


BMJ Open Sex-specific sleep profiles in Spanish adults: cross-sectional actigraphy-PSQI study with cluster analysis in Salamanca and Ávila

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ABSTRACT

Objective To identify sex-specific patterns based on determinants related to sleep quality, using a representative sample of the Spanish adult population.

Design Cross-sectional, age-stratified and sex-stratified study.

Setting Community-based assessments in two Spanish provinces (Salamanca and Ávila).

Participants Adults aged 25–65 years (n=500), equally distributed by sex and five age strata, selected from the regional health-card database.

Primary and secondary outcome measures Objective sleep metrics from wrist actigraphy (time in bed, total sleep time (TST), sleep efficiency, wake after sleep onset, number/duration of awakenings, fragmentation/movement indices) and self-reported sleep quality (Pittsburgh Sleep Quality Index).

Methods Standardised baseline assessments collected sociodemographic, clinical, mental-health and lifestyle variables using validated instruments. Actigraphy (ActiGraph GT3X+) recorded triaxial acceleration at 30 Hz over 5 days; data were aggregated in 60 s epochs (ActiLife). Sleep/wake was classified with Cole-Kripke and nocturnal episodes identified with Tudor-Locke before deriving sleep indices. Two-step cluster analysis was applied separately by sex.

Results Three clusters were identified for each sex, with age and educational level being the most influential factors. In men, the 65-year-old cluster with university education and lower anxious-depressive load showed the highest sleep efficiency (91.8±3.8%) and the lowest TST (351.7±74.8 min). In contrast, the 35-year-old cluster with middle or high school presented the lowest efficiency (88.3±10.0%) and higher TST (368.1±83.8 min). In women, the 55-year-old cluster with middle or high school and low emotional load showed the highest efficiency (93.6±2.8%), despite a reduced TST (352.0±79.7 min), while the 35-year-old cluster, with middle or high school and high levels of anxiety and depression, showed the worst efficiency metrics (89.5±3.9%) and a higher TST (394.8±67.3 min).

Conclusion Sleep quality in Spanish adults is heterogeneous across sex-specific clusters shaped by age, education and mental-health burden. Cluster-based characterisation may support tailored public-health interventions.

Trial registration number NCT05324267.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Both wrist actigraphy (ActiGraph GT3X+) and the Pittsburgh Sleep Quality Index were used within the same population, enabling triangulation of sleep measures.
- ⇒ Age-stratified and sex-stratified random sampling from regional registries improved internal representativeness.
- ⇒ Standardised, interviewer-administered case report form with validated instruments reduced measurement variability.
- ⇒ Cross-sectional design precludes causal inference.
- ⇒ Generalisability beyond two provinces with lower sociodemographic diversity may be limited.

INTRODUCTION

Impact of sleep quality

Sleep is a complex and dynamic process, essential for the maintenance of health and a state of optimal well-being throughout life. Today's modern society, in which more and more people live permanently connected, with demanding work schedules and a very fast pace of life, is contributing to a significant increase in sleep disorders, constituting a major health problem.¹

The term 'sleep quality' can be defined as a subjective experience of all aspects related to sleep, including its duration, efficiency, latency, wake time after sleep onset and sleep architecture itself.² According to the International Classification of Sleep Disorders-Third Edition, from the American Academy of Sleep Medicine, sleep disorders are grouped into seven main categories: insomnia disorders, sleep-related breathing disorders, central disorders of hypersomnolence, circadian rhythm sleep-wake disorders, sleep-related movement disorders, parasomnias and other sleep disorders.³ Of these, insomnia disorder, defined as a dissatisfaction with the quantity

or quality of sleep, is the most prevalent,⁴ affecting women to a greater extent than men.⁵

High-quality sleep provides multiple benefits, including a sense of restfulness, maintenance of optimal cognitive functioning and satisfactory interpersonal relationships. However, poor sleep quality increases the predisposition to develop numerous comorbidities,⁶ such as obesity, diabetes mellitus and cardiovascular disease,⁷ as well as psychological and neurological problems, including attention deficit,⁸ cognitive impairment,⁹ impaired executive functions,¹⁰ anxiety¹¹ and depression.¹² In the same way, a recent study has shown that irregular sleep patterns significantly increase the risk of major cardiovascular events, a fact that seems to be partially mitigated by complying with sleep duration recommendations.¹³ An increased risk of death from any cause has even been shown to be associated with poor sleep quality.¹⁴

Determinants of sleep quality and their differences by sex

Several factors have a direct or indirect influence on sleep. In relation to nutritional habits, a diet rich in processed foods and simple carbohydrates is associated with poorer sleep quality,¹⁵ whereas adherence to the Mediterranean diet, considered a high-quality dietary pattern, is associated with good sleep quality.¹⁶

Insufficient physical activity is considered a risk factor for the development of poor sleep quality,¹⁷ although the impact of physical exercise on sleep quality may be more pronounced in men than in women.¹⁸ Notably, this relationship may not be directly causal but is potentially mediated by its regulatory effect on emotions.¹⁹

Toxic habits, such as alcohol and tobacco consumption, can also have a negative effect. Alcohol, even in moderate amounts, impairs sleep quality, and its negative effect can be maintained in the long term.²⁰ With respect to tobacco, the available evidence shows a worse self-reported sleep quality in smokers, also impairing sleep maintenance and duration, with more marked effects in women and people with high nicotine dependence. These effects could make smoking cessation more difficult, increasing its negative impact.²¹

The presence of morbidities constitutes another determining factor with a known negative impact on sleep quality,²² with independent associations being identified between sleep disorders and various specific pathologies such as cancer, angina pectoris or hypertension, among others.²³

Finally, mental health is a critical factor, with a strong association between anxiety and depressive symptoms and poor sleep quality.²⁴ Likewise, a higher prevalence of self-reported social anxiety disorders and suicidal thoughts has been identified in women compared with men, which could be related to poorer sleep quality in this group.²⁵

Importance of cluster analysis in pattern identification and its application in sleep studies

Cluster analysis is a technique that regroups individuals who share certain characteristics into homogeneous

groups, called clusters. This approach facilitates the identification of specific patterns, which allows guiding the design of more effective interventions in the field of health,²⁶ significantly improving the accuracy of statistical models compared with the direct analysis of individual data. In this way, data are simplified and organised, grouping people with similar characteristics, facilitating the identification of common patterns, reducing the complexity derived from the high variability between individuals and homogenising the information analysed,²⁷ which allows examining the multidimensional characteristics of sleep from a comprehensive perspective, and advancing in the understanding and treatment of possible associated disorders.²⁸

Taken together, these considerations motivated a data-driven approach to identify sex-specific clusters in an age-stratified random sample, based on determinants of sleep quality (sociodemographic, mental-health and lifestyle), and to characterise between-cluster differences in objective actigraphy-derived measures and subjective measures using the Pittsburgh Sleep Quality Index (PSQI).²⁸

Objective

The main objective was to identify specific patterns based on determinants related to sleep quality, using a representative sample of the general adult population in Spain.

METHODS

Study design

This is a cross-sectional observational study carried out in two locations located in the central region of Spain: Ávila and Salamanca. The study was performed between May 2022 and April 2024 and was registered on the ClinicalTrials.gov platform (NCT05324267), as indicated in the previously published study protocol.²⁹

Estimation of sample size

The sample size calculation was based on the expected score on the PSQI, from the values reported by Gómez-García *et al* who, after analysing a sample of Spanish nurses, determined a mean±SD of 6.8±3.38 points on the PSQI.³⁰ With this data, it was calculated that a randomised sample of 500 people would be sufficient to estimate the population mean with a CI of 95% and a precision of ±0.32 units, considering an approximate SD of 3.38. The rate of loss to follow-up was estimated at 15%.

Study population and recruitment

The sample consisted of 500 adults aged between 25 and 65 years, residents of Salamanca and Ávila. The participants were selected by stratified random sampling by age and sex, using the health card database of the Health Service of Castilla y León (SACYL). A total of 100 individuals were included in each of the defined age groups (25, 35, 45, 55 and 65 years), distributed equally between men and women, who were contacted by telephone. Those individuals who refused to participate were replaced to



Figure 1 Individuals contacted and included in the study, segmented by age groups and sex.

complete the established sample size. The data segmented by age group and sex are shown in [figure 1](#). The participants were not integrated into the project design.

Inclusion criteria

Individuals aged 25, 35, 45, 55 or 65 years at the time of sampling, registered in the SACYL health card database, residing in Salamanca or Ávila, who gave their free and voluntary consent to participate in the study and who did not present any of the established exclusion criteria were included.

Exclusion criteria

Participants who were terminally ill, those who lacked the capacity to attend health centres for the necessary evaluations and pregnant women were excluded. For clarity, inclusion and exclusion criteria are summarised in [table 1](#).

Inclusion criteria	Exclusion criteria
Ages 25, 35, 45, 55 or 65 years (at sampling)	Terminal illness
Registered in the SACYL health-card database	Inability to attend health centres for required assessments
Residence in Salamanca or Ávila	Pregnancy
Free and voluntary informed consent	
Absence of any exclusion criterion	
SACYL, Health Service of Castilla y León.	

Planning and structure of evaluation visits

Once the sample had been selected, the researchers contacted the participants by telephone to offer them the opportunity to take part in the study, making sure that they met the established inclusion criteria. Those who agreed to participate were invited for an interview with the researcher responsible for the evaluations. During the visits, which lasted an average of 60–90 min, the participants received information about the development and objectives of the study, informed consent was collected and questionnaires were administered. The interviewer followed a standardised case report form (CRF) that included sociodemographic, anthropometric and housing variables, as well as the administration of validated questionnaires (PSQI, Generalised Anxiety Disorder-7 (GAD-7), Patient Health Questionnaire-9 (PHQ-9), Mediterranean Diet Adherence Screener (MEDAS), List of Threatening Experiences (LTE), Drug Abuse Screening Test (DAST), Charlson Comorbidity Index (CCI)). It also incorporated standardised modules on alcohol consumption. All items were closed-ended or scored using validated scales, ensuring comparability and reproducibility. Finally, the accelerometer was placed on the non-dominant wrist, which they had to wear for 5 days, and the self-administered questionnaires were given. The ActiGraph GT3X+ triaxial accelerometer (ActiGraph LLC, Pensacola, Florida, USA) was used, placed on the non-dominant wrist for five consecutive days. The device records raw acceleration in three axes at 30 Hz. Data were aggregated into 60 s epochs using ActiLife software, and nocturnal sleep episodes were identified with the Tudor-Locke algorithm, validated against polysomnography in adults. From these data, the following sleep parameters were derived: time in bed (TIB), total sleep time (TST), wake after sleep onset (WASO), sleep efficiency,

number and duration of awakenings and fragmentation and movement indices. Once this period had elapsed, the participants returned to the research centre to return the accelerometer and completed questionnaires. The complete version of the standardised case-report form (SSQD Questionnaire) can be consulted in online supplemental appendix 1.

Study variables

Sociodemographic variables

Data were collected on age, sex, marital status, educational level, current employment status and family income level. In addition, weight and height were recorded, from which the body mass index, expressed in kg/m², was calculated.

Clinical variables

Anxiety

It was analysed using the validated GAD-7 questionnaire,³¹ designed to assess the intensity of anxiety symptoms and detect possible cases of generalised anxiety disorder. This instrument consists of 7 items based on Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV criteria and uses a 4-point Likert scale, with responses ranging from 0 to 3 (0: Never; 1: Several days; 2: More than half of the days; 3: Almost every day), in relation to symptoms experienced in the last 2 weeks. The total score varies between 0 and 21, and the established cut-off points allow the anxiety intensity to be classified as follows: 0–4 indicates minimal anxiety, 5–9 indicates mild anxiety, 10–14 moderate anxiety and a score of 15–21 corresponds to severe anxiety.³²

Depression

The validated Spanish version of the PHQ-9³³ was used to assess the severity of depressive symptoms in participants. Consisting of 9 items, based on the DSM-IV criteria, this tool analyses the symptoms experienced during the last 2 weeks, evaluated using a 4-point Likert scale, which varies according to the frequency of presentation, from 0 (no day) to 3 (almost every day). The total score of the PHQ-9 ranges from 0 to 27, with established cut-offs for classifying the level of depressive symptoms: no clinically significant depression (0–4), mild (5–9), moderate (10–14), moderately severe (15–19) and severe (20–27).³⁴

Morbidity

The presence of comorbidities was assessed by means of the CCI,³⁵ a validated tool used to predict long-term mortality risk in patients with multiple comorbidities. Developed in 1987, it evaluates 19 chronic diseases, assigning a score of 1–6 points to each according to the associated relative risk. The total score ranges from 0 to 37 and is adjusted by adding one point for each decade of life after the age of 50.

Stressful events

The LTE,³⁶ a validated questionnaire composed of 12 items that assess exposure to stressful experiences in the last 6 months, such as health problems, family conflicts,

losses or work difficulties, was used. Responses are collected dichotomously (Yes=1, No=0). Although no universal cut-off points have been defined, a higher score on the LTE indicates greater exposure to stressful events, which is generally associated with greater psychological impact.

Variables related to lifestyles and healthy habits

Dietary habits

The adherence to the Mediterranean diet was assessed using the MEDAS,³⁷ a validated tool consisting of 14 dichotomous questions (Yes/No). Of these questions, 12 refer to food consumption frequencies and 2 to eating habits considered representative of the Spanish Mediterranean diet. Each affirmative response was scored 1, while negative responses were scored 0, resulting in a total score ranging from 0 to 14. The results were classified into three levels: low adherence (0–7), moderate adherence (8–9) and high adherence (10–14).³⁸

Alcohol consumption

Information was collected on the type and quantity of alcohol consumed during the last 7 days, to obtain a complete overview of the pattern of consumption in the recent period. Subsequently, consumption was quantified in grams of alcohol per week.

Physical activity

The physical activity level and sedentary lifestyle were quantified using ActiGraph GT3X+ accelerometry devices (ActiGraph), which made it possible to analyse physical activity by collecting information on daily physical activity, sedentary time, number of steps taken and kilocalories consumed. These systems are also capable of measuring the acceleration of the wearer in the three axes of space. This triaxial acceleration is measured in counts per minute (CPM) and, from the regression equation proposed by Freedson *et al*,³⁹ the standard resting metabolic rate (MET) can be estimated, with 1 MET corresponding to the amount of energy the body consumes while at rest and can be expressed as 1 Kcal/(Kg × hour). Thus, a MET rate of 2.0 indicates that, during that time, the person was using twice as much energy compared with his or her usual resting level.

For quantification of physical activity intensity, the cut-off points proposed by Freedson *et al*³⁹ were used: sedentary: <100 CPM; light: 100–1951 CPM; moderate: 1952–5724 CPM; vigorous: 5725–9498 CPM; very vigorous: >9498 CPM. This allowed subsequent identification of the percentage of sedentary time.

Sleep assessment

Sleep assessment by actigraphy (ActiGraph)

Objective sleep measurement was performed using the above-mentioned accelerometry devices, considered a validated and reliable analysis system in sleep studies.⁴⁰ Accelerometry data were downloaded and analysed using ActiLife 6 software (V.6.13.15, ActiGraph). For sleep data analysis, the Cole-Kripke sleep scoring algorithm⁴¹

was applied to classify each epoch as sleep or wake, and the Tudor-Locke sleep scoring algorithm⁴² was used to identify the nocturnal sleep episode, defining sleep onset as ≥ 5 consecutive epochs scored as sleep. Accelerometry data were downloaded and analysed using ActiLife 6 software (V.6.13.15, ActiGraph). This procedure provided continuous, accurate and reliable data on sleep/wake cycles, generating detailed reports and graphs. Actigraphy-derived sleep indices included TIB, TST, WASO, sleep efficiency, number and duration of awakenings and fragmentation/movement indices.⁴² The complete definitions of these parameters are provided in online supplemental appendix 2.⁴³

Sleep assessment using the Pittsburgh Sleep Quality Index

It is a validated test for the assessment of sleep quality. It comprises 19 items that give a total of 7 key components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of drugs for sleep and daytime dysfunction. Each component is scored between 0 (no difficulty) and 3 (severe difficulty), generating a total scale of 0–21 points by adding the partial scores, so that the higher the overall score in this index, the lower the self-reported sleep quality. Its validation in the general Spanish population showed a high internal consistency (Cronbach's $\alpha=0.81$), together with a sensitivity of 88.63% and a specificity of 74.99%.^{44 45}

Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Statistical analysis

Statistical analysis was carried out in accordance with the study protocol.²⁹ For this manuscript, the distribution of the variables was tested using the Kolmogorov-Smirnov test. The quantitative variables analysed have a normal distribution and are expressed as means \pm SD, while the categorical variables are expressed by number and frequency distribution.

Linear regression models were fitted to evaluate associations between socioeconomic/cultural indicators and sleep outcomes. The dependent variables were the PSQI total score and actigraphic metrics (TST, sleep efficiency, WASO, number of awakenings and sleep fragmentation index (SFI)). Predictors included sex, age group, educational attainment, household income and employment status, together with prespecified clinical/behavioural covariates (GAD-7, PHQ-9, CCI, MEDAS, LTE, METs, alcohol intake (g/week) and percentage of sedentary time). Full model coefficients are provided in the online supplemental appendix 3 tables S1–S5.

The two-step cluster analysis, an exploratory tool for identifying natural groupings, was performed separately by sex. The number of clusters in each sex was set to 3. The likelihood distance measure assumes that the variables in the cluster model are independent. In addition,

each continuous variable is assumed to have a normal (Gaussian) distribution, and each categorical variable is assumed to have a multinomial distribution. Internal empirical checks indicate that this procedure is quite robust to violations of both the independence assumption and the distributions.

Finally, to analyse the differences in sleep quality indices between the three clusters in each of the sexes, analysis of variance (ANOVA) and the Bonferroni test were used in the post hoc contrasts. In all cases, a risk α of 0.05 was set as the limit of statistical significance for hypothesis testing. Data were analysed using IBM SPSS Statistics for Windows, V.28.0 (IBM, Armonk, New York, USA).

RESULTS

Clinical and sociodemographic characteristics

Men and women differed significantly in marital status ($p=0.003$), with a predominance of the 'Married/Unmarried Union' category in men (60.0% vs 50.4% in women), while women presented slightly higher percentages of separated/divorced and single. Notable discrepancies were also observed in the employment situation ($p=0.037$): although paid employment was in the majority in both sexes, women showed a greater diversity of situations, including home and family care, as well as maternity leave, which was absent in the male group. As for family income, women were more concentrated in the lowest income range ($<€27\,000$) (40.4% in women vs 29.6% in men, $p=0.015$). In contrast, educational level did not show significant differences ($p=0.100$), with similar distributions between primary, secondary and university education in both groups.

Regarding the clinical variables analysed, significant differences were detected in those related to lifestyle and mental health. Regarding lifestyle, men showed slightly higher values of physical activity, measured through METS (1.54 \pm 0.20 vs 1.47 \pm 0.20; $p=0.000$), although more sedentary time (49.3 \pm 7.5 vs 48.0 \pm 7.6; $p=0.047$), to which was added a significantly higher alcohol consumption (73.9 \pm 102.2 vs 30.5 \pm 63.4g/week; $p=0.000$). In contrast, the healthy dietary pattern, measured through the MEDAS, was more favourable in women (9.1 \pm 2.2 vs 8.5 \pm 2.1; $p=0.000$).

When analysing variables related to psychological well-being, women obtained higher scores in both PHQ-9 (4.0 \pm 4.9 vs 2.9 \pm 4.4; $p=0.009$) and GAD-7 (3.9 \pm 4.6 vs 2.6 \pm 3.8; $p=0.000$), indicating a greater presence of depressive and anxious symptomatology compared with men. No significant differences were found in the adverse life events index (LTE; $p=0.114$) or in the CCI ($p=0.104$). **Table 2** summarises the complete clinical and sociodemographic characteristics.

To complement these group comparisons, multivariable linear models were used to examine the associations between socioeconomic/cultural indicators and sleep outcomes. Restricting the analysis to these indicators, we observed the following associations: for PSQI, marital

**Table 2** Clinical and sociodemographic characteristics

	Men (n=250)	Women (n=250)	P value	Overall (N=500)
Marital status, n (%)			0.003	
Married/unmarried union	150 (60.0)	126 (50.4)		276 (55.2)
Separated/divorced	11 (4.4)	18 (7.2)		29 (5.8)
Single	89 (35.6)	96 (38.4)		185 (37.0)
Others	–	10 (4.0)		10 (2.0)
Educational level, n (%)			0.1	
Elementary school	26 (10.4)	27 (10.8)		53 (10.6)
Middle or high school	113 (45.2)	90 (36.0)		203 (40.6)
University studies	111 (44.4)	133 (53.2)		244 (48.8)
Work situation, n (%)			0.037	
Student	7 (2.8)	1 (0.4)		8 (1.6)
Employed	162 (64.8)	166 (66.4)		328 (65.6)
Maternity leave	–	3 (1.2)		3 (0.6)
Unemployed	30 (12)	25 (10)		55 (11)
Disability to work	7 (2.8)	4 (1.6)		11 (2.2)
Retired	43 (17.2)	44 (17.6)		87 (17.4)
Home and childcare	–	6 (2.4)		6 (1.2)
Others	1 (0.4)	1 (0.4)		2 (0.4)
Household income, n (%)			0.015	
<€27 000	74 (29.6)	101 (40.4)		175 (35.0)
€27 000–47 000	108 (43.2)	107 (42.8)		215 (43.0)
>€47 000	62 (24.8)	37 (14.8)		99 (19.8)
It does not say	6 (2.4)	5 (2.0)		11 (2.2)
Charlson Comorbidity Index	0.48±0.96	0.35±0.79	0.104	0.41±0.88
Standard resting metabolic rate	1.54±0.20	1.47±0.20	0	1.51±0.20
Sedentary time (%)	49.3±7.5	48.0±7.6	0.047	48.7±7.5
Mediterranean Diet Adherence Screener	8.5±2.1	9.1±2.2	0	8.8±2.2
Alcohol (g/week)	73.9±102.2	30.5±63.4	0	52.2±87.7
PHQ-9 score	2.9±4.4	4.0±4.9	0.009	3.4±4.7
GAD-7 score	2.6±3.8	3.9±4.6	0	3.2±4.3
LTE score	0.8±1.1	1.0±1.1	0.114	0.9±1.1

GAD-7, Generalised Anxiety Disorder-7 questionnaire; LTE, List of Threatening Experiences; PHQ, Patient Health Questionnaire-9.

status ($B=0.843$; $p<0.001$) and educational attainment ($B=0.593$; $p=0.021$); for sleep efficiency, employment status ($B=0.621$; $p=0.018$); for WASO, household income ($B=2.567$; $p=0.020$) and employment status ($B = -2.247$; $p=0.006$); for the number of awakenings, household income ($B=0.860$; $p=0.011$); and for the fragmentation index (FI), educational attainment ($B=1.151$; $p=0.033$) and employment status ($B = -0.729$; $p=0.036$). Complete coefficients are reported in the online supplemental appendix 3 tables S1–S5.

Relationship between determinants of sleep quality and sleep quality indices

All determinants correlated with at least one sleep variable; those related to mental health had a more

prominent influence on subjective quality and continuity of sleep, while factors related to lifestyle seem to have a more moderate effect.

Among the most prominent correlations, all of them with statistical significance ($p<0.05$), is the positive relationship between the PSQI and the PHQ-9 ($r=0.488$), as well as between the PSQI and the GAD-7 ($r=0.430$). These findings suggest that emotional well-being is one of the most influential determinants on the perception of sleep quality. Similarly, the presence of adverse life events, measured through the LTE, also presents a significant, although more moderate, association with the subjective evaluation of sleep ($r=0.241$). A smaller, but still relevant, effect was observed in the relationship between PSQI and the CCI ($r=0.180$).

Table 3 Correlations between sleep quality determinants and sleep quality indices

Variable	METS	% Sedentary	MEDAS	Alcohol	Charlson	PHQ-9	GAD-7	LTE
TST—Total sleep time (min/day)	-0.128*	0.153*	0.039	-0.027	-0.013	-0.066	-0.030	0.012
WASO—Wake after sleep onset (min)	0.107*	0.055	0.015	0.067	0.063	0.052	0.050	0.087
Number of awakenings	0.031	0.116*	0.044	0.106*	0.005	-0.025	-0.005	0.045
Sleep fragmentation index	0.004	0.068	0.046	0.090*	0.077	0.157*	0.134*	0.113*
Movement index	-0.026	0.151*	0.060	0.046	0.058	0.144*	0.107*	0.081
Fragmentation index	0.018	-0.007	0.030	0.094*	0.071	0.123*	0.107*	0.084
Pittsburgh Sleep Quality Index score	-0.041	0.073	-0.126*	0.101*	0.180*	0.488*	0.430*	0.241*

Partial correlations controlled for age group and sex.

* $p < 0.05$.

GAD-7, Generalised Anxiety Disorder-7 questionnaire; LTE, List of Threatening Experiences; MEDAS, Mediterranean Diet Adherence Screener; METS, standard resting metabolic rate; PHQ-9, Patient Health Questionnaire-9.

In relation to lifestyle habits, adherence to a Mediterranean diet (MEDAS) showed a moderate negative correlation with the PSQI ($r = -0.126$), indicating that a balanced diet could contribute to a more favourable perception of sleep quality. On the other hand, a higher level of physical activity (METS) was negatively associated with TST ($r = -0.128$), suggesting that excessive exercise could lead to slight reductions in the duration of nighttime rest.

Likewise, the number of awakenings was positively related to sedentary lifestyle ($r = 0.116$) and to alcohol consumption ($r = 0.106$), while the latter behaviour was also more weakly reflected in the SFI ($r = 0.090$). In relation to this, this index also showed positive correlations with the PHQ-9 ($r = 0.157$), the GAD-7 ($r = 0.134$) and the LTE ($r = 0.113$), reinforcing the idea that sleep instability is related to mental health and adverse life circumstances.

The complete results can be found in [table 3](#).

Characterisation of identified clusters

The two-stage cluster analysis allowed us to identify three clusters differentiated by sex. In both, age emerged as the most determining factor in the construction of these clusters, followed by educational level. The most relevant characteristics of each cluster, segmented by sex, as well as the relative weight of their predictors, are summarised below. The complete results can be found in online supplemental figures 1 and 2:

Men

The order of the predictors according to their relative weight in the model was: age (1), educational level (0.9), anxiety (GAD-7: 0.19), depression (PHQ-9: 0.17) and comorbidity (Charlson: 0.12). The remaining predictors showed relative values below 0.10.

Cluster 1 ($n = 84$, 33.7%): is composed mostly of men aged 35 years (38.1%) and all with middle or high school education. They have intermediate levels of anxiety and depression (GAD-7: 1.86; PHQ-9: 2.24) with respect to the other two clusters and the lowest levels of comorbidity (Charlson: 0.24).

Cluster 2 ($n = 88$, 35.3%): most of the patients were men aged 65 years (56.8%), 48.9% of whom had university education. They had the lowest levels of anxiety (GAD-7: 1.41) and depression (PHQ-9: 1.49), but the highest comorbidity of the three groups (Charlson: 0.86).

Cluster 3 ($n = 96$; 30.9%): is mainly represented by males aged 25 years (46.8%), with a high proportion of university studies (87%). They present the highest anxiety (GAD-7: 4.69) and depression (PHQ-9: 5.13) scores and intermediate comorbidity, with respect to the other groups (Charlson: 0.30).

Women

The predictors with the greatest relative weight were: age (1), educational level (0.62), anxiety (GAD-7: 0.20) and depression (PHQ-9: 0.20). The remaining predictors presented values below 0.10.

Cluster 1 ($n = 65$, 26.1%): Women were predominantly 35 years old (43.1%) and 78.5% had middle or high school education. They have the highest levels of anxiety (GAD-7: 6.74) and depression (PHQ-9: 7.17) compared with the other two female clusters.

Cluster 2 ($n = 88$, 35.3%): the majority were women aged 45 years (40.9%), all of them with university studies. Their levels of anxiety and depression are at intermediate values, with respect to clusters 1 and 3 (GAD-7: 3.80; PHQ-9: 3.51).

Cluster 3 ($n = 96$, 38.6%): consisting mainly of women aged 55 years (51.0%), 40.6% with middle or high school education. They have the lowest anxiety and depression scores (GAD-7: 2.04; PHQ-9: 2.19).

Indices of quality of sleep in the identified clusters

Using ANOVA, the behaviour of the sleep quality variables in each cluster was investigated.

Men

Among males, statistically significant differences were found in sleep efficiency, TIB, TST, WASO and number of awakenings. Post hoc analyses revealed a particular pattern. Cluster 2 showed the lowest values in

**Table 4** Sleep quality indices in the different clusters in men and women

Sex	Variable	Cluster 1	Cluster 2	Cluster 3	P value
Men	PSQI	6.0±3.2	6.2±4.1	6.4±4.0	0.771
	Efficiency*	88.3±10.0	91.8±3.8	89.4±3.9	0.002
	Total minutes in bed*†	417.2±81.2	383.2±80.8	429.0±80.8	<0.001
	TST†	368.1±83.8	351.7±74.8	384.2±75.3	0.030
	WASO*†	43.6±17.8	31.2±15.7	44.1±18.5	<0.001
	Number of awakenings*†	15.6±5.6	12.2±5.0	16.0±5.4	<0.001
	Average awakening length	3.0±1.4	2.8±1.3	2.8±0.9	0.255
	Sleep fragmentation index	25.8±6.8	24.5±8.6	26.2±6.8	0.305
	Movement index	14.2±3.2	14.0±4.3	14.3±3.3	0.796
	Fragmentation index	11.4±4.6	10.6±5.7	11.8±4.7	0.294
Women	PSQI*	9.4±4.4	6.8±3.9	7.8±4.1	<0.001
	Efficiency†‡	89.5±3.9	90.1±4.7	93.6±2.8	<0.001
	Total minutes in bed†‡	439.9±70.1	439.3±60.1	375.8±83.3	<0.001
	TST†‡	394.8±67.3	396.2±59.8	352.0±79.7	<0.001
	WASO†‡	44.4±16.9	42.3±18.6	23.8±11.1	<0.001
	Number of awakenings†‡	15.1±5.6	15.0±5.2	10.3±4.5	<0.001
	Average awakening length†‡	3.3±1.7	3.0±1.3	2.3±0.6	<0.001
	Sleep fragmentation index‡	24.6±7.8	22.9±6.9	20.6±6.5	0.002
	Movement index†‡	13.8±3.8	12.8±3.8	11.3±3.0	<0.001
	Fragmentation index	10.6±5.4	10.0±4.6	9.3±5.0	0.250

*Cluster 1 versus Cluster 2.

†Cluster 2 versus Cluster 3.

‡Cluster 1 versus Cluster 3.

PSQI, Pittsburgh Sleep Quality Index; TST, total sleep time; WASO, wake after sleep onset.

TIB (383.2±80.8 min), TST (351.7±74.8 min), WASO (31.2±15.7 min) and number of awakenings (12.2±5.0), with respect to the other two clusters. However, it also showed the highest efficiency (91.8±3.8%).

Women

In women, the differences were more pronounced and with a distinct pattern, with statistical significance in all variables except FI ($p=0.250$). Post hoc analysis showed that cluster 3 diverged from the other two clusters in most of the indicators. This cluster presented higher sleep efficiency (93.6±2.8%), less WASO (23.8±11.1 min), a lower number of awakenings (10.3±4.5) and a shorter mean duration of awakenings (2.3±0.6 min), as well as better scores in the FIs (movement index (MI) and SFI), suggesting a greater stability of the sleep pattern. However, this same cluster recorded the lowest values in TIB (375.8±83.3 min) and TST (352.0±79.7 min), with clusters 1 and 2 showing better performance in these metrics, respectively. Regarding PSQI, significant differences were observed between groups, with cluster 2 showing the lowest values (6.8±3.9) and cluster 1 the highest (9.4±4.4). The complete results are presented in [table 4](#), showing the main differences detected ($p<0.05$)

DISCUSSION

Major findings

The classification of the sample into different clusters differentiated by sex revealed that sleep quality has a multifactorial nature influenced by age, educational level, mental health status, comorbidities and lifestyle factors such as diet, alcohol consumption or physical activity. Mental health emerged as an essential determinant, coinciding with evidence highlighting the relationship between anxiety, depression and poorer sleep quality.^{11 12 23 24} However, the magnitude and direction of these relationships varied according to sex and the subgroup analysed, demonstrating the heterogeneity existing in the population.

When focusing on socioeconomic/cultural indicators, employment status emerged as the most consistent socioeconomic status (SES) correlate of objective sleep (being associated with higher sleep efficiency, lower WASO and a lower FI), whereas household income related to WASO and the number of awakenings. In contrast, subjective sleep quality (PSQI) was associated with marital status and educational attainment, but not with employment status or income. This pattern suggests that labour market position may be more salient for actigraphy-derived

phenotypes (in line with population data linking employment status to objectively measured sleep duration, TST), whereas marital/educational factors align more strongly with self-reported sleep quality.^{46 47}

In men, a subgroup (consisting mainly of those over 65 years of age, with university education and reduced levels of anxiety and depression) was observed that, despite presenting greater comorbidity and sleeping less time (lower TIB and TST), showed better sleep efficiency and fewer awakenings. This could be due to the ageing process, which is associated with a restructuring of sleep architecture, with less need for TIB, but with a more stable and consolidated sleep pattern.⁴⁸ This profile could reflect a greater physiological and psychological adaptation to comorbidity, supported by more effective coping strategies and a lifestyle adapted to chronic limitations. Thus, emotional stability and assimilation of the disease could compensate, at least partially, for the shorter duration of sleep, maintaining adequate efficiency.⁴⁹

On the opposite side, a male cluster (mostly young and university-educated) was identified with higher anxious–depressive and intermediate comorbidity burden, with more TIB and TST, but also higher WASO and number of awakenings. This pattern suggests that, although they are in bed longer, the presence of emotional symptoms interferes with sleep continuity. Previous studies point out that more TIB does not always translate into better rest, especially when depressive and anxious symptomatology conditions the lack of restful sleep.^{6 15} The influence of these emotional factors could explain the reduction in sleep efficiency and the increase in awakenings, even with prolonged TIB and TST.⁶

In women, the influence of emotional factors is more evident. The worst metrics in the variables PSQI, efficiency, WASO, number of awakenings, average awakening length, SFI and MI, as well as intermediate values of TIB and TST, corresponded to the cluster characterised by women aged 35 years with middle or high school and with greater signs of anxiety and depression. In contrast, the best results in sleep efficiency, WASO, number of awakenings, average awakening length, SFI and MI, as well as intermediate values on the PSQI, were identified in the cluster characterised, for the most part, by 55-year-old women with middle or high school education and the lowest levels of anxiety and depression. These results are consistent with the existing literature, which highlights female vulnerability to psychoemotional factors,^{18 50 51} showing worse sleep quality metrics compared with men.⁴⁹ Hormonal, sociocultural and caregiving role differences influence this greater emotional reactivity, reflected in patterns of lower efficiency, greater latency, greater number of awakenings and worse scores on PSQI and SFI.^{52–54}

This greater variability in the male sex could derive from the diversity of socioeconomic, behavioural and chronobiological roles, combined with genetic differences related to circadian gene expression.⁵⁵ In addition, some studies show that cultural, occupational and social

differences in the male population may heterogeneously influence the quality of sleep.^{56 57}

Regarding adherence to the Mediterranean diet, the best scores coincided with greater sleep efficiency, which coincides with research linking healthy dietary patterns with better subjective quality of sleep.^{15 16} However, its relative weight as a predictor was low, suggesting that diet exerts a modulating effect, but not a determining one.

Alcohol consumption showed a partial association with greater sleep fragmentation, with a clearer impact on women, which could indicate that alcohol intake acts as an amplifier of the impact of stress and anxiety on sleep architecture, with women being more sensitive to these factors.²⁰

The relationship between physical activity and sleep quality was inconclusive. One possible explanation could be the type and intensity of the physical activity, as well as the time of day at which it is performed. In this respect, it has been observed that vigorous exercise performed close to bedtime can generate a physiological activation that makes it difficult to fall asleep, while moderate physical activity, practised regularly and at early hours, seems to favour the stability of the sleep–wake cycle.^{58 59}

It is important to note that Spain has unique sociocultural characteristics that could influence sleep patterns. Siesta, despite its perception as a deep-rooted tradition, is practised regularly by only 27–33% of the young population (18–34 years),³⁰ a percentage that decreases to 16% in the adult population.⁶⁰ On the other hand, the late prime time television schedule in Spain delays both dinner and bedtime,⁶⁰ a factor that contributes to placing the country, together with Portugal, Greece and Romania, among the regions with the longest delay in the reconciliation of sleep, surpassed only by Russia.⁵⁷ Despite this, only 12% of Spaniards have irregular sleep schedules, a figure considerably lower than that of other European nations such as Italy, Germany or the UK, where this percentage is three times higher than in other countries.⁶⁰

Overall, the findings are consistent with the existing literature, which describes sleep as a multidimensional phenomenon.^{1 4 52 61} Emotional state,^{24 62} SES,^{63 64} which could constitute a secondary effect on sleep quality by influencing the perception of health status and depressive symptoms,⁵¹ comorbidity^{23 24} and lifestyles^{15–17 19–21} have been reported as influential factors. However, some authors do not find such a clear impact of educational level or socioeconomic position^{51 56} which could be explained by cultural differences, unmeasured factors (psychological resilience, social support) or genetically determined chronotype.⁵⁵

Cluster analysis, successfully used in studies on hypersomnia, attention deficit hyperactivity disorder or risk behaviours in adolescents,^{26 52 65} is shown here to be effective in understanding the internal diversity of the population, identifying subgroups with specific needs. This comprehensive approach can contribute to designing more precise and effective interventions.⁶⁶



Clinical implications

The identification of clusters with specific profiles suggests that health interventions should be personalised. In subgroups with high anxious–depressive load, the implementation of psychological therapies (such as neurofeedback) together with sleep hygiene education could be particularly effective.^{6 61} In groups with poorer dietary adherence, recommending healthy nutritional guidelines, such as those based on the Mediterranean diet, could improve not only diet but also the perceived quality of sleep.^{15 16 59} For groups with high alcohol consumption or sedentary lifestyles, comprehensive strategies combining promotion of regular physical activity, reduction of toxic habits and stress management could be promising options.²⁰

In summary, the cluster analysis reinforces the view of sleep health as a complex phenomenon that requires multifactorial approaches and personalised interventions, sensitive to differences by sex, emotional state, educational level and lifestyle habits, in line with current recommendations in public health, which advocate measures tailored to specific sociodemographic and psychoaffective characteristics.^{1 24 50} This comprehensive approach could optimise the allocation of resources, maximise the effectiveness of interventions and ultimately improve the quality of sleep and the overall well-being of the population.

Limitations

The main limitations of this study include, first, the origin of the sample, since, although calculations were made to guarantee its national representativeness, the data were obtained from two specific geographical areas in the centre-west of Spain (Salamanca and Ávila), which could limit the extrapolation of the results to the Spanish. These provinces were selected for feasibility and logistic reasons. However, they are less diverse than large metropolitan regions in terms of ethnicity and socioeconomic background, which may compromise national representativeness. Nevertheless, this focus provides valuable evidence in under-represented populations, and the stratified sampling by age and sex ensured internal representativeness of the study population. Furthermore, the study, which is cross-sectional in nature, does not allow us to establish causal relationships or to analyse the temporal relationship of the associations detected. Finally, it should be noted that, despite the large number of variables studied, it is presumable to consider the existence of other potentially relevant and unstudied variables, such as genetic, cultural or chronological factors, which could interfere with the relationships found.

The very low representation of rural participants and of ethnicities other than white/Caucasian prevented carrying out contrasts with sufficient power for area of residence and ethnicity.

CONCLUSIONS

A male cluster (mostly young and university-educated) was identified as having a higher anxious–depressive and intermediate comorbidity burden, with more TIB and TST, but also higher WASO and number of awakenings. The worst metrics in the variables PSQI, efficiency, WASO, number of awakenings, average awakening length, SFI and MI, as well as intermediate values of TIB and TST, corresponded to the cluster characterised by women aged 35 years with middle or high school and with greater signs of anxiety and depression.

Cluster segmentation, based on sociodemographic, mental health, lifestyle and clinical conditions, allows a more precise understanding of the determinants of sleep quality. Although the relationship between factors such as diet, physical activity, alcohol consumption, comorbidity and mental health with sleep is complex, our results support its multifactorial nature, which supports the need for personalised interventions. This combination of factors highlights the importance of approaching sleep in a comprehensive manner, taking into account both psychological and clinical conditions and the socioeconomic aspects and lifestyle habits that characterise each individual.

Availability of materials, data and code

The actigraphy devices employed in this study were procured with project funds and are managed by the Instituto de Investigación Biomédica de Salamanca (IBSAL, Salamanca, Spain). These devices are available to IBSAL-affiliated investigators via the institutional equipment booking system and subject to standard operating procedures. As these are physical assets, external sharing is not feasible.

In accordance with Spanish and European data-protection legislation, deidentified participant-level data are available on reasonable request from RA-D (Universidad de Salamanca; ralonsod@usal.es). Access is conditional on submission of a brief proposal outlining aims and planned analyses, a signed Data Use Agreement prohibiting reidentification and onward sharing and evidence of local ethics approval (or exemption). Data will be transferred via security channels; direct identifiers and any reidentification keys will not be shared. On acceptance, the deidentified data set will also be deposited in the DRYAD digital repository, and a persistent DOI will be provided.

The analysis code (IBM SPSS Statistics V.28 syntax files) will be made publicly available in an open repository (OSF/Zenodo) with a persistent DOI on acceptance; a link will be added at that time. Prior to publication, the code is available on reasonable request from the corresponding author.

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