganti et al., 2023).

To ensure the stability of the DAG, the approach described by Briganti et al. (2023) was followed: first, bootstrap resampling of 10000 samples based on five random restarts and 10 perturbations with the bootstrap strength function was performed; second, structure learning was applied to each bootstrap sample; and third, the DAG average was calculated to obtain a final model. Moreover, a data-based threshold based on the method of Scutari and Nagarajan (2013) was used to retain the frequency of edges, while at least 50% presence in that direction was considered to identify the direction of surviving edges in bootstrap networks (Briganti et al., 2023).

Finally, two plots were created using the strength plot function for proper interpretation. In the first plot, the arrows represent the BIC values in the fit, indicating that the thicker the arrow, the greater the contribution to the network structure. In the second plot, the arrows represent the directional probability, meaning that the thicker the arrow, the higher the proportion of presence in that direction (Briganti et al., 2023).

Ethics

This study analyzed a subset of data collected as part of a larger project called "Study on psychological factors associated with sleep and rest," which was approved by the Research Ethics

Table 1
Descriptive Statistics and Correlation Matrix.

Symptoms	M (SD)	Correlation Matrix							
Difficulty Falling Asleep	1.25 (1.33)	-							
Difficulty in Stay Asleep	.88 (1.18)	.47	-						
Nighttime Awakenings	.88 (1.29)	.55	.68	-					
Tiredness on Awakening	1.70 (1.56)	.50	.43	.40	-				
Anhedonia	2.08 (.78)	.27	.22	.20	.49	-			
Depressed Mood	2.11 (.93)	.35	.20	.30	.42	.62	-		
Nervousness	2.06 (.84)	.31	.25	.32	.30	.41	.54	-	
Uncontrollable Worry	2.08 (.90)	.32	.22	.26	.32	.42	.51	.61	-

Note. M = mean; SD = standard deviation.

Committee of the University of Sciences and Humanities (approval code: 055-23). This study followed the recommendations of the Declaration of Helsinki (World Medical Association, 1964) and the ethical code of the College of Psychologists of Peru (Colegio de Psicólogos del Perú, 2017). This study did not involve invasive or potentially harmful procedures; therefore, approval from the ethics committee of a single country was sufficient.

Results

Descriptive Statistics

Table 1 shows that the highest arithmetic mean was observed for Depressed Mood (*M* = 2.11), with the lowest values in Difficulty in Stay Asleep (*M* = .88) and Nighttime Awakenings (*M* = .88). The highest standard deviation was found in Tiredness on Awakening (*SD* = 1.56) and the lowest in Anhedonia (*SD* = .78). The correlation matrix showed moderate correlations between Difficulty in Stay Asleep and Nighttime Awakenings (*r* = .68), Anhedonia and Depressed Mood (*r* = .62), and Nervousness and Uncontrollable Worry (*r* = .61). In topological overlap analysis, there were no indications of redundant pairs of nodes.

DAG Estimation

Table 2 reports the Bayesian Information Criterion (BIC) values and directional probability maintained by each arrow among the nodes. A graphical representation of the estimated DAG structure is shown in Figure 1.

Regarding the model fit, the most significant arrows contribute to the model-connected Nighttime Awakenings with Difficulty in Stay Asleep (BIC = -137.00), Anhedonia with Depressed Mood (BIC = -89.84), Uncontrollable Worry with Nervousness (BIC = -49.01), and Anhedonia with Tiredness on Awakening (BIC = -39.66). These results are visually appreciated in Figure 1, section A, represented by the thickness of each arrow. Table 2 displays the changes in BIC values of the remaining arrows.

In terms of directional probability, Figure 1, section B, and Table 2 identify the thickest arrow points from Depressed Mood to Nervousness (directional probability of .70). This indicates that the arrow was present in that direction in 70% of the bootstrap networks and in the other direction, it was only 30%. Similarly, other thicker arrows point from Nighttime Awakenings to Nervousness (directional probability of .67), Depressed Mood to Uncontrollable Worry (directional probability of .67), and Anhedonia to Uncontrollable Worry (directional probability of .64), and to Tiredness on Awakening (directional probability of .61).

In terms of cascades, two parent nodes were observed: Nighttime Awakenings (in-degree = 0, out-degree = 4) and Anhedonia (in-degree = 0, out-degree = 3). In other words, Peruvian adults experiencing Nighttime Awakenings were statistically more likely to experience symptoms associated with Nervousness, Depressed Mood, Difficulty Falling Asleep, and Difficulty in Stay Asleep, although in these last three, the directional probabilities were close to .50, indicating that the direction could go either way. Meanwhile, individuals exhibiting Anhedonia are more likely to experience symptoms associated with Uncontrollable Worry, Tiredness on Awakening, and Depressed Mood, although the latter symptom can be bidirectional (probability value close to .50). Additionally, Difficulty Falling Asleep (in-degree = 2, out-degree = 2) and Depressed Mood (in-degree = 3, out-degree = 2) were important nodes as key steps in the cascade mode.

Finally, Nervousness is positioned as a node at the end of the DAG structure. This indicates that Nervousness is the result of conditional dependency on Depressed Mood, Nighttime Awakenings, and Uncontrollable Worry.

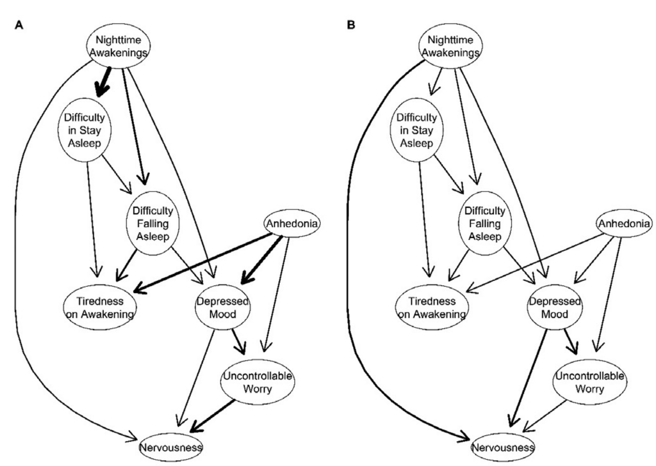

Figure 1. DAG in Sleep Quality, Generalized Anxiety, and Depressive Symptoms. Section A corresponds to the overall model fit in which the thickness of the arrow highlights a greater contribution to the fit. Section B relates to directional probability, in which the thickness of the arrow emphasizes a greater proportion of the presence of the bootstrapped network in that direction.

Discussion

In this study, the relationships between the symptoms of sleep quality, generalized anxiety, and depression were addressed using a

Table 2.
BIC Values and Directional Probabilities of Arrows in the DAG.

Arrows in the DAG		Values Determining Arrow Thickness	
From	To	BIC	Directional Probability
Difficulty Falling Asleep	Tiredness on Awakening	-23.04	.57
Difficulty Falling Asleep	Depressed Mood	-1.97	.59
Difficulty in Stay Asleep	Difficulty Falling Asleep	-3.32	.51
Difficulty in Stay Asleep	Tiredness on Awakening	-8.38	.54
Nighttime Awakenings	Difficulty Falling Asleep	-25.74	.56
Nighttime Awakenings	Difficulty in Stay Asleep	-137.00	.53
Nighttime Awakenings	Depressed Mood	-1.04	.57
Nighttime Awakenings	Nervousness	-2.69	.67
Anhedonia	Tiredness on Awakening	-39.66	.61
Anhedonia	Depressed Mood	-89.84	.57
Anhedonia	Uncontrollable Worry	-1.91	.64
Depressed Mood	Nervousness	-17.93	.70
Depressed Mood	Uncontrollable Worry	-27.15	.67
Uncontrollable Worry	Nervousness	-49.01	.50

Note. BIC represents Bayesian Information Criterion. Negative BIC values indicate that the model fit improved in the presence of the arrow. The directional probability values indicate that the arrow was present in that direction in 10,000 bootstrapped networks.

Bayesian network approach. To our knowledge, this is the first study to analyze directional dependencies in an adult population.

These findings indicate that Nighttime Awakenings and Anhedonia play important and distinct roles in the network dynamics of symptoms. Nighttime Awakenings emerged as parent nodes in the DAG, with directional probabilities of the four symptoms. The highest value was found for Nervousness, suggesting that adults reporting Nighttime Awakenings are statistically more likely to experience Nervousness. Previous studies have suggested that individuals with anxiety symptoms experience chronic sleep maintenance insomnia characterized by nighttime awakenings, which leads to poor health-related quality of life, awakenings with headaches, restless legs syndrome, bruxism, and nightmares (Bolge et al., 2010; Lucchesi et al., 2010). However, our findings indicate a bidirectional relationship, where while the presence of anxiety symptoms, including nervousness, can cause disruptions in normal sleep continuity, nighttime awakenings can also increase experienced nervousness. This association might be understood by considering that during Nighttime Awakenings, the autonomic nervous system and brain regions associated with wakefulness exhibit abrupt activation, which exceeds normal physiological needs and contributes to the manifestation of elevated alert and anxious states (Ukraintseva & Soloveva, 2023).

Difficulty Falling and Stay Asleep, characteristic of insomnia, are associated with hyperactivation that disrupts sleep-wake cycle regulation (Riemann et al., 2015); therefore, their close relationship with Nighttime Awakenings is direct (Levenson, Kay, & Buysse, 2015). These difficulties are frequently manifested in individuals with sleep apnea disorders, with a prevalence of 18% and 42% for difficulties initiating and maintaining sleep due to respiratory problems, respectively (Zhang et al., 2019). Prevalence rates in the general population are 14% and 28.3%, respectively. Although sleep problems are linked to psychological factors, such as stress and anxiety, the evidence from this study does not directly support this claim. However, it establishes a direct link between these symptoms, which leads to serious health consequences such as cardiovascular diseases and cognitive impairment (Robbins et al., 2019; Tan et al., 2020).

Similarly, the connection between Nighttime Awakenings and Depressed Mood aligns with previous research suggesting that Nighttime Awakenings provoke slow-wave activity during sleep, resulting in a reduced positive mood state, which could explain the high comorbidity between insomnia and depression (Finan et al., 2015). A controlled experimental study showed that even a single night with nighttime awakenings caused mood changes and attention maintenance difficulties in young adults (Kahn et al., 2014). Additionally, unpleasant dream content and cognitive dysfunction are present in patients diagnosed with anxiety depression (McNamara et al., 2010).

Another key node was Anhedonia, with directional probabilities toward three symptoms: Tiredness on Awakening, Uncontrollable Worry, and Depressed Mood. Literature indicates that anhedonia is a fundamental element in the study of sleep problems, negative thoughts, and quality of life (Barthel et al., 2020). It is also a mediator in the association between depression and anxiety, as a person who loses interest in activities generates depressive symptoms, decision-making difficulties, poor motivation, and Uncontrollable Worry (Barkus, 2021; Treadway & Zald, 2013; Winer et al., 2017), whereas the latter is strongly associated with sleep problems and negative thoughts (Barthel et al., 2020). Furthermore, individuals experiencing anhedonia often suffer from cognitive exhaustion, which can lead to issues such as lack of energy during the day. Therefore, the findings are consistent with the literature describing depression through symptoms, such as Anhedonia, Uncontrollable Worry, and Depressed Mood (Sibitz et al., 2010).

From the cascade model perspective, two symptoms were identified as bridges in the directional probabilities. Specifically, Difficulty Falling Asleep presented incoming arrows from Nighttime Awakenings and Difficulty in Stay Asleep, and outgoing arrows presented Depressed Mood and Tiredness on Awakening. Meanwhile, Depressed Mood presented incoming arrows from Anhedonia, Nighttime Awakenings, and Difficulty Falling Asleep, and outgoing arrows from Uncontrollable Worry and Nervousness. This finding indicates that both symptoms play a fundamental role in directional relationships with other symptoms, consistent with research indicating that Difficulty Falling Asleep is associated with daytime fatigue, attention deficits, mood variations (Riemann et al., 2015), and chronic health problems (Lee, 2001), which could lead to more severe sleep disorders (Bansal et al., 2013). Additionally, Depressed Mood, difficulty relaxing, and Uncontrollable Worry have been identified as key symptoms in the network structure of depression and anxiety in various populations, including epilepsy patients, nursing students, and older adults (Bai et al., 2021; Ren et al., 2021; Wei et al., 2021).

On the other hand, it is evident that Nervousness does not present outgoing arrows to other symptoms but shows conditional dependence with Uncontrollable Worry, Depressed Mood, and Nighttime Awakenings. This indicates that Nervousness depends on the presence of three symptoms: sleep quality, depression, and generalized anxiety. Literature establishes that central symptoms of depression, such as Depressed Mood and Anhedonia, exert a significant influence on Nervousness (Beard et al., 2016). Additionally, Uncontrollable Worry, a central symptom of anxiety and depression, is associated with Nervousness because both are part of the symptomatology of generalized anxiety (Vîslă et al., 2021; Wang et al., 2023). There is little evidence on the association between Nighttime Awakenings and Nervousness, and it was found that environmental factors such as noise interrupt sleep, producing nighttime awakenings, which would be linked to symptoms of depression and anxiety (Peltz, 2022). Furthermore, children under 2 years of age who present frequent nighttime awakenings would have problems in social information processing and socioemotional behavior (Mäkelä et al., 2021). Therefore, it can be inferred that frequent nighttime awakenings in adulthood may be associated with emotional management difficulties. However, this hypothesis should be the focus of future studies.

Limitations

A strength of this study is the use of network models that are suitable for describing complex dynamic relationships (Nelson et al., 2017). However, this study has some limitations need to be mentioned. First, it had a cross-sectional design that obtained data from a single point in time. The DAG provides preliminary information on the strength and direction of potential connections between the analyzed variables; therefore, caution must be exercised when making causal inferences (Moffa et al., 2017). Subsequent studies could conduct a longitudinal assessment to capture the potential dynamics of changes between study variables. Second, non-probabilistic sampling was used, which limits the generalization of the sample results to the population. Probabilistic sampling is recommended to obtain a more representative sample of the population. Third, the use of nonprobabilistic sampling also resulted in a sample with nonhomogeneous characteristics, where, for instance, a higher proportion of women was observed. This could bias the results and limit their generalizability, as women tend to exhibit poorer sleep quality (Madrid-Valero et al., 2017), as well as a higher prevalence and comorbidity of anxiety and depression (Bangasser & Cuarenta, 2021; Farhane-Medina et al., 2022). This suggests that future studies should consider ensuring more homogeneous samples with respect to sex to minimize bias in the findings. Fourth, measures of sleep quality, anxiety, and depression symptoms were self-reported, and responses depend on individuals' subjective experiences and may be vulnerable to social desirability bias when reporting their own experiences (Delgadillo et al., 2023). It is recommended that the measures used be complemented by more objective ones. Five, some directional arrows were thin, indicating that a proportion pointed in the other direction. Future studies should use temporal network models to confirm these bidirectional dependencies (Blanchard et al. 2023).

Conclusion and Implications

Despite these limitations, to our knowledge, this study is the first to elucidate the associations between sleep quality, depression, and anxiety symptoms in a sample of Peruvian individuals and any Latin American country. In conclusion, Nighttime Awakenings and Anhedonia play important and distinct roles in symptom network dynamics. Nighttime Awakenings showed directional probabilities toward four symptoms: Nervousness, Difficulty Falling, Stay Asleep, and Depressed Mood. Anhedonia also showed directional probabilities toward three symptoms: Tiredness on Awakening, Uncontrollable Worry, and Depressed Mood. However, while Nervousness does not present outgoing arrows to other symptoms, it does show conditional dependence with Uncontrollable Worry, Depressed Mood, and Nighttime Awakenings.

The findings of this study have several important implications for mental health and general well-being. This study also suggests how Bayesian networks can be applied in behavioral research. Health behaviors such as sleep problems are modifiable risk factors that can improve health and prevent the presence of other mental illnesses. Identifying sleep quality symptoms that are most closely linked to anxiety and depression symptoms is important for designing effective interventions. First, identifying Nighttime Awakenings as key nodes in the symptom network suggests that addressing this specific issue can have a significant impact on sleep quality, anxiety, and depression in adults. This could imply the need for interventions specifically aimed at improving nighttime sleep continuity to reduce the adverse effects on mental health. Additionally, the connection between Anhedonia and various symptoms, such as Tiredness on Awakening, Uncontrollable Worry, and Depressed Mood, highlights the importance of addressing the loss of interest in pleasurable activities as an integral part of the treatment of depression and anxiety. Interventions that encourage participation in rewarding activities could significantly improve mood and quality of life. The above aligns with scientific evidence on the impact of sleep interventions on anxiety and depression symptoms. For instance, a random-effects meta-analysis that included 49 non-pharmacological sleep interventions (n = 5,908) reported a standardized mean difference for depression symptoms post-treatment of -0.45 (95% CI: -0.55, -0.36). This finding suggests that non-pharmacological sleep interventions can reduce the severity of depression (Gee et al., 2019). Similarly, another meta-analysis comprising 43 non-pharmacological sleep interventions (n = 5,945) indicated a moderate effect size (Hedges' g = -0.38) for anxiety symptoms, demonstrating a reduction in anxiety symptoms (Staines et al., 2022). Lastly, a meta-analysis of randomized controlled trials, including 65 trials, 72 interventions, and 8,608 participants, showed that interventions improving sleep led to a reduction in symptoms of depression, anxiety, and other mental health aspects (Scott et al., 2021).

The cascade model identified in the study, where Difficulty Falling Asleep and Depressed Mood act as bridges between different symptoms, underscores the complexity of these interactions. It suggests that interventions targeting these intermediate symptoms could positively affect multiple areas of mental health. Overall, these findings emphasize the importance of a comprehensive approach in treating sleep disorders, anxiety, and depression by considering the interconnections among various symptoms and addressing not only the primary symptoms but also those that serve as mediators or bridges within the symptom network. This approach can lead to more effective and personalized treatment strategies, ultimately enhancing patients' overall well-being.

In terms of practice and implementation, the findings suggest that training primary healthcare professionals should include raising awareness and developing skills to assess specific symptoms of sleep problems (Scott et al., 2021), such as nighttime awakenings and anhedonia, which showed directional probabilities toward other anxiety and depression symptoms. Furthermore, a potential mechanism explaining the impact of sleep on mental health is emotional regulation (Palmer & Alfano, 2017; Vandekerckhove & Wang, 2018). Emotional regulation involves recognizing the need to regulate, deciding whether and how to regulate, and implementing a regulation strategy (Webb et al., 2012). Poor sleep quality negatively affects these three processes, which may explain the relationship between inadequate sleep and mental health (Scott et al., 2021). Consequently, health professionals could benefit from incorporating measures of emotional regulation into their practice to elucidate the mechanisms through which improved sleep quality enhances mental health.

In general, psychological treatments should aim to reduce behavioral components (e.g., irregular sleep schedules), cognitive components (e.g., unhelpful worries and beliefs), and psychophysiological components (e.g., physical tension) that sustain poor sleep quality (Morin & Benca, 2012). The following techniques have been suggested: sleep time restriction, limiting the time spent in bed to consolidate sleep; stimulus control, associating the bedroom and bed exclusively with sleep; progressive muscle relaxation, reducing physical tension to facilitate sleep; mindfulness practice, enhancing present-moment awareness, and reducing ruminative thoughts; cognitive restructuring, modifying dysfunctional thoughts related to sleep; paradoxical intention, encouraging patients to perform thoughts or behaviors preventing sleep to reduce associated worry; and sleep hygiene promotion, establishing environmental conditions conducive to adequate sleep. These interventions have been shown to improve sleep quality, and consequently, mental health (García & Correa, 2020).

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