

How Mental Health and Diabetes Shape Sleep Problems: A Holistic, Population-Based Study

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Abstract

This project investigates the complex relationship between self-reported diabetes, mental health and sleep problems in the Spanish population. The cross-sectional research project applied logistic regression and hierarchical cluster analysis to study a sample of 23,019 participants of Spain's National Health Survey (NHS 2017). Although diabetes demonstrated a significant effect (OR: 1.36, 95% CI [1.23-1.50]), in multivariate analysis was not found to be an independent risk factor for sleep problems after adjusting for depression (OR: 4.96, 95% CI [4.56 - 5.39]) and anxiety (OR: 1.93, 95% CI [1.73 - 2.16]), socio-demographic factors, and self-perceived health (OR: 1.31, 95% CI [1.28-1.34]), were found to be stronger predictors of having sleep disturbances significantly and diminishing the effect of diabetes. Hierarchical cluster analysis permitted to aggregate this population into 5 homogeneous groups based on their mental and emotional conditions measured by the General Health Questionnaire. These 5 clusters showed significant inter-group heterogeneity in their composition, including the prevalence of sleep disorders and diabetes. As the emotional burden increased across the clusters, the prevalence of diabetes, depression, and sleep problems increased. These findings suggest that sleep disorders aggregate in groups with higher prevalence of diabetes and mental and emotional distress, and reinforce the importance of addressing emotional distress and socio-demographic factors for better diabetes management and improvement of sleep quality.

Introduction

Sleep problems are a prevalent global health concern, significantly impacting physical and mental well-being. Poor sleep quality and disorders such as insomnia and sleep apnea affect up to 30% of adults worldwide, contributing to reduced productivity, impaired cognitive function and increased risks of chronic diseases (Grandner, 2022). Type 2 Diabetes Mellitus (T2DM) is one of these chronic diseases, and it affects millions of people across the world. According to the World Health Organization (WHO) (2024), in 2022, there were 830 million people with diabetes. One of the comorbidities associated with T2DM is sleep disturbances, which diminish quality of life and may worsen diabetic symptoms (Luyster & Dunbar-Jacob, 2011). In order to ease the burden of diabetes, it is important to study this intersection. In particular, exploring how socio-demographic, emotional and psychological factors mediate the bidirectional relationship between diabetes and sleep may influence future care for patients with T2DM. It is known that the disease is associated with older age, family history (Diabetes Prevention Program Research Group, 2015) and lifestyle (American Diabetes Association, 2023). The mechanism of T2DM involves the body's inability to produce insulin, causing hyperglycemia. Beyond these direct metabolic consequences, T2DM is strongly associated with comorbidities such as cardiovascular disease, neuropathy and mental health disorders (Brzecka et al., 2020). Notably, sleep disturbances, such as sleep apnea, are prevalent in up to 58% of diabetic patients, creating a cyclical relationship where poor glycemic control disrupts sleep, and inadequate sleep further impairs glucose metabolism (Khalil et al., 2020; Reutrakul & Van Cauter, 2014). However, emerging evidence suggests that this relationship is not isolated; it is mediated or moderated by a complex network of socio-demographic, emotional, and psychological factors. For instance, age and economic status can make certain groups more vulnerable to both diabetes and sleep disorders. Older adults with diabetes are at higher risk for insomnia due to age-related changes in their sleep-wake cycles (Grandner, 2022). Similarly, low-income individuals experience higher rates of sleep apnea, often because of limited healthcare access and stress related to financial instability (Papadopoulos & Sosso, 2023). Emotional factors such as chronic stress and poor emotional regulation can increase the physical impact of diabetes, leading to poorer sleep quality through increased cortisol levels at night (Reutrakul & Van Cauter, 2014). Additionally, a lack of strong spousal support and emotional stress lead to higher blood sugar levels in diabetic patients (Rook et al., 2016). There is also a lot of evidence of bidirectionality between depression and diabetes (Basiri et al., 2023; Peleg et al., 2019; Shinalieva et al., 2023). Overall, there are multiple sources that indicate interactions between sleep, diabetes, mental health and socio-demographic factors.

Shinalieva et al. (2023) studied how insomnia affected depression and anxiety in 376 T2DM patients who lacked glycemic control. The research team found a strong association between the severity of insomnia, anxiety and depression, suggesting that sleep disturbances act as a pathway for psychological comorbidities. (OR: 1.09 - 1.10) However, the study had some limitations. The research team chose to include only patients with uncontrollable diabetes. Thus, their findings cannot be applied to patients with stable glycemic control. Also, the researchers did not consider socio-demographic factors, which could influence both mental health, diabetes and sleep. Hence, a broader research scope is needed.

Similarly, Coccaro et al. (2020) investigated how emotional regulation skills and negative emotionality influenced the burden of diabetes in T1DM and T2DM adults.. The findings showed that

negative emotionality and poor emotional regulation were associated with a higher prevalence of depressive symptoms ($\beta = 0.45$). After adjusting for diabetes self-care and self-perceived stress level, the association remained moderate, only decreasing by 18% ($\beta = 0.38$). This underscores the importance of emotional factors in diabetes-related distress. However, the study had a limitation. The sample of patients was drawn from a diabetes clinic, meaning many of the enrolled patients could already have psychological issues and the feeling of a burden. Thus, the group could not represent the general population. Hence, the results could not be applicable to any diabetic person.

It is worth noting that Peleg et al. (2019) studied the association between sleep problems, depression, and T2DM. They compared 107 T2DM patients with 48 prediabetic and 154 healthy patients. The research team found that people with diabetes had worse sleep quality and more depressive symptoms than other groups (72.9% vs 43.5%). The most important results of this research were that depression fully mediated the association between sleep issues and diabetes. Thus, the original sleep-diabetes association (OR=1.04, 95% CI [1.01-1.07]) became zero (OR = 1.0, $p = 0.84$). Depression alone strongly predicted diabetes as well. This suggests that treating depression in people with sleep issues might prevent the development of diabetes. Yet, the study was based on self-reported data, which might be inaccurate. Since the study was cross-sectional, causation between depression and diabetes could not be proved.

Lou et al. (2015) conducted a study of 944 Chinese patients with T2DM. The study shares results that a significant portion of diabetic people reported poor sleep quality. The researchers justified this trend by a lower quality of life, which was associated ($p < 0.001$) with lasting diabetes burden, comorbidities, mental health problems, etc. Yet, the study did not examine the role of sociodemographic factors that might mediate these effects.

Rook et al. (2016) investigated how emotional stress reactivity and spousal support influenced fasting blood glucose in 129 older adults with T2DM. The study provided mixed results. The research team discovered that a higher stress response was linked to greater fluctuations in fasting glucose levels ($p = 0.015$). Yet, patients with greater spousal support also showed higher levels of fasting glucose. Also, higher stress response combined with low spousal support led to elevated average glucose levels ($p = 0.001$). All in all, spousal support proved itself to be a strong factor, influencing the burden of diabetes. Yet, the study's focus on diabetic individuals only limits understanding of how stress reactivity might affect people without diabetes or those in pre-disease stages.

Papadopoulos and Eindele Sosso (2023) reviewed 336 studies to explore the connection between socioeconomic status and sleep health. Their analysis showed that people with low socioeconomic status are more likely to experience poor sleep. For instance, people with lower socioeconomic status experienced longer time for falling asleep ($p < 0.001$), frequent awakenings during sleep ($p = 0.012$), and insomnia (75-94.1% of studies, $p < 0.001$). These problems are influenced by factors such as chronic stress, limited access to healthcare, and unhealthy lifestyle choices.

Similarly, Basiri et al. (2023) explored bidirectional relationships between diabetes, depression, and anxiety. They found that people with depression/anxiety have a higher chance of developing T2DM ($r = 1.60$, $p < 0.001$). The research team also emphasized the mediating role of nutrition in this association. Their results indicate that diets with higher sugar and processed foods are associated with a higher risk of developing diabetes ($p < 0.05$), and vice versa. This study underlined

the importance of nutrition in the prevention of the development of diabetes comorbidities, such as depression. However, the study did not examine sleep disturbances, an important factor that links diabetes and mental health, leaving a gap in understanding how these overlapping risks affect overall health.

Considering current research outcomes, there is a need for a broader, holistic approach to the problem of sleep issues in a diabetic population. For instance, none of the studies examined how socio-demographic factors could moderate the relationship. Shinalieva et al. (2023) and Coccaro et al. (2021) focused on clinical or psychological variables but overlooked economic disparities, while Lou et al. (2015) included income but did not analyze its interaction with emotional regulation.

This study addresses a critical gap in the literature by proposing a multidimensional framework to examine how socio-demographic, emotional, and mental health factors intersect with diabetes to influence sleep outcomes. We aim to summarize the characteristics of the study sample, explore diabetes as an effect modifier in this relationship, and assess the combined impact of socio-demographic factors, emotional variables, depression, anxiety, and diabetes on sleep problems. Specifically, we investigate whether economic status and education level moderate sleep problem severity in diabetic populations, how emotional variables (e.g., happiness, concentration difficulties) mediate the diabetes-sleep relationship, and the extent to which depression and anxiety amplify or diminish the effect of diabetes on sleep quality. By integrating these factors, our research moves beyond simplistic cause-effect models to reveal how overlapping vulnerabilities create unique risk profiles for sleep disturbances in individuals with diabetes. Understanding these relationships is crucial for effective disease management and diagnosis. Building on prior studies, we control for key confounders to provide a more nuanced analysis. This study aims to explore the relationship between depression, anxiety, and sleep problems in individuals with and without diabetes while accounting for age, sex, and comorbidities. Due to the exploratory nature of this research, we do not presuppose a specific association. Yet, we seek to identify potential patterns or interactions among these variables. The aim of the study was to explore the relationships between diabetes, sleep disturbances and mental health problems in the Spanish population.

Specific aim(s):

1. Characterize the relationship between T2DM, sleep issues and mental health problems in the Spanish population;
2. Investigate how socio-demographic factors mediate the association between sleep problems and T2DM;
3. Investigate how emotional factors mediate the association between sleep problems and T2DM.

Materials and Methods

Study Design and Participants

The research was designed as a retrospective study analysing secondary data. The database used for the analysis was obtained from the National Health Survey of 2017 (NHS 2017), a nationally representative survey of the general population of Spain with 23,019 participants. The dataset included comprehensive information on health status, lifestyle and sociodemographic characteristics.

Ethics

Ethical approval was not required for this study, as the analysis was based on an anonymised, publicly available database from the NHS 2017. There was no identifiable private information, ensuring the participants' confidentiality. All procedures adhered to the ethical guidelines for the use of publicly available data in research.

Variable Recoding

To simplify the analysis and interpretation, several variables were recoded into categorical or binary formats. For binary variables, values were assigned as 0 (indicating “no” or absence of a condition) and 1 (indicating “yes” or presence of a condition). Self-perceived health in the last 12 months, which was measured with the Likert scale, was recoded into two groups : 0 for Fair, Poor, and Very poor, and 1 for Very good and Good. Similarly, responses to whether the participants recently lost much sleep over worry (Not at all, No more than usual, Rather more than usual, Much more than usual) were recoded as 0 for Not at all and No more than usual, and 1 for Rather more than usual and Much more than usual. This binary recoding approach was applied consistently to additional emotional variables: ability to concentrate, feeling useful, ability to make decisions, enjoyment of daily activities, overall happiness, losing confidence, feeling worthless, and feeling unhappy. Additionally, continuous and categorical variables were recoded into ordinal categories. Age was recoded into three groups: Young Adults (15-44) = 0, Middle-Aged Adults (45-64) = 1, and Older Adults (65+) = 2. Education level was recoded as Basic Education (Less than elementary, Elementary, Junior High School) = 0, Secondary Education (High School, Vocational) = 1, and Higher Education (University) = 2. Economic status was recoded as Not Working - Long-Term (Retired, Disabled, At Home, Other) = 0, Working = 1, and Not Working - Temporary (Unemployed, Student) = 2. These recoding strategies ensured consistent and clear analysis.

Statistical Analysis

Statistical analysis was performed using IBM SPSS version 23. The analysis included descriptive and inferential statistics, including 2 different types of analysis: 1) univariate and multivariate logistic regression analysis to determine the possible association of diabetes with sleep problem, adjusted by relevant variables, using binary logistic regression analysis; and 2) hierarchical cluster analysis with dendrogram construction to identify patterns and homogeneities within the data. Cluster analysis used Ward's method and binary Squared Euclidean distance for measurements. The cluster analysis was based on the following binary emotional variables that are included in the survey from the 12-Item General Health Questionnaire (GHQ-12): “Ability to Concentrate”, “Feeling Useful”, “Ability to Make Decisions”, “Feeling Under Strain”, “Inability to Overcome Difficulties”,

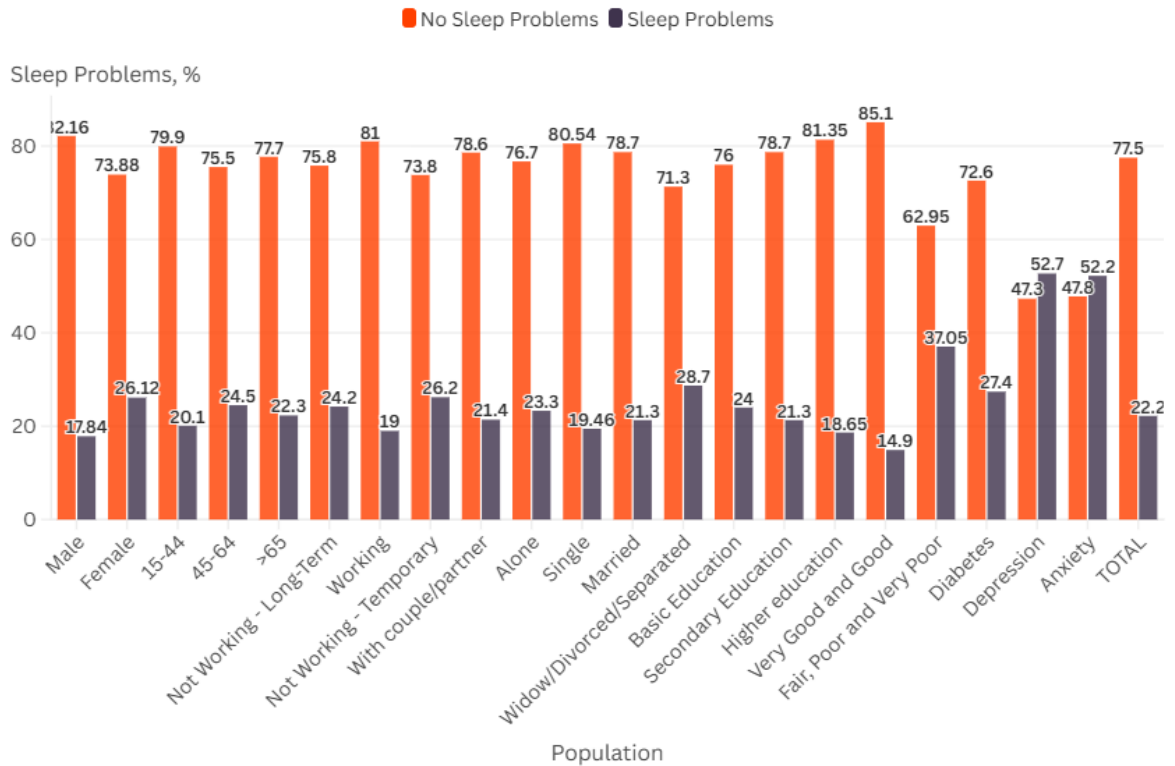
“Enjoying life”, “Feeling Unhappy”, “Losing Confidence”, “Feeling Worthless”, “Overall Happiness”.

Results

Our study aimed to investigate the relationship between depression, anxiety, and sleep problems in individuals with or without diabetes, controlling for age, sex and comorbidities. We conducted a secondary analysis of the National Health Survey of 2017 (NHS 2017), a nationally representative dataset of the general population of Spain. The study population included 23,019 participants stratified by demographic and health-related variables, as shown in Table S1. Figure 1 illustrates the main variables analysed in the presence of sleep issues. Overall, the prevalence of persons reporting sleep problems was 22.20%. Significant variations in this prevalence were also identified by relevant variables. The sample comprised 8,681 males (82.16% without sleep problems, 17.84% with sleep problems) and 9,202 females (73.98% without sleep problems, 26.12% with sleep problems), with a median age of 53 years (interquartile range: 39-68 years).

Figure 1

Socio-Demographic Characteristics by Sleep Problems

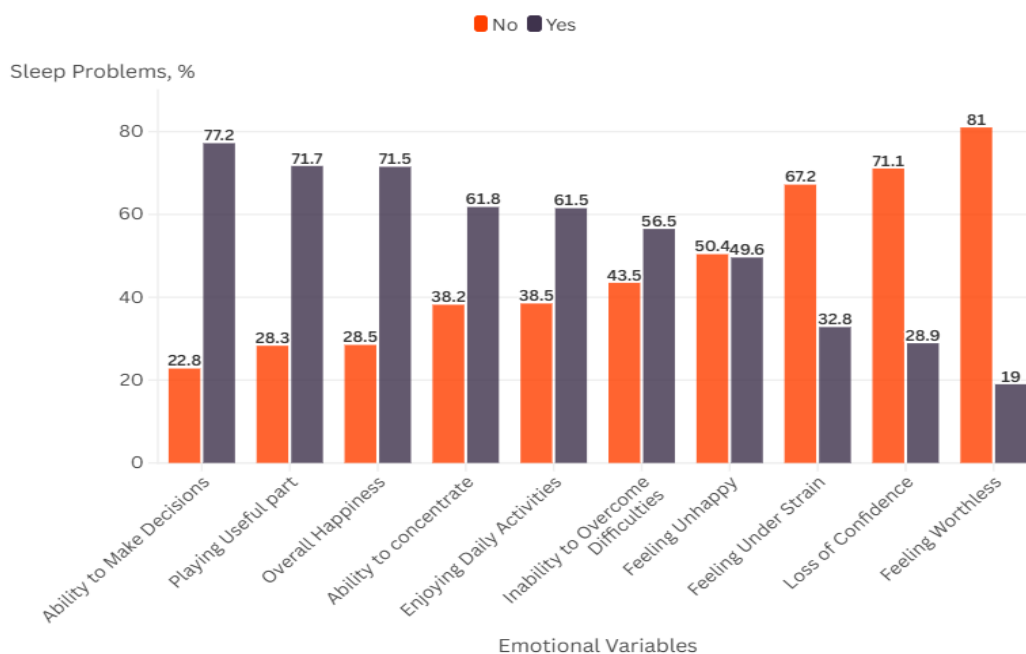


The chi-square analysis demonstrated significant associations (with a p-value less than 0.05) between sleep problems and all examined variables (Table S1). There was a notable sex difference ($\chi^2 = 225.314$, $p = 0.000$), with women more likely to report sleep issues than men (26.12% vs. 17.84%). Age showed a strong association ($\chi^2 = 181.047$, $p = 0.000$), with the middle-aged group (45-64 years) having the highest sleep problem prevalence (24.5%). Economic activity ($\chi^2 = 116.636$, $p = 0.000$) highlighted unequal distribution of sleep problems between the temporarily non-working population (unemployed/students) and working population (26.2% vs. 19.0%). Marital Status ($\chi^2 = 147.662$, $p = 0.000$) showed that widow/divorced individuals had the highest sleep problem rates (28.7%), while

single people had the lowest (19.46%). Education level ($\chi^2 = 56.803$, $p = 0.000$) demonstrated a protective effect, with less sleep problems in highly educated people (18.65% vs. 24.0% basic education). Self-perceived health status ($\chi^2 = 1449.597$, $p = 0.000$) had a strong gradient: people with poor/very poor health had a higher prevalence of sleep problems in comparison with people with good/very good health (37.05% vs. 14.90%). Having chronic conditions such as diabetes ($\chi^2 = 37.365$, $p = 0.000$), depression ($\chi^2 = 1604.083$, $p = 0.000$) and anxiety ($\chi^2 = 1302.858$, $p = 0.000$) was associated with a higher prevalence of sleep problems (27.40%, 52.70% and 52.20%, respectively). Surprisingly, relatively low frequency of sleep issues was associated with negative emotionality (Table S2; Figure 2). For instance, feeling unhappy ($\chi^2 = 5846.288$, $p = 0.000$, 49.60%), not enjoying daily activities ($\chi^2 = 4092.206$, $p = 0.000$, 38.50%), feeling worthless ($\chi^2 = 2127.643$, $p = 0.000$, 19.00%), losing confidence ($\chi^2 = 3296.945$, $p = 0.000$, 28.90%), inability to concentrate ($\chi^2 = 4051.949$, $p = 0.000$, 38.20%), inability to make decisions ($\chi^2 = 2538.887$, $p = 0.000$, 22.80%) correlated with sleep disturbances. Moreover, the ability to overcome difficulties was also associated with poorer sleep ($\chi^2 = 5032.339$, $p = 0.000$, 43.50%).

Figure 2

Emotional Characteristics by Sleep Problems



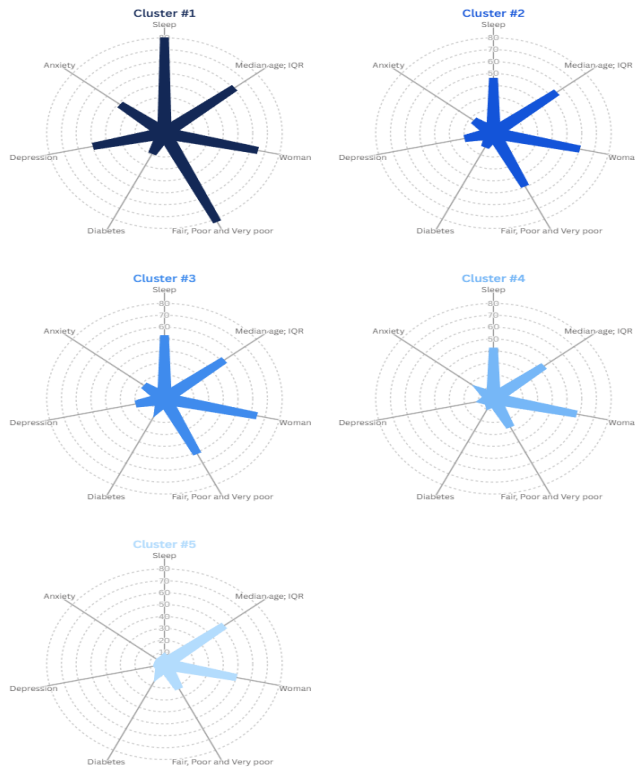
The binary logistic regression analyses showed insights into the relationship between diabetes and sleep problems. In the initial model (Table S3), diabetes demonstrated a significant individual effect with the odds ratio (OR) of 1.36 (95% CI [1.23-1.50]). This indicated a moderate association with sleep issues. Yet, this association became insignificant after being adjusted for such factors as depression (OR: 2.49; 95% CI [2.25-2.77]), anxiety (OR: 1.93; 95% CI [1.73-2.16]) and poor self-perceived health status (OR: 1.29; 95% CI [1.27-1.31]). This tendency was also observed in the further forward conditional logistic regression (Table S4). The diabetes variable was excluded entirely due to its negligible effect on sleep problems after adjusting to such predictors as depression (OR: 4.96; 95% CI [4.56-5.39]), self-perceived health status (OR: 1.27; 95% CI [1.25-1.29]), age groups (OR for middle-aged/older adults: 1.74-1.61) and sex (OR: 1.37; 95% CI [1.28-1.47]). These findings

contradicted our initial goal, which presumed diabetes to be a solid risk factor for having sleep disturbances. The results of the logistic regression modelling suggest that the association between sleep issues and diabetes may be mediated by other variables such as mental health and socio-demographic factors.

Given these limitations, we switched to hierarchical cluster analysis to aggregate patients based on their emotional characteristics. This method allowed us to explore patients' unobserved, unsupervised shared characteristics without assuming cause and effect. Thus, instead of focusing on single risk factors, we aimed to reveal diverse subgroups with shared characteristics. The cluster analysis was useful, as it simulated real-world complexity, where there are many unseen interactions and connections between health-related factors. The number of valid cases was 22,831 (98.9% of the total population). The resulting dendrogram (Figure S1) was analysed, and 5 clusters were chosen for further crosstabulation. Table S5 and Figure 3 demonstrate the results of the hierarchical cluster analysis cross-tabulated with calculated mean age, sleep problems, diabetes, depression, anxiety, etc. Table S6 and Figure 4 report the distribution of emotional variables in populations of each cluster. Across all clusters, women represented the majority of participants, with the highest proportion in cluster #1 (65.1%) and the lowest in cluster #5 (50.2%) (Table S5). Cluster #1, was characterised by patients with low scores in the ability to concentrate (26.3%), feeling useful (27.2%), the ability to make decisions (41.0%), feeling under strain (12.8%), inability to overcome difficulties (10.3%), enjoying life (16.9%), overall happiness (30.7%), and high scores in feeling unhappy (88.3%), losing confidence (75.9%), feeling worthless (59.8%) (Table S6). The median age of the population of cluster #1 was 61.64 years old, reporting the highest prevalence of sleep problems (80.3%) and the highest proportion of poor self-perceived health status (82.6%) (Figure 3). In comparison with other clusters, patients included in cluster #1 were susceptible to diabetes (19.0%), depression (49.8%) and anxiety (38.5%) the most (Figure 3).

Figure 3

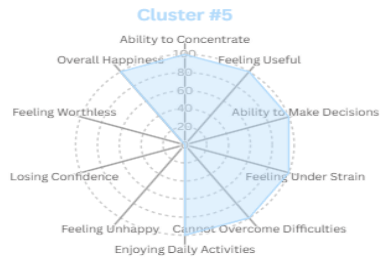
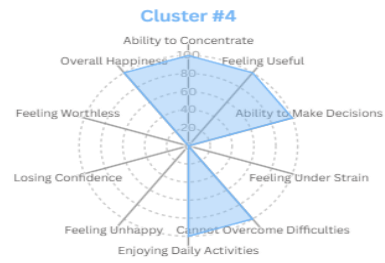
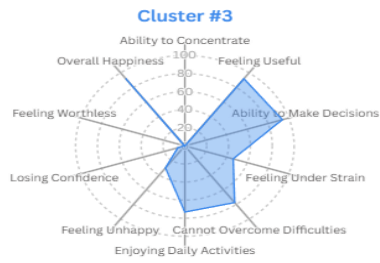
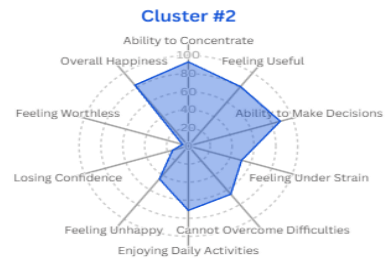
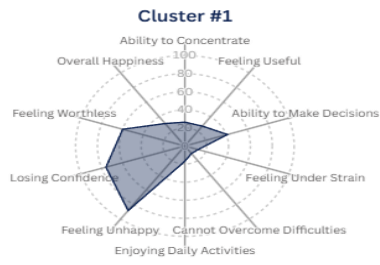
Socio-demographic Characteristics by Clusters



Patients from cluster #2 reported the ability to concentrate, overcome difficulties, feel useful, and enjoy life more often (93.0%, 66.0%, 81.2%, and 71.3%, respectively) (Table S6; Figure 4). With improving positive emotional characteristics, the prevalence of sleep problems, self-perceived poor health condition, diabetes, depression and anxiety showed a simultaneous decrease (Table S5; Figure 3). Analogically, as the prevalence of sleep problems decreased across the clusters, the prevalence of other conditions decreased similarly. For instance, the prevalence of diabetes, depression, and anxiety decreases along with the prevalence of sleep problems from clusters 1 to 5.

Figure 4

Emotional Characteristics by Clusters



Discussion

What did we find?

In this study, we found that a significant proportion of the Spanish population reports some sleep problems. Several relevant variables were associated with differences in sleep disorders in the general population. The findings also suggest that diabetes is not an important factor influencing sleep problems, but it is not a direct or independent predictor of sleep problems. After adjusting for variables like self-perceived health, depression, and anxiety, the association between diabetes and sleep disturbances became statistically insignificant. This might suggest that emotional well-being and socio-demographic factors are stronger determinants of sleep issues than diabetes. Applying the hierarchical cluster analysis, we aggregated the sample analyzed into 5 groups, which demonstrated to be internally intra-homogeneous and heterogeneous in comparison with the other groups based on their emotional characteristics. Patients from clusters with a higher prevalence of negative emotional traits such as low confidence, inability to concentrate, and feelings of worthlessness exhibited sleep problems, diabetes, depression and anxiety more often. In comparison, people from clusters with better emotional health showed significantly lower rates of these conditions. Although diabetes at the population level did appear to have a significant effect, it is relevant that clusters that included a higher prevalence of people with diabetes were the clusters that had a higher prevalence of sleep disorders, suggesting that diabetes and sleep disorders aggregate in certain individuals.

What are the limitations of this study?

This project encountered several limitations that might affect the interpretation of the results. We could not control or influence the original data collection process since we used secondary data from the NHS 2017. So, certain variables may not have been measured with sufficient care and detail. Additionally, most of the characteristics were self-reported and could be biased. While emotional factors, depression and anxiety, diabetes and sleep issues vary in their severity in real life, our study limited this variability to either having or not having a certain condition, which could have influenced the results. Finally, the retrospective nature of this project prevents the establishment of causal relationships. So, it is unclear whether diabetes, emotional factors and sleep problems cause one another or are influenced by other unmeasured confounding variables. In our analysis, we separated the cases into five clusters. Yet, a different number of clusters could change the results.

What are the strengths of this study?

The main strength of this project was the analysis, which was based on a sample of 23,019 people, ensuring diversity and generalizability. To our knowledge, for the first time, we moved beyond simplistic cause-effect models by integrating socio-demographic, mental health and chronic diseases in a hierarchical cluster analysis. This holistic perspective provided a more nuanced understanding of overlapping factors contributing to sleep issues.

How does this research align with existing literature?

Our research results were found to be consistent with the existing concepts and research on the relationship between diabetes and sleep problems. The statistical analysis confirmed the significant role of socio-demographic and emotional factors in mediating the relationship between

sleep problems and diabetes. For instance, the binary logistic regression in this project revealed that depression (OR: 4.96, 95% CI [4.56 - 5.39]) and anxiety (OR: 1.93, 95% CI [1.73 - 2.16]) were strong predictors of sleep issues. In the same way, Shinalieva et al. (2023) found that the severity of insomnia was significantly associated with anxiety and depression in T2DM patients (ORs: 1.07-1.10). Similarly, Peleg et al. (2019) demonstrated that depressive symptoms fully mediated the relationship between sleep disturbances and T2DM, supporting the importance of mental health. Additionally, Lou et al. (2015) highlighted significant associations between depression (OR: 5.61) and anxiety (OR: 5.12) with poor sleep quality. Yet, there are some contradictions about diabetes as an independent risk factor. Our results indicate that T2DM becomes insignificant after adjusting for mental health and socio-demographic factors, whereas Peleg et al. (2019) and Shinalieva et al. (2023) implicitly support the influence of diabetes on sleep problems, particularly in decompensated T2DM patients. Furthermore, together with Lou et al. (2015), these studies overlook the contribution of socio-demographic factors to mediating the association of sleep quality and diabetes. The hierarchical cluster analysis reinforced the trend, as the prevalence of diabetes and sleep issues gradually decreased with an increase in positive emotional characteristics. This tendency suggests that managing emotional well-being might improve the side effects of diabetes, specifically sleep problems, and vice versa.

The cluster analysis technique in this study was mostly inspired by the research of Sarria-Santamera et al. (2024), in which this method helped to understand complex interactions between variables. This universal method is useful for studying conditions that involve many factors, such as diabetes, mental health, and sleep problems, or factors for ICU admissions. Yet this method is unsupervised. Thus, it did not assumed any labels, but grouped individuals based on naturally co-occurring conditions. Some cases were grouped together, while different were not. By clustering patients based on risk factors, we can discover or propose possible disease mechanisms. This may also help to identify biomarkers. As a result, findings from a cluster analysis help to improve treatment and predict severe conditions (Sarria-Santamera et al., 2024).

What are the clinical and public health implications?

There is multiple evidence of the efficiency of integrated care in managing depression and diabetes symptoms. The study by Wang et al. (2024) tested a community-based integrated care model for patients with diabetes and depression in China. The study compared intervention from a multidisciplinary team with usual patient care. The results showed that patients who received integrated care throughout 12 months had a reduction of depressive symptoms by 50% and the HbA1c by 0.5% ($p < 0.001$). Moreover, meta-analysis by Cooper et al. (2024) revealed that both collaborative and co-located integrated care show consistent results in decreasing levels of depression and HbA1c. Additionally, Khosravan et al. (2015) found that sleep quality in diabetic people improved significantly ($p < 0.001$) after introduction to the Continuous Care Model, including sleep hygiene, stress management and cognitive-behavioral therapy. Multidisciplinary approaches involving endocrinologists, psychologists, and sleep specialists should be implemented to address the combined presence of diabetes, mental health, and sleep disturbances, where patients receive simultaneous mental health screenings, sleep assessments, and glycemic control evaluations. These results also suggest high-risk groups (women, middle and older ages) that may be targeted for early detection of these problems.

What are the implications for future research?

Considering the hypothesis-generating nature of our project, we provide a baseline for future research. The new hypothesis should explore the potential mechanisms behind the relationship between sleep problems, diabetes and mental health. For instance, future research could explore whether interventions in emotional regulation could diminish sleep problems in diabetic patients. In this study, we identified the risk factor group for having diabetes and sleep problems, specifically older women with low confidence and feelings of worthlessness. The new research could suggest tailored interventions such as gender specific programs or community-based support targeting the particular needs of risk groups. Yet, the cross-sectional nature of our research limits the understanding of causal relationships. So, there is a place for longitudinal studies that would identify the causational mechanisms and suggest appropriate interventions. Finally, further research is needed to incorporate objective measures such as HbA1c levels and polysomnography to validate our findings and explore the biological mechanisms (e.g. inflammatory markers, hormonal changes) that would explain the mediating role of emotions to the association between sleep issues and T2DM.

Conclusion

In conclusion, this project reinforces diabetes care with a holistic approach, which includes addressing mental health, emotional well-being, and socio-demographic characteristics. It was found that emotions, self-perceived health, and depression are stronger risk factors for having sleep issues than diabetes. A better emotional state is associated with a lower prevalence of diabetes, depression and sleep issues. Yet, further longitudinal research is needed to reveal causal relationships and suggest targeted care.

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Supplementary Material

Table S1

Socio-Demographic and Health Status Characteristics of the Population Analyzed by the Presence of Sleep Problems

| variable | subgroup | No sleep problems | | Sleep problems | | p value |
|--|--------------------------|-------------------|--------|------------------|--------|---------|
| | | n | % | n | % | |
| Sex | Male | 8681 | 82.16% | 1885 | 17.84% | 0.00 |
| | Female | 9202 | 73.88% | 3251 | 26.12% | |
| Age (median; 25th and 75th percentile) | | 17883 (53, 39-68) | | 5136 (54; 41-69) | | 0.00 |
| Age Groups | 15-44 | 6414 | 79.90% | 1614 | 20.10% | 0.00 |
| | 45-64 | 6045 | 75.50% | 1965 | 24.50% | |
| | >65 | 5424 | 77.70% | 1557 | 22.30% | |
| Economic Status | Not Working - Long-Term | 7055 | 75.80% | 2258 | 24.20% | 0.000 |
| | Working | 8030 | 81.00% | 1883 | 19.00% | |
| | Not Working - Temporary | 2798 | 73.80% | 995 | 26.20% | |
| Relationships Status | With couple/partner | 9783 | 78.60% | 2669 | 21.40% | 0.001 |
| | Alone | 7995 | 76.70% | 2435 | 23.30% | |
| Marital Status | Single | 4729 | 80.54% | 1138 | 19.46% | 0.000 |
| | Married | 9792 | 78.70% | 2648 | 21.30% | |
| | Widow/Divorced/Separated | 3330 | 71.30% | 1343 | 28.70% | |

| | | | | | | |
|-----------------------|--------------------------|-------|--------|------|--------|-------|
| Education Level | Basic Education | 9634 | 76.00% | 3043 | 24.00% | 0.000 |
| | Secondary Education | 4843 | 78.70% | 1312 | 21.30% | |
| | Higher education | 3406 | 81.35% | 781 | 18.65% | |
| Self-perceived health | Very Good and Good | 13035 | 85.10% | 2283 | 14.90% | 0.000 |
| | Fair, Poor and Very Poor | 4848 | 62.95% | 2853 | 37.05% | |
| Diabetes | | 1641 | 72.60% | 619 | 27.40% | 0.000 |
| Depression | | 1258 | 47.30% | 1401 | 52.70% | 0.000 |
| Anxiety | | 1085 | 47.80% | 1186 | 52.20% | 0.000 |
| TOTAL | | 17883 | 77.50% | 5136 | 22.20% | 0.000 |

Table S2*Emotional Characteristics of the Population Analyzed by the Presence of Sleep Problems*

| Variable | | Sleep Problems | | χ^2 | p value |
|---------------------------|----|----------------|--------|----------|---------|
| | | n | % | | |
| Enjoying Daily Activities | No | 1975 | 38.50% | 4092.206 | 0.000 |
| | | 3154 | 61.50% | | |
| Feeling Unhappy | No | 2586 | 50.40% | 5846.288 | 0.000 |
| | | 2544 | 49.60% | | |
| Feeling Worthless | No | 4144 | 81.00% | 2127.643 | 0.000 |
| | | 971 | 19.00% | | |
| Loss of Confidence | No | 3637 | 71.10% | 3296.945 | 0.000 |
| | | 1480 | 28.90% | | |
| Overall Happiness | No | 1458 | 28.50% | 3341.673 | 0.000 |
| | | 3659 | 71.50% | | |
| Ability to concentrate | No | 1959 | 38.20% | 4051.949 | 0.000 |
| | | 3171 | 61.80% | | |
| Playing Useful part | No | 1442 | 28.30% | 2905.423 | 0.000 |
| | | 3656 | 71.70% | | |
| Ability to Make Decisions | No | 1169 | 22.80% | 2538.887 | 0.000 |
| | | 3955 | 77.20% | | |
| Feeling Under Strain | No | 3448 | 67.20% | 7349.422 | 0.000 |

| | | | | | |
|---------------------------------------|----|------|--------|----------|-------|
| | | 1683 | 32.80% | | |
| Inability to Overcome Difficulties | No | 2226 | 43.50% | 5032.339 | 0.000 |
| | | 2894 | 56.50% | | |

Table S3*Binary Logistic Regression Analysis of Diabetes and Socio-Demographic Variables Influencing Sleep*

| Variable | OR | 95% C.I. for EXP(B) | |
|--|------|---------------------|-------|
| | | Lower | Upper |
| Diabetes | 1.36 | 1.23 | 1.50 |
| Sex | 1.29 | 1.20 | 1.38 |
| Living Alone | 0.90 | 0.83 | 0.98 |
| Widow, divorced, separated | | | |
| Single | 0.68 | 0.60 | 0.76 |
| Married | 0.69 | 0.58 | 0.83 |
| Far + Poor + Very poor | 1.29 | 1.27 | 1.31 |
| Depression | 2.49 | 2.25 | 2.77 |
| Anxiety | 1.93 | 1.73 | 2.16 |
| Older Adults (65+) | | | |
| Young Adults (15-44) | 1.73 | 1.51 | 1.99 |
| Middle-Aged Adults | 1.57 | 1.40 | 1.76 |
| Not Working - Temporary : Unemployed, Student | | | |
| Not Working - Long-Term : Retired, Disabled, At Home, Other | 0.69 | 0.61 | 0.79 |
| Working | 0.69 | 0.62 | 0.76 |

Table S4*Binary Forward Logistic Regression Analysis of Diabetes and Socio-Demographic Variables Influencing Sleep*

| Variable | OR | 95% C.I. for EXP(B) | | |
|----------|----------------------------|---------------------|-------|------|
| | | Lower | Upper | |
| Step 1 | Depression | 4.96 | 4.56 | 5.39 |
| Step 2 | Self-perceived health | 1.27 | 1.25 | 1.29 |
| | Depression | 3.34 | 3.05 | 3.65 |
| Step 3 | Self-perceived health | 1.32 | 1.29 | 1.34 |
| | Depression | 3.51 | 3.21 | 3.85 |
| | Young Adults (15-44) | | | |
| | Middle-Aged Adults (45-64) | 1.74 | 1.59 | 1.90 |
| | Older Adults (65+) | 1.61 | 1.48 | 1.75 |
| Step 4 | Sex | 1.37 | 1.28 | 1.47 |
| | Self-perceived health | 1.31 | 1.28 | 1.34 |
| | Depression | 3.34 | 3.05 | 3.66 |
| | Young Adults (15-44) | | | |
| | Middle-Aged Adults (45-64) | 1.76 | 1.61 | 1.93 |
| | Older Adults (65+) | 1.64 | 1.51 | 1.79 |

Figure S1

Hierarchical Cluster Dendrogram

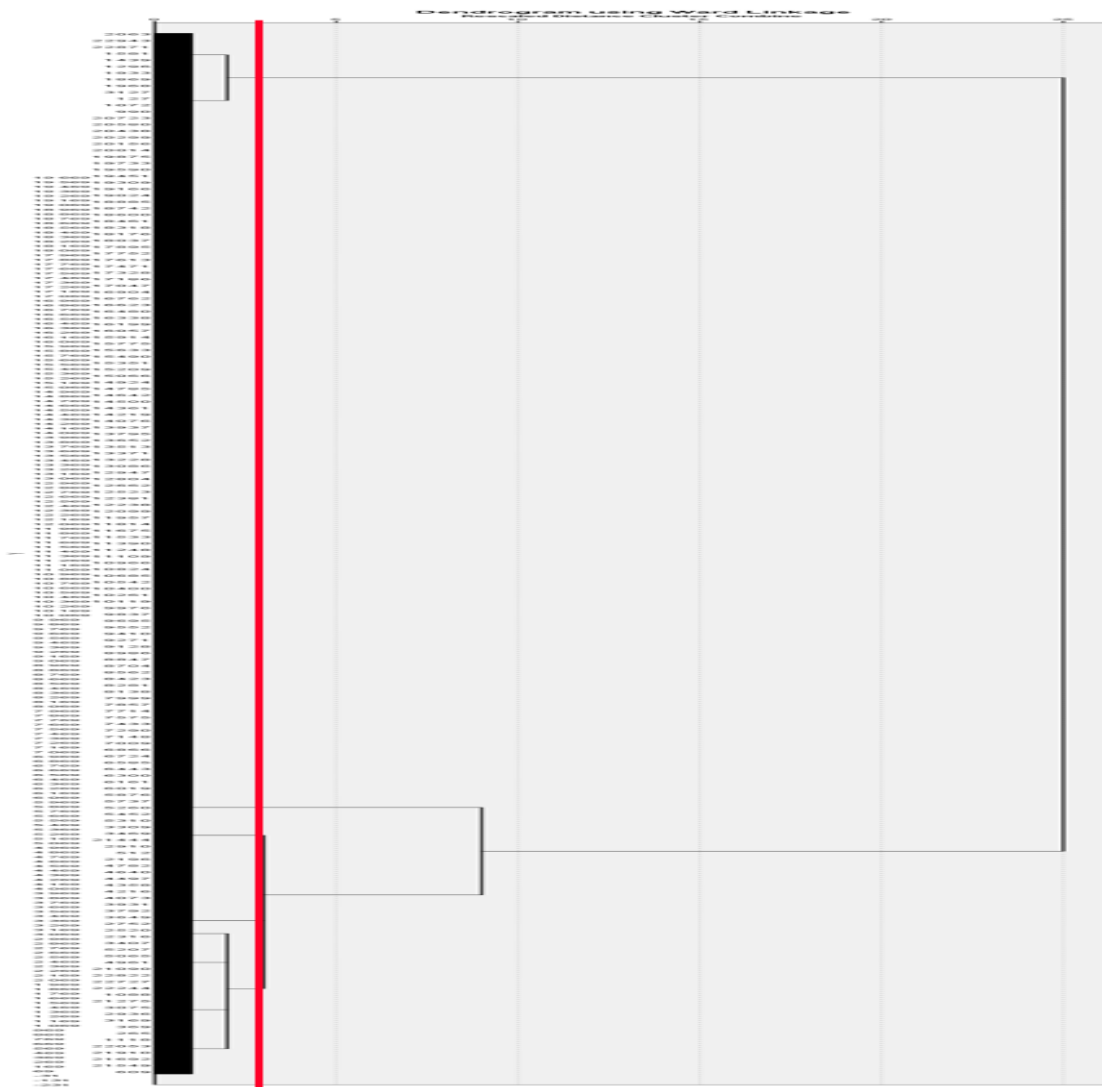


Table S5*Sleep Patterns and Health Conditions Variables across Hierarchical Clusters*

| Cluster # | Sleep | Median age ; IQR | Woman | Fair, Poor and Very poor | Diabetes | Depression | Anxiety |
|------------------|--------------|-------------------------|--------------|---------------------------------|-----------------|-------------------|----------------|
| 1 | 80.30% | 61; (48-78) | 65.10% | 82.60% | 19.00% | 49.80% | 38.50% |
| 2 | 46.30% | 55; (41-70) | 60.20% | 49.40% | 12.70% | 19.90% | 16.90% |
| 3 | 53.20% | 52; (37-70) | 64.40% | 51.40% | 8.70% | 19.80% | 17.60% |
| 4 | 42.70% | 44; (34-56.75) | 58.00% | 26.40% | 6.00% | 6.70% | 9.20% |
| 5 | 5.60% | 52; (39-67) | 50.20% | 22.80% | 8.40% | 4.70% | 4.20% |

Table S6*Sleep Patterns and Health Conditions Variables across Hierarchical Clusters*

| Cluster # | Ability to Concentrate | Feeling Useful | Ability to Make Decisions | Feeling Under Strain | Cannot Overcome Difficulties | Enjoying Daily Activities | Felling Unhappy | Losing Confidence | Feeling Worthless | Overall Happiness |
|------------------|-------------------------------|-----------------------|----------------------------------|-----------------------------|-------------------------------------|----------------------------------|------------------------|--------------------------|--------------------------|--------------------------|
| 1 | 26.30% | 27.20% | 41.00% | 12.80% | 10.30% | 16.90% | 88.30% | 75.90% | 59.80% | 30.70% |
| 2 | 93.00% | 81.20% | 88.40% | 51.20% | 66.00% | 71.30% | 45.10% | 15.10% | 5.60% | 83.20% |
| 3 | 0.00% | 91.90% | 93.80% | 46.50% | 77.50% | 73.20% | 30.20% | 6.80% | 0.60% | 92.30% |
| 4 | 100.00% | 100.00% | 100.00% | 0.00% | 100.00% | 100.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| 5 | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 0.00% | 0.00% | 0.00% | 100.00% |