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ORIGINAL

Network analysis of sleep quality symptoms in individuals from four spanish-speaking countries in Latin America and Europe

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Abstract

Introduction/objective: Identifying sleep quality patterns is crucial for health authorities in order to understand their detrimental impacts and develop appropriate preventive strategies. This study aimed to analyse sleep quality symptoms using network analysis in individuals from four Spanish-speaking countries in Latin America and Europe. **Method:** A total of 1,899 participants from Peru, El Salvador, Honduras, and Spain took part in the study. A non-probabilistic snowball sampling method was employed and the Jenkins Sleep Scale was used to assess sleep quality symptoms. The bootnet package in RStudio was used to estimate a general network, and the node centrality was calculated using the Strength index. The networks were compared across countries using the NetworkComparisonTest package. **Results:** The results indicated that difficulty staying asleep was the most central symptom, meaning that it was the most relevant symptom within the sleep quality network when considering the overall sample from all evaluated countries. However, a more specific analysis revealed that in Spain and El Salvador, the most central symptom was "difficulty staying asleep," while in Peru and Honduras, the most central symptom was "difficulty falling asleep." Additionally, network comparisons by country showed that at a general level, the sleep quality symptom networks of

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the four countries were invariant. **Conclusion:** The findings of this study may serve as a starting point to better understand the associations between sleep quality symptoms based on network analysis in Spanish-speaking countries.

Keywords: Network analysis, sleep quality, Spanish-speaking, symptoms

Análisis de redes de síntomas de calidad del sueño en individuos de cuatro países hispanohablantes de América Latina y Europa

Resumen

Introducción/objetivo: Identificar los patrones de calidad del sueño es crucial para que las autoridades sanitarias comprendan sus efectos perjudiciales y desarrollen estrategias preventivas adecuadas. Este estudio tuvo como objetivo analizar los síntomas de calidad del sueño mediante análisis de redes en personas de cuatro países de habla hispana de América Latina y Europa. **Método:** Participaron 1899 personas de Perú, El Salvador, Honduras y España. Se empleó un método de muestreo no probabilístico de bola de nieve y se utilizó la Escala de Sueño de Jenkins para evaluar los síntomas de calidad del sueño. El paquete bootnet de RStudio se utilizó para estimar una red general y la centralidad de los nodos se calculó utilizando el índice Strength. Las redes se compararon entre países utilizando el paquete NetworkComparisonTest. **Resultados:** Los resultados indicaron que la dificultad para permanecer dormido era el síntoma más central, lo que significa que era el síntoma más relevante dentro de la red de calidad del sueño al considerar la muestra general de todos los países evaluados. Sin embargo, un análisis más específico reveló que en España y El Salvador, el síntoma más central era la "dificultad para permanecer dormido", mientras que en Perú y Honduras, el síntoma más central era la "dificultad para conciliar el sueño". Además, las comparaciones de redes por país mostraron que, a nivel general, las redes de síntomas de calidad del sueño de los cuatro países eran invariables. **Conclusión:** Los hallazgos de este estudio pueden servir como punto de partida para comprender mejor las asociaciones entre los síntomas de calidad del sueño basados en el análisis de redes en los países de habla hispana.

Palabras clave: Análisis de redes, calidad del sueño, hispanohablantes, síntomas

Sleep is a fundamental component of the sleep-wake cycle and is considered a period of inactivity that allows for the restoration of mental and physical functions (Berhanu et al., 2018). Sleep provides time for processing and integrating the information acquired during wakefulness, restoring interactions between different brain regions, replenishing energy in various bodily systems, and repairing tissues (Baranwal et al., 2023; Dijk & Landolt, 2019). These processes are essential for promoting well-being and health (Barros et al., 2019; Grandner, 2022; Hale et al., 2020). Individuals with good sleep quality exhibit better cognitive and memory functions, robust immune system activity, greater attention capacity, and improved daytime performance (Besedovsky et al., 2019; Garbarino et al., 2021; Hudson et al., 2020; Klinzing et al., 2019; Mason et al., 2021). Conversely, sleep disturbances or poor sleep quality have been linked to chronic diseases (Maung et al., 2016; Yunus et al., 2018), increased mortality risk (García-Perdomo et al., 2019), stroke (Lao et al., 2018), coronary issues (Madsen et al., 2019), cancer (Mogavero et al., 2021), diabetes (Ogilvie & Patel, 2018), glucose intolerance (Iyegha et al., 2019), hypertension (Han et al., 2020), higher rates of absenteeism (Saidane et al., 2018), and increased risk of mental health problems such as depression and anxiety (Arenas et al., 2019; Huang & Zhao, 2020).

The prevalence of poor sleep quality varies depending on the criteria and time frame used. When considering the presence of sleep-related complaints, the prevalence of sleep disorders in the general population ranges from 1.6% to 76.3%. However, if dissatisfaction with sleep quality or quantity is assessed, the prevalence of sleep problems ranges from 7.0% to 50.5% (Li et al., 2018). Among clinical populations, the prevalence of poor sleep quality is notably higher, with over 90% of patients experiencing anxiety and depression and sleep problems (Cox & Olatunji, 2020; Freeman et al., 2020).

Identifying sleep quality patterns is essential for health authorities in order to understand their harmful impacts and develop appropriate preventive strategies. Sleep quality problems have traditionally been examined using total scores from various instruments to describe the severity of the issue and its relationships with other variables (Duo et al., 2023; Itani et al., 2017; Perlis et al., 2022; Rodrigues & Shigaeff, 2022). However, traditional approaches do not always account for meaningful relationships between individual symptoms (Borsboom & Cramer, 2013). Network analysis has recently been proposed as an alternative and suitable approach to better understand the co-occurrence of mental health symptoms (Borsboom et al., 2021). Traditionally, latent constructs such as sleep problems have been considered to generate symptoms such as insomnia, sleep efficiency issues, and sleep disturbances (Pavlova & Latreille, 2019). However, the network analysis model suggests that mental health symptoms do not arise from underlying variables but rather interact, mutually reinforce, or inhibit one another (Borsboom, 2017). Within this framework, the interaction between symptoms constitutes a latent variable (Fried et al., 2017; Schmittmann et al., 2013).

The network analysis model identifies the most influential symptoms within a network (central symptoms) that are pivotal in generating other symptoms (Epskamp et al., 2018; Jones et al., 2021). This allows for the identification of highly interconnected symptoms and the exclusion of those with minimal relationships within the network (Elliott et al., 2020). The relationships among the symptoms are referred to as edges. Network analysis also identifies symptoms that trigger the onset of other disorders, known as bridge symptoms (Kaiser et al., 2021). Understanding the bridge symptoms may elucidate the emergence and persistence of comorbidities (Cramer et al., 2010). Identifying central and bridge symptoms in a network offers insights into the mechanisms by which individuals are at risk of comorbidities, paving the way for effective interventions (Fried & Cramer, 2017).

Symptom networks are considered dynamic rather than static (Borsboom et al., 2021; Robinaugh et al., 2020). Comparing symptom networks across countries could enhance our understanding of the mechanisms underlying symptom interactions (Bringmann, 2021). Research on sleep in Spanish-speaking countries in Latin America and Europe primarily comprises studies conducted in individual countries using different measures, making direct comparisons challenging (Barahona-Correa et al., 2018; López-Gil et al., 2022; Ramón-Arbués et al., 2022; Villarreal-Zegarra et al., 2022; Yupanqui-Lorenzo et al., 2024). Various studies have indicated that sociocultural factors influence sleep disorders, leading to differences in their prevalence rates. This highlights the importance of examining sleep disorders in distinct societies and populations (Gureje et al., 2007; Ohayon & Partinen, 2002). Beyond its physiological processes, sleep is also shaped by sociocultural structures (Grandner, 2022). For instance, in Latin America, sleep health could be considered a public health concern due to factors such as unemployment, low income, educational challenges, and social disparities (Barria-Asenjo et al., 2022; Etindele Sosso et al., 2023). Conversely, in Europe, urbanisation, economic growth, and transportation are associated with higher levels of environmental noise, contributing to noise-induced sleep disorders (Ristovska & Lekaviciute, 2013). Additionally, a systematic review found that Europeans tend to sleep later than Americans (Gradisar et al., 2011). Despite these findings, there is limited information on transnational sleep patterns, and a comprehensive understanding of how cultural factors affect sleep quality has yet to be achieved (Willoughby et al., 2023).

Considering these factors, the current study aimed to analyse sleep quality symptoms through a network analysis in individuals from four Spanish-speaking countries in Latin America and Europe. The specific objectives were (a) to analyse the network structure of sleep quality symptoms, (b) to identify the most important symptoms using centrality and predictability indices, and (c) to compare networks among the evaluated Spanish-speaking countries in Latin America and Europe.

Method

Participants

This study included 1,899 individuals from four Spanish-speaking countries in Latin America and Europe: Peru, El Salvador, Honduras, and Spain. The selection of these four countries was not the result of a systematic process but rather based on negotiations regarding the potential interest of local researchers to participate and their ability to meet the study requirements. Participants were selected based on the following inclusion criteria: (1) being of legal age according to the laws of each country, (2) residing in one of the aforementioned countries, and (3) providing informed consent to participate. A non-probabilistic snowball sampling method was used to achieve a significant number of responses (Parker et al., 2019).

The sample size was calculated using the Monte Carlo simulation method proposed by Constantin et al. (2021), which recommends a minimum of 710 participants. However, the final number of participants exceeded this recommendation.

The majority of participants were female, both in the overall sample (67.83%) and in each country (> 60%). The average age of the sample was 26.14 years (*SD* = 9.96). Regarding marital status, most participants were single (ranging from 72.85% to 85.40%). Additionally, over 70% of participants reported having complete or incomplete university education. Across all countries, most participants did not have a set bedtime (ranging from 50.33% to 64.50%) and engaged in low physical activity levels (ranging from 38.08% to 43.59%).

Table 1 provides a detailed summary of the sociodemographic characteristics of participants from each of the four countries.

Instruments

Sociodemographic Questionnaire. A sociodemographic questionnaire was developed to collect information on gender (male and female), age, marital status (single, married, cohabiting, divorced, widowed), educational level (primary, secondary, technical, and university), whether participants had set sleeping hours (Yes or No), and physical activity levels (none, low, moderate, and high).

The Jenkins Sleep Scale (JSS; Jenkins et al., 1988). The JSS assesses sleep problems over the last four weeks

Table 1. Sociodemographic characteristics of participants from the four countries

	Peru		El Salvador		Honduras		Spain	
	n	%	*n*	%	*n*	%	*n*	%
Age (M/SD)	24.53 (9.87)		27.67 (8.78)		24.50 (7.72)		28.87 (13.86)	
Gender								
Male	174	34.32	224	39.86	139	26.33	74	24.50
Female	333	65.68	338	60.14	389	73.67	228	75.50
Marital status								
Single	433	85.40	419	74.56	439	83.14	220	72.85
Married	40	7.89	87	15.48	51	9.66	53	17.55
Cohabiting	27	5.33	45	8.01	21	3.98	13	4.30
Divorced	5	0.99	9	1.60	2	0.38	13	4.30
Widowed	2	0.39	2	0.36	15	2.84	3	0.99
Education level								
Incomplete primary	0	0.00	1	0.18	0	0.00	2	0.66
Complete primary	0	0.00	2	0.36	6	1.14	3	0.99
Incomplete secondary	3	0.59	3	0.53	41	7.77	4	1.32
Complete secondary	90	17.75	32	5.69	85	16.10	23	7.62
Incomplete technical	6	1.18	16	2.85	0	0.00	7	2.32
Complete technical	22	4.34	25	4.45	19	3.60	25	8.28
Incomplete university	287	56.61	395	70.28	318	60.23	169	55.96
Complete university	99	19.53	88	15.66	59	11.17	69	22.85
Set bedtime								
No	327	64.50	335	59.61	320	60.61	152	50.33
Yes	180	35.50	227	40.39	208	39.39	150	49.67
Physical activity								
None	91	17.95	96	17.08	111	21.02	49	16.23
Low	221	43.59	219	38.97	204	38.64	115	38.08
Moderate	163	32.15	195	34.70	163	30.87	103	34.11
High	32	6.31	52	9.25	35	6.63	35	11.59

Note: *M* = mean; *SD* = standard deviation.

using four items that measure difficulty falling asleep, difficulty staying asleep, waking up multiple times during the night, and waking up tired after the usual amount of sleep. Each item has six response options (none = 0, 1–3 days = 1, 4–7 days = 2, 8–14 days = 3, 15–21 days = 4, and 22–28 days = 5). The total score is calculated by summing the item scores and ranges from 0 to 20, with a higher score indicating more disturbed sleep. This study used an adapted and previously validated Spanish version for the Latin American and Spanish populations. This version confirmed the unidimensional structure and high reliability of the JSS in each country and demonstrated invariance across countries (Palao-Loayza et al., 2024).

Procedure

This study was part of a larger research project that utilised an online survey in Spanish, which included a sociodemographic questionnaire, the JSS, and other variables. The online survey was distributed to individuals who met the inclusion criteria via social media platforms (Instagram and Facebook) and email. First, the survey presented the study's objective and informed consent, followed by sociodemographic questions and the JSS. An online survey was conducted between July and August of 2023. The average time to complete the survey was approximately 10 min. All countries followed the same data-collection procedure.

Ethical approval

This study analysed a subset of data from a larger research project entitled *"Study on Psychological Factors Associated with Sleep and Rest,"* which received ethical approval from the Research Ethics Committee of the Universidad de Ciencias y Humanidades (approval code: 055-23). This study aimed to analyse various psychological factors associated with sleep and rest, such as bedtime procrastination, mobile device use before sleeping, symptoms of anxiety and depression, anger reactions, mindfulness, and daytime or wake-up fatigue, among others. However, as previously mentioned, for the purposes of this study, only data on sleep quality measured by the Jenkins Sleep Scale were used. This study adhered to the confidentiality, equality, and justice recommendations of the Declaration of Helsinki. Participants provided online informed consent to be part of the study, confidentiality of information was maintained, and it was stated that they could withdraw from the study at any time.

Data analysis

Calculations were performed using the R 4.2.1 statistical software in four phases. First, using the Bootnet package (Epskamp, 2023), a general network was estimated by considering the total sample. The ggmModSelect estimator was used with non-regularised partial correlations to control the association between nodes and avoid spurious correlations (Epskamp & Fried, 2018). Spearman correlation matrices were calculated based on the ordinal nature of the items (Isvoranu & Epskamp, 2023). The network graph was generated using the Fruchterman-Reingold algorithm, which groups nodes with greater interconnections, and was implemented using the qgraph package (Epskamp et al., 2012). To interpret the network, it is essential to consider that each node (circle) represents a symptom of loneliness and depression, and that its connectivity is represented by edges (lines), which are thicker and clearer if the correlation is higher. Conversely, thinner or fainter edges indicate lower correlation. Green denotes a positive or direct relationship (Fonseca-Pedrero, 2018).

Second, node centrality was calculated using the Strength index, as it is the most appropriate for networks with nodes that show a single direction in correlations; in this case, all indicated a positive or direct relationship. Furthermore, this index is more suitable than closeness or betweenness (Robinaugh et al., 2016).

Third, network stability and precision were analysed at the edge and centrality levels using bootstrapping with 1,000 resamples. Stability explores the number of cases that can be removed to achieve a correlation of at least .70 between the real data and the removed cases with 95% probability, while precision replicates interconnections between nodes to determine network robustness. To interpret precision, the overlap between bootstrap trends and real sample data should be observed; for stability, a coefficient (CS) above .25 is considered adequate (Epskamp et al., 2018).

Fourth, networks and centrality by gender were estimated to test for invariance. Networks were compared across countries using the NetworkComparisonTest package with default configuration, which performs a two-tailed permutation test with 100 replications. A value below .05 is expected to indicate that differences exist between networks (Van Borkulo, 2015). Additionally, a moderated network approach was employed to examine whether the network structure changed when including country as a covariate (Haslbeck, 2022). For this purpose, the **mgm** package was used (Haslbeck & Waldorp, 2020), through which the network was modelled and its stability estimated via bootstrapping with 500 resamples (Haslbeck et al., 2019). The Extended Bayesian Information Criterion (EBIC) was applied with the default gamma hyperparameter set at 0.25, and the AND rule was used to identify significant connections. Finally, when interpreting the results, interactions were considered stable if they appeared in 50%–80% of the resamples or in more than 80% (Haslbeck, 2022).

Supplementary material

The anonymised data (https://osf.io/nat24), as well as the R code used for analyses (https://osf.io/q3s6t), are also available on the Open Science Framework (https://osf.io/s4qtk/).

Results

Table 2 presents the descriptive statistics for each node, for both the total sample and each country. Additionally, to better compare centrality, the Strength index value is reported. In general, the node with the highest mean was JSS1 (M = 2.79, SD = 1.40). However, this trend changed when considering individual countries, as the node with the highest mean was JSS4 (M_{Peru} = 2.69, SD_{Peru} = 1.54; $M_{El\ Salvador}$ = 2.63, $SD_{El\ Salvador}$ = 1.58; $M_{Honduras}$ = 2.78, $SD_{Honduras}$ = 1.66; and M_{Spain} = 3.24, SD_{Spain} = 1.80).

In Figure 1, the results of the general network are displayed, showing a density of 100%, indicating full interconnectivity among the nodes. Centrality was concentrated in node JSS3 (difficulty staying asleep), highlighting it as the most relevant symptom in the network. Additionally, JSS3 showed stronger associations with waking up multiple times during the night (r = .41) and difficulty falling asleep (r = .31).

Figure 2 illustrates the results of the bootstrap analysis, demonstrating that the edges were precise be-

Table 2. Descriptive statistics for the total sample and each country

	Total			Peru			El Salvador			Honduras			Spain		
	M	*SD*	*St*	*M*	*SD*	*St*	*M*	*SD*	*St*	*M*	*SD*	*St*	*M*	*SD*	*St*
JSS1	2.79	1.40	0.85	2.13	1.28	0.85	2.03	1.32	0.86	2.19	1.44	0.84	2.61	1.57	0.77
JSS2	2.14	1.38	0.70	1.86	1.06	0.62	2.07	1.36	0.68	2.12	1.33	0.70	2.80	1.75	0.78
JSS3	1.87	1.30	0.86	1.78	1.19	0.83	1.78	1.22	0.95	1.77	1.18	0.78	2.33	1.70	0.93
JSS4	2.79	1.64	0.54	2.69	1.54	0.49	2.63	1.58	0.53	2.78	1.66	0.45	3.24	1.80	0.67

Note: *M* = average; *SD* = standard deviation.

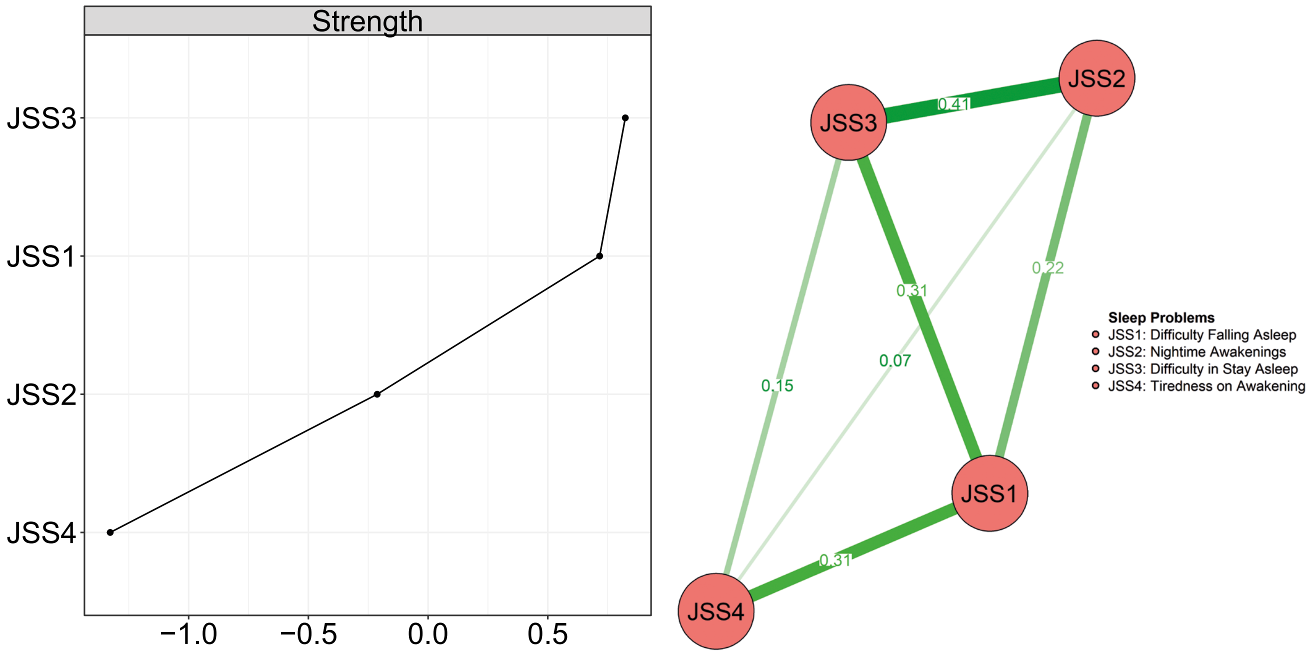

Figure 1. Network structure of sleep quality symptoms in the general sample

cause of the good overlap between the real data and resampling (CS = .75). Additionally, stability is confirmed, as the coefficient exceeded the threshold of .25 (CS = .75). Therefore, it can be concluded that the network is stable and precise.

Figure 3 presents the results of the network comparisons by country. The networks in Peru and Honduras exhibited a density of 83%, whereas in El Salvador and Spain, the density reached 100%, indicating greater symptom connectivity. In both El Salvador and Spain, a correlation was observed between JSS2 (waking up multiple times during the night) and JSS4 (feeling tired and exhausted after normal sleep), although the effect was

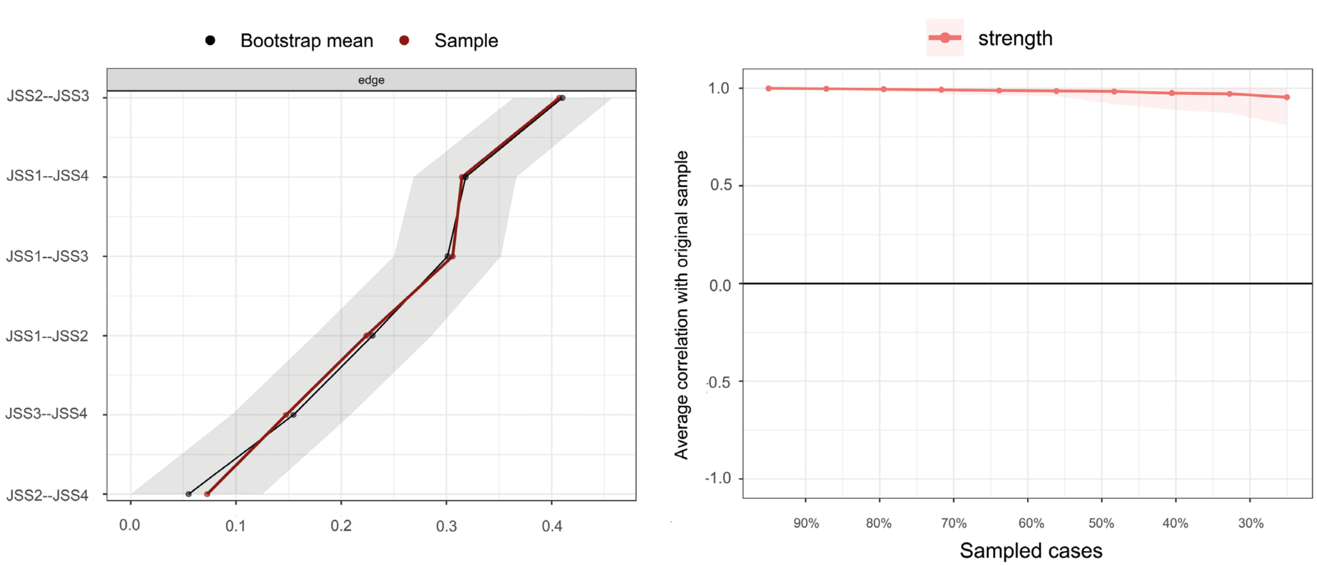

Figure 2. Stability and Precision of the Network in a General Sample. Right: Stability of centrality index. Left: Precision through 95% non-parametric bootstrap confidence intervals for the estimated network edges

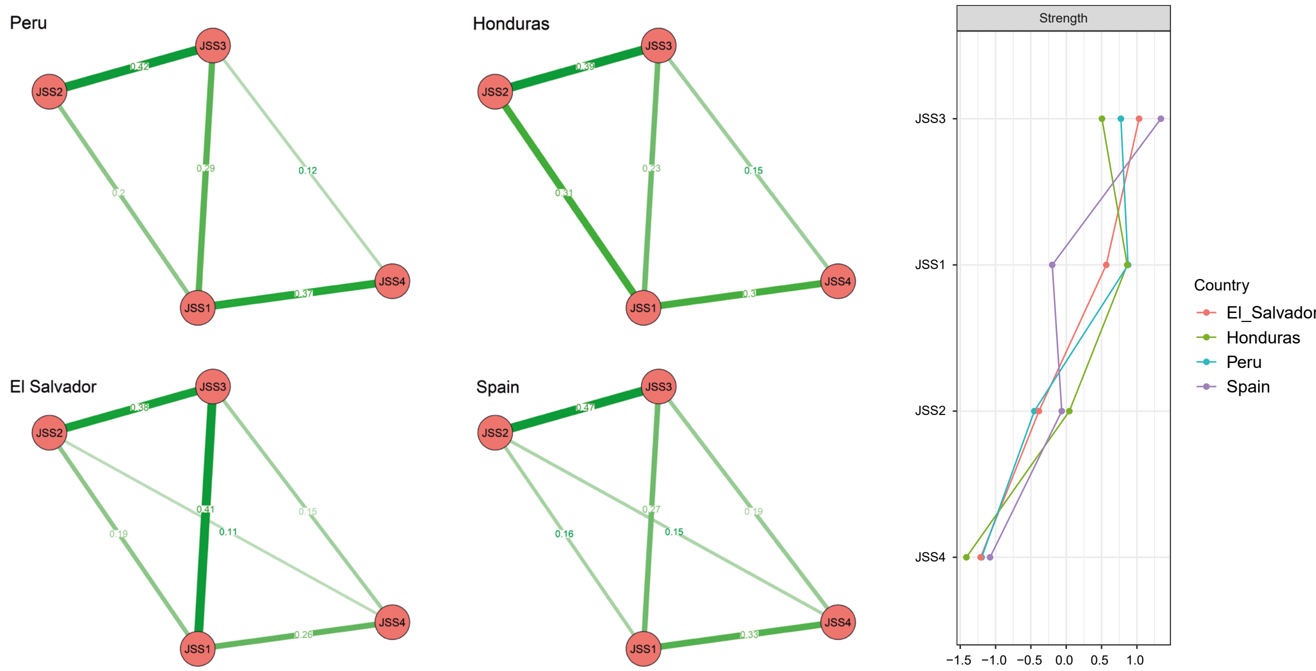

Figure 3. Networks by country

stronger in Spain (r = .15) than in Honduras (r = .11). Additionally, in Honduras, the strongest correlation was observed between JSS1 (difficulty falling asleep) and JSS3 (difficulty staying asleep).

The results regarding the precision and stability of the networks by country are shown in Figures 4 and 5, respectively. These figures demonstrate a good overlap between the bootstrap and empirical data across all the countries. Specifically, the stability coefficients of the networks were above 0.25 for Peru (CS = 0.52), El Salvador (CS = 0.59), Honduras (CS = 0.67), and Spain (CS = 0.28) indicating that the networks were precise.

Similarly, the stability of the Strength index was adequate for Peru (CS = 0.59), El Salvador (CS = 0.67) and Honduras (CS = 0.52). However, no stability was observed for this index in Spain (CS = 0.21).

The most relevant node in Spain and El Salvador was JSS3 (*difficulty staying asleep*), whereas in Peru and Honduras, it was JSS1 (*difficulty falling asleep*). However, the findings indicate that the networks of the four countries are generally invariant, as the p-values for the M statistic were greater than .05. Nonetheless, differences in centrality were observed between the networks of Peru-Spain (S = .18; p = .01), El Salvador-Honduras (S = .13; p = .02), and Honduras-Spain (S = .19; p = .01), as the p-values for the S statistic were below .05. Additionally, the highest and lowest correlations between adjacency matrices were found between the networks of Peru-Spain (r = .94) and El Salvador-Honduras (r = .60), respectively (see Table 3).

Table 3. Correlation between adjacent matrices

Groups	*M*	*p*	*S*	*p*	*rs*
Peru - El Salvador	0.13	0.54	0.11	0.08	0.83
Peru - Honduras	0.11	0.38	0.02	0.79	0.83
Peru - Spain	0.15	0.56	0.18	0.01	0.94
El Salvador - Honduras	0.18	0.09	0.13	0.02	0.60
El Salvador - Spain	0.14	0.79	0.07	0.30	0.77
Honduras - Spain	0.15	0.30	0.19	0.01	0.66

Note: *M* = M statistic used to assess the invariance of the overall network structure; *S* = S statistic used to assess the invariance of specific edge weights; *p* = p-value (significance level set at .05); *rs* = Spearman correlation coefficient.

The results of the moderated network analysis identified two significant interactions (Figure 6): between *Difficulty Falling Asleep* and *Tiredness on Awakening* (weight = .929), and between *Nighttime Awakenings* and *Difficulty Staying Asleep* (weight = 1.854). However, the stability of the moderation effects was suboptimal, as they were below the 50% threshold, supporting the notion that the network structure is invariant across countries.

Discussion

Sleep issues are the second most common mental health issue worldwide (Qi et al., 2023). However, as previously mentioned, sleep quality issues have traditionally been examined using classical approaches that rely on total scores from various instruments to describe problem

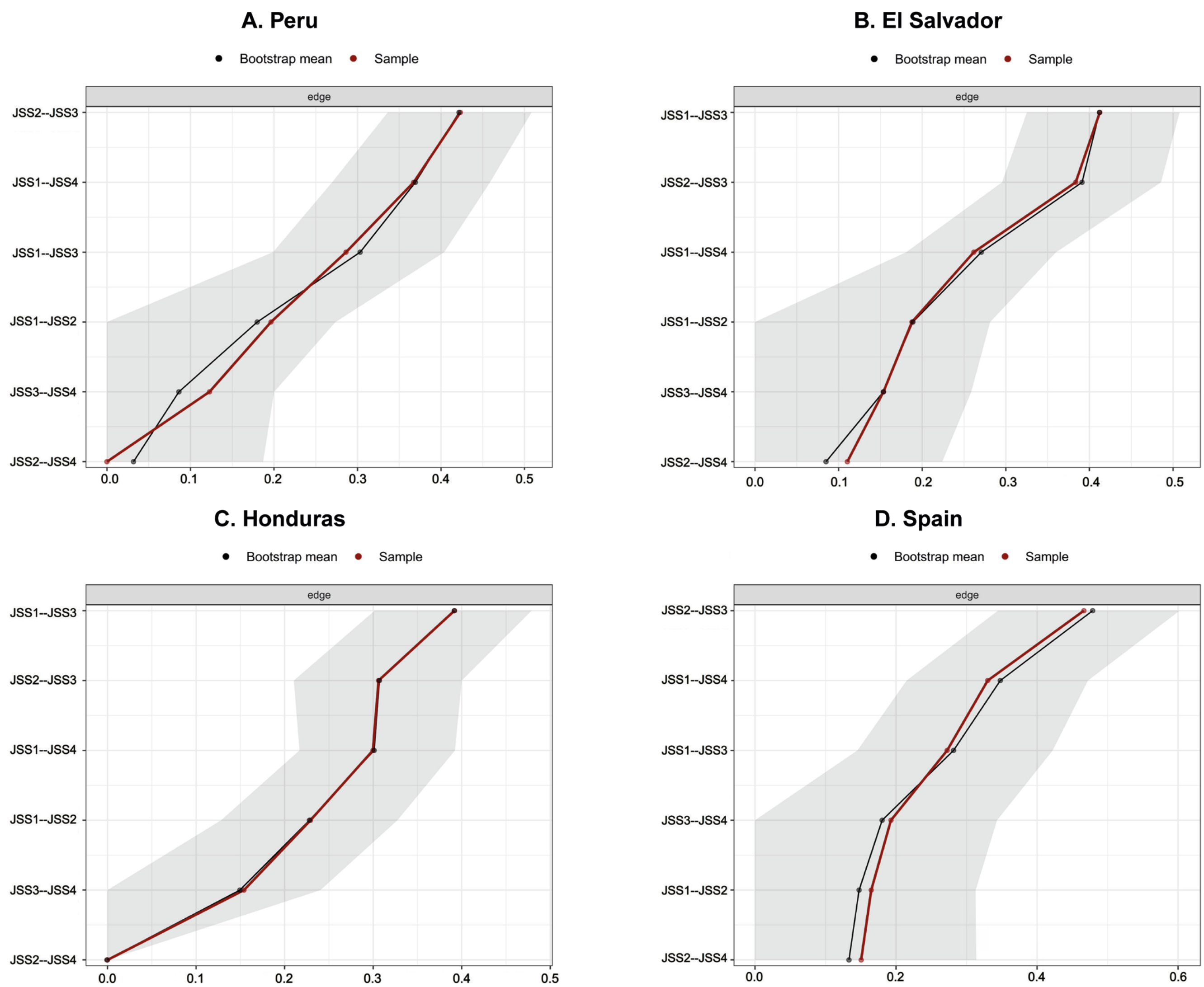

Figure 4. Precision through 95% non-parametric bootstrap confidence intervals of the estimated network edges for each country

severity and its relationship with other variables (Duo et al., 2023; Itani et al., 2017; Perlis et al., 2022; Rodrigues & Shigaeff, 2022). These methods limit the understanding of the meaningful relationships between individual sleep quality symptoms (Borsboom & Cramer, 2013). To our knowledge, this is the first study to characterise the network structure of sleep quality symptoms in the general population across four Spanish-speaking countries in Latin America and Europe.

For the combined analysis of the four countries, the most central node was *difficulty staying asleep*, indicating that it was the most relevant symptom in the network. This finding is consistent with those of previous studies conducted in different contexts (Astill Wright et al., 2021; Bai et al., 2022; Takano et al., 2023a; Yupanqui-Lorenzo et al., 2024). This is expected, as difficulty staying asleep is a significant symptom of sleep disorders (American Psychiatric Association, 2013) and is often associated with changes in sleep architecture, such as reduced slow-wave sleep or increased rapid eye movement (REM) sleep (Cha et al., 2022). Consequently, the Strength value for *difficulty staying asleep* was higher than that for other sleep quality symptoms, suggesting that changes in this symptom may influence other symptoms. In the context of the four Spanish-speaking countries studied, *difficulty staying asleep* may be an essential focus for intervention and evaluation, particularly for the early detection of sleep quality issues. This symptom was strongly related to *waking up multiple times during the night* and *difficulty falling asleep*. These associations suggest that alongside the issue of maintaining sleep, difficulty initiating sleep and waking up multiple times may be critical symptoms to target for interventions aimed at reducing the severity of sleep quality issues (Takano et al., 2023b).

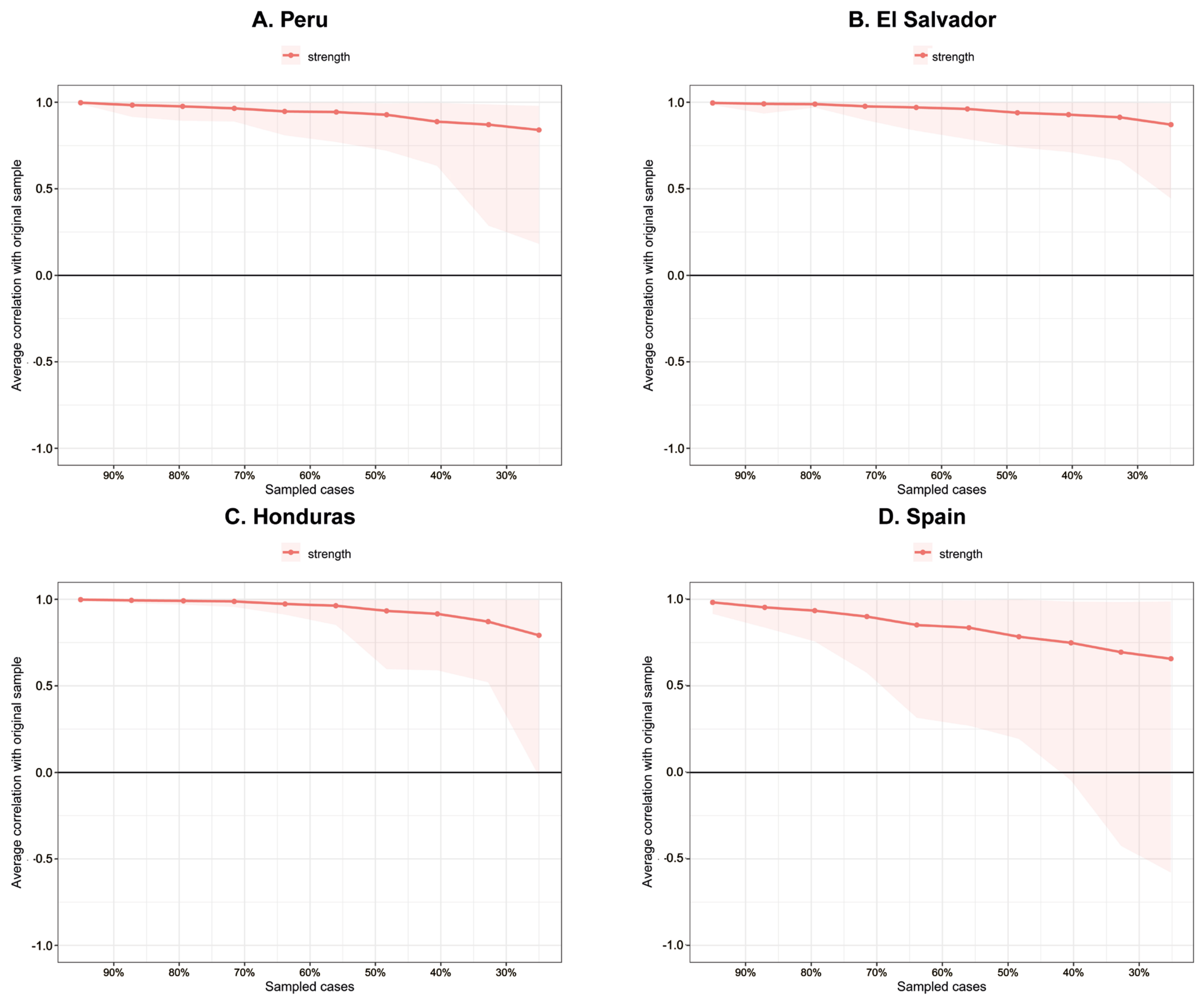

Figure 5. Stability of the centrality index for each country

When examining networks by country, the networks were precise and showed stable Strength values across all countries except Spain, where the Strength stability was below expectations. Variability in the centrality of sleep quality symptoms was observed across participating countries. In Spain and El Salvador, the most central symptom was *difficulty staying asleep*. In Spain, this finding aligns with reports that approximately 20% of Spanish adults experience difficulties falling or staying asleep (Ohayon & Sagales, 2010). A previous Spanish study suggested that difficulties in maintaining sleep might be linked to increased irritability, less efficient homeostatic processes, or higher arousal levels, especially among Spaniards who do not nap, thereby affecting their perception of sleep depth (Vela-Bueno et al., 2008). These findings are significant considering that approximately 35% of Spaniards nap, primarily for relaxation (49%) or fatigue (36%), with an average of four naps per week (Vizmanos et al., 2023). Similar percentages have been reported in other European, American, and Asian countries (Faraut et al., 2017). However, the low Strength stability in Spain suggests that central symptoms may vary in future studies.

In El Salvador, a previous study also identified *difficulty staying asleep* as one of the most critical symptoms within the sleep quality network, particularly in relation to depression, anxiety, and exhaustion symptoms (Yupanqui-Lorenzo et al., 2024). The same study proposed that individuals with difficulty staying asleep might also experience a higher likelihood of nocturnal awakening (Biggs et al., 2020).

In Peru and Honduras, the most central symptom was *difficulty falling asleep*. In Peru, this finding aligns with prior research, which also identified *difficulty falling asleep* as the most central symptom (Yupanqui-Lorenzo et al., 2024). Additionally, in these two countries, *difficulty falling asleep* was strongly related to *difficulty staying asleep*. A previous Peruvian study sug-

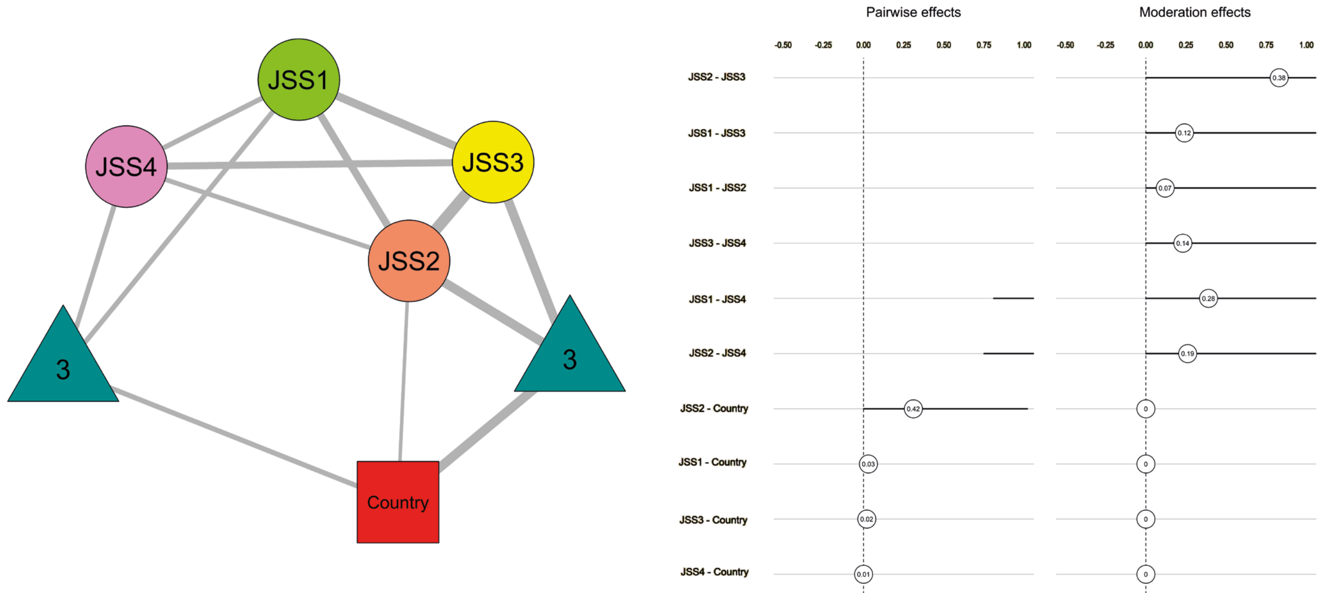

Figure 6. Moderated Network Model of sleep quality symptoms and country. Circular nodes represent variables, while triangular nodes labelled with a "3" indicate moderation effects, corresponding to three-way interactions

gested that difficulty falling asleep might be associated with functional dyspepsia symptoms, a condition involving digestive tract issues without an organic origin (Ramírez-Vásquez & Mejia, 2018). This relationship is significant considering that Peru has one of the highest prevalence rates of gastrointestinal problems, such as irritable bowel syndrome, in Latin America (Pontet & Olano, 2021). Another study suggested that relaxation and nervousness issues might contribute to sleep initiation problems in Peru (Baños-Chaparro et al., 2022). No prior study has explored this phenomenon in Honduras. However, depressive symptoms have been linked to difficulty in falling asleep in various cultural contexts (Takano et al., 2023a; Xie et al., 2024). This is particularly relevant given that 30–39% of the Honduran population experiences depressive symptoms (Fountoulakis et al., 2022; González et al., 2018), which may be exacerbated by economic instability, unemployment, loneliness, and other challenges in Honduras and Central America (Espinoza-Turcios et al., 2023).

Although network models have faced criticism for limited replicability across samples with varying characteristics (Forbes et al., 2017), the present findings indicate that at a general level, the sleep quality symptom networks of the four countries are invariant. This suggests that the network structures of sleep quality symptoms are similar in Peru, El Salvador, Honduras, and Spain, providing insight into how these symptoms manifest in different countries. To our knowledge, no prior studies have compared sleep quality symptoms using the JSS through a network analysis in Spanish-speaking countries. This finding is even more valuable when considering the various ways that cultural contexts influence sleep (Cheung et al., 2021). Anthropological and epidemiological studies have indicated diverse sleep parameters across cultures (Airhihenbuwa et al., 2016; Jenni & Werner, 2011). For instance, while monophasic sleep patterns are typical in industrialised countries, biphasic sleep is more common in the Mediterranean and South American countries (Samson et al., 2017).

Regarding the moderated network analysis, it was found that country positively moderated the effect between *Nighttime Awakenings* and *Difficulty Staying Asleep*. This suggests that, in the general adult population, the strength of this relationship may systematically vary depending on participants' country of origin. Additionally, it was observed that country also positively moderated the effect of *Difficulty Falling Asleep* on *Tiredness on Awakening*, although this effect did not exhibit sufficient stability. The lack of stability in this moderation effect implies that it may depend on more specific factors or be subject to sample variability. In contexts where this moderation effect is stronger—such as in our study's sample from Honduras—it is possible that cultural, environmental, or healthcare system factors influence the way in which *Nighttime Awakenings* translate into greater *Difficulty Staying Asleep*. As previously noted, mental health symptoms associated with difficulties falling asleep may be influenced by economic instability, unemployment, loneliness, and other challenges that are particularly prevalent in Honduras and other Central American countries (Espinoza-Turcios et al., 2023). Previous studies have reported changes in sleep routines and increased sleep disturbances, especially in samples from Latin America and the Caribbean, compared to countries in North America, Europe, or Central Asia (Yuksel et al., 2021), a pattern consistent with the findings of the present study. The inadequate stability of the country's moderating effect on the relationship between *Difficulty Falling Asleep* and *Tiredness on Awakening* may reflect methodological differences in how the evaluated symptoms (in this case, sleep quality symptoms) are measured or reported across cultures (Haslbeck, 2022; Walters & Simons, 2022). This aligns with a recent review noting that, while various self-report instruments used to assess sleep quality in different contexts demonstrate adequate psychometric properties, many do not clearly define the underlying theoretical model of the constructs being measured, nor do they offer reliable cutoff scores that health professionals can use to distinguish between poor and good sleepers (Fabbri et al., 2021).

Limitations

Our findings should be interpreted in the light of certain limitations. First, the study's cross-sectional design did not allow causal inferences regarding the directionality of the associations between sleep quality symptoms. Future research should incorporate longitudinal network analyses to examine temporal perspectives (Snijders, 2009). Second, the non-probabilistic sampling approach limited the generalisability of the results to a broader population. Additionally, the use of snowball sampling may have led to the omission of important confounding factors, such as homophily, defined as the tendency of individuals to associate and form relationships with others who share similar characteristics, traits, or values. In this context, it is possible that participants experiencing sleep deprivation may have recruited others who also suffer from sleep deprivation. Future studies should employ probabilistic sampling methods to minimise the presence of confounding factors and improve the generalisability of the findings. Third, although the JSS is a psychometrically robust instrument (Fabbri et al., 2021; Jahrami et al., 2024), it lacks the details of longer questionnaires. Future research should use scales such as the Pittsburgh Sleep Quality Index (PSQI) to capture more comprehensive symptom interactions. Fourth, self-reported measures may introduce a social desirability bias. Additionally, using the JSS instead of clinical interviews precludes the identification of atypical features of sleep quality problems and potentially biased results. Future studies should include objective observations and clinical interviews. Finally, findings on symptom centrality should be cautiously interpreted, as further empirical research is needed to validate the results.

Implications

The results offer a starting point for understanding sleep quality symptom associations through network analysis in Spanish-speaking countries. Unlike traditional models that rely on latent constructs (Schmittmann et al., 2013), network analysis provides a detailed framework for conceptualising sleep quality by highlighting the direct relationships between symptoms. Identifying highly central symptoms can inform interventions targeting interconnected symptoms to improve sleep quality. For example, *difficulty staying asleep* emerged as a central symptom across the four countries, suggesting that it should be a key intervention focus. Cognitive-behavioural therapy (CBT) has been shown to improve symptoms by addressing related issues, such as worry and sleep inefficiency (Benz et al., 2020; Van Straten et al., 2018). Behavioural therapy improves sleep efficiency and dissatisfaction, while cognitive therapy addresses sleep initiation problems and early awakenings (Blanken et al., 2021; Takano et al., 2023b). The findings support the use of brief and specific tools such as the JSS for screening central sleep quality symptoms. Early detection can reduce the psychological burden and guide healthcare systems towards targeted interventions.

Conclusion

In conclusion, *difficulty staying asleep* was identified as the most central and relevant symptom in the sleep quality network across the total sample. However, specific analyses revealed that in Spain and El Salvador, the most central symptom was *difficulty staying asleep*, whereas in Peru and Honduras, it was *difficulty falling asleep*. Country-level network comparisons indicate that, at a general level, the sleep quality symptom networks of the four countries are invariant; however, the strength of the relationships between symptoms may systematically vary depending on the participants' country of origin.

Authorship contribution statement

DEY-L and TC-R provided initial conception, organisation, and main writing of the text. AS-V analysed the data and prepared all figures and Tables. LP-L, TA-L, MEL-R, EC-Z, M-IM-S, JB-Ch, JT, IB and NAB-A were involved in data collection and acted as consultants and contributors to research design, data analysis, and text writing. The first draft of the manuscript was written by TC-R, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declaration of competing interest

The authors have no competing or conflicting interests.

Informed Consent Statement

Informed consent was provided by all participants.

Data Availability Statement

The anonymised data (https://osf.io/nat24), as well as the R code used for analyses (https://osf.io/q3s6t), are also available on the Open Science Framework (https://osf.io/s4qtk/).

Additional information

No additional information is available for this paper.

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Permission of the original creators of the instrument

Permission was not necessary

Ethics approval

This study analysed a subset of data from a larger research project entitled “Study on Psychological Factors Associated with Sleep and Rest,” which received ethical approval from the Research Ethics Committee of the Universidad de Ciencias y Humanidades (approval code: 055-23).

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