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Gender differences in sleep quality and its associated factors in patients with hypertension: a cross-sectional study

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Abstract

Introduction In Malaysia, one third of the adult population suffer from hypertension and literature reported poor sleep quality led to cardiovascular events. However, little study was conducted to look at the gender-specific differences in sleep quality among hypertensive patients. This study aimed to examine gender difference in sleep quality and its associated factors among hypertensive population in a primary care clinic.

Method This was a cross-sectional study conducted from December 2023 to February 2024 using systematic approach with validated questionnaires (PSQI, DASS-21, STOP-BANG). Multiple logistic regression and Firth's penalized regression (to address sparse data/complete separation) were used to identify the determinants of poor sleep among different gender hypertensive patients.

Results Three hundred thirty-five participants (62.9% female, mean age 58 years) were recruited in this study. Prevalence of poor sleep among male and female were 91.1% and 84.8% respectively. In the multivariable analysis for men, a lack of regular physical exercise (< 150 min/week) was identified as the sole significant predictor of poor sleep (aOR 6.278, $p = 0.040$). Among women, poor sleep was significantly associated with anxiety symptoms (aOR 11.486; 95% CI: 1.37–96.21; $p = 0.024$) and income, where those in the B40 (bottom 40% income) and T20 (top 20% income) groups had higher odds of poor sleep compared to the M40 group (aOR 3.46; 95% CI: 1.23–9.72; $p = 0.019$).

Conclusion These findings highlight gender-specific determinants of sleep disturbances among those with hypertension, suggesting tailored interventions addressing physical inactivity for men and socioeconomic support or anxiety management for women to improve sleep quality.

Keywords Hypertension, Sleep, Quality, Gender, Malaysia

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Introduction

Hypertension is a prevalent non-communicable disease in Malaysia as data have shown that more than one thirds of Malaysians have hypertension [1]. Uncontrolled blood pressure leads to development of cardiovascular diseases, stroke and ends stage kidney disease [2, 3]. There are growing evidence that demonstrate the association between sleep disturbance which exacerbate hypertension and complicated with cardiovascular events [4–6]. Sleep quality is influenced by biological, psychological, and socioeconomic factors, with notable differences between genders [7, 8]. Women report poorer sleep quality than men, often due to hormonal fluctuations, caregiving roles, and higher rates of anxiety and depression [9]. Conversely, men experience more sleep-disordered breathing, such as obstructive sleep apnoea (OSA), which is strongly linked to hypertension [10]. Despite these finding, few studies were conducted to look at gender-specific determinants in sleep quality among patients with hypertension particularly in Malaysia [4, 5]. Understanding the gender difference is important for developing targeted interventions in primary care setting. Therefore, this study aims to determine the gender differences in sleep quality among patients with hypertension and to identify its associated factors.

Ethics

Ethics was obtained from the Malaysia Medical Research and Ethics Committee (ID:23-01029-UDQ).

Method

This study was conducted among primary care patients attending a public primary care clinic in Penang, Malaysia. All patients with hypertension (≥ 18-year-old) were recruited with systematic random sampling from 1 December 2023 to 28 February 2024. Patients with health conditions that render them unable to understand or complete the questionnaires were excluded from the study. Validated English and Malay version of the Pittsburgh Sleep Quality Index (PSQI), Depression, Anxiety and Stress Scale-21 (DASS-21), and the STOP-BANG questionnaires were used to assess sleep quality, psychological distress and screening for obstructive sleep apnoea (OSA). Poor sleep quality is defined when PSQI was ≥ 5, which is a well-established and validated criterion in international sleep research [11, 12].

A descriptive statistic was reported for the sociodemographic data in the form of mean, SD or percentages. Chi-square or independent student t-tests was used to compared sleep quality between genders. Multiple logistic regression was used to identify gender-specific predictors of poor sleep after adjusted for confounders. Those variables with p-value < 0.25 were entered into the analysis. Statistical significance was defined as $p < 0.05$.

Table 1 Prevalence of poor sleep, median, IQR, SD and mean PSQI scores among patients with hypertension by gender ($N = 335$)

	Good quality of sleep $n = 124$	Poor quality of sleep $n = 211$	PSQI score, Mean ± SD	PSQI score, Median (IQR)
Male, *n* (%)	11 (8.9)	113 (91.1)	8.66 ± 2.68	9.00 (4.00)
Female, *n* (%)	32 (15.2)	179 (84.8)	7.42 ± 2.64	7.00 (4.00)

Results

A total of 335 patients with hypertension took part in the study, yielding a response rate of 98.2%. The prevalence of poor sleep was 91.1% among male participants and 84.8% among female participants. The mean PSQI score was significantly higher in males (8.66 ± 2.68) compared to females (7.42 ± 2.64), with a p-value < 0.001. This disparity was further evidenced by the median scores and interquartile ranges, which were 9.00 (IQR 4.00) for men and 7.00 (IQR 4.00) for women (Table 1). Both gender groups demonstrated an identical total score range, spanning from a minimum of 3.00 to a maximum of 14.00.

Table 2 reported the gender differences in sociodemographic, clinical characteristics, and sleep quality among 335 primary care patients with hypertension. There were no significant differences between males and females in age, race, education level, marital status, household income, comorbidity status, obesity, depressive symptoms, or anxiety. Females were more likely to be unemployed or self-employed, non-smokers, and non-alcohol drinkers, while males were more likely to smoke, consume alcohol, and have a higher risk of OSA.

Table 3 reported the association between socio-demographic factors, clinical characteristics and sleep quality among participants with hypertension using chi-square or independent t-test. Variables with p-values less than 0.25 were included in the multiple logistic regression model. For male, variable with p-value less than 0.25 consisted of occupation, income categories, smoking status, exercise, obesity, risk of OSA, anxiety, stress, systolic and diastolic blood pressure. For women, variables with p-value less than 0.25 included occupation, income categories, exercise, obesity, risk of OSA, depression, anxiety, stress, age, and duration of hypertension.

Tables 4 and 5 present the predictors of poor sleep quality by gender. Initial analyses exhibited indicators of complete separation due to zero-count cells in several key predictors, specifically anxiety and stress, for male and depression for female. To address this, we conducted a sensitivity analysis. Variables causing separation were removed from the final multivariate model to ensure stability and interpretability. Furthermore, the "Income" variable was collapsed into two categories (M40 vs. B40/

Table 2 Gender differences in the sociodemographic, clinical characteristics and sleep quality among patients with hypertension ($n=335$)

Profile	Male N (%) ($n=124$)	Female N (%) ($n=211$)	*P* value
Age	58 (9.5)	58 (10.6)	0.953
Race			
Malay	92 (74.2)	163 (77.3)	0.526
Non malay	32 (25.8)	48 (22.7)	
Education level			
None	15 (12.1)	21 (10.0)	0.870
Primary	43 (34.7)	74 (35.1)	
Secondary	52 (41.9)	87 (41.2)	
Tertiary	14 (11.3)	29 (13.7)	
Marital Status			
Single	10 (8.1)	22 (10.4)	0.478
Married, Widow (er), Divorcee	114 (91.9)	189 (89.6)	
Occupation			
Self-employed or unemployed	15 (12.1)	71 (33.6)	< 0.001*
Public or private sector employee or retiree	109 (87.9)	140 (66.4)	
Household income			
B40 and T20	103 (83.1)	171 (81.0)	0.986
M40	21 (16.9)	40 (19.0)	
Comorbidity			
Hypertension only	45 (36.3)	86 (40.8)	0.418
Hypertension with other comorbidities	79 (63.7)	125 (59.2)	
Smoking			
Non-smoker	63 (50.8)	208 (98.6)	< 0.001*
Smoker	61 (49.2)	3 (1.4)	
Alcohol consumption			
Yes	16 (12.9)	3 (1.4)	< 0.001*
No	108 (87.1)	208 (98.6)	
Exercise			
≥ 150 min/week	59 (47.6)	139 (65.9)	0.001*
< 150 min/week	65 (52.4)	72 (34.1)	
Obese (BMI ≥ 27.5 kg/m^2)			
Yes	66 (53.2)	124 (58.8)	0.323
No	58 (46.8)	87 (41.2)	
Risk of OSA			
Yes	116 (93.5)	71 (33.6)	< 0.001*
No	8 (6.5)	140 (66.4)	
Risk of depression			
Yes	10 (8.1)	12 (5.7)	0.396
No	114 (91.9)	199 (94.3)	
Risk of anxiety			
Yes	38 (30.6)	54 (25.6)	0.317
No	86 (69.4)	157 (74.4)	
Risk of stress			
Yes	41 (33.1)	44 (20.9)	0.013*
No	83 (66.9)	167 (79.1)	
Systolic blood pressure	129.4 (10.9)	129.6 (12.3)	0.560
Diastolic blood pressure	72.6 (10.4)	75.1 (10.2)	0.063
Duration of hypertension in years	8.5 (7.1)	7.5 (6.5)	0.037*

n (%) for categorical variables; Mean (SD) for continuous variables

*Indicate there is a significant association with *p*-value < 0.05

T20) because the T20 group had zero participants with good sleep quality for both gender, preventing the calculation of stable estimates for that specific tier. The refined multivariate analysis for men identified a lack of regular physical exercise as the primary predictor of poor sleep quality. Men who did not engage in regular exercise were over six times more likely to report poor sleep compared to those who exercised (adjusted odds ratio [aOR] 6.278; 95% CI: 1.085–36.32; $p=0.040$) (Table 4). Other factors, including occupation, income, smoking, risk of OSA, blood pressure and body mass index, did not achieve statistical significance in the final adjusted model. These results were further validated through a sensitivity analysis using Firth's penalized logistic regression (refer appendix).

Events Per Variable (EPV) was assessed for both gender-specific analyses. For the female model, the EPV was 17.9, based on 179 events of poor sleep quality and 10 predictor variables. For the male model, the EPV was 14.1, based on 113 events and 8 variables. Although both models met the conventional requirements for adequate sample size per variable, Firth's penalized logistic regression was utilized for both genders to further enhance parameter stability and mitigate the risk of overfitting associated with the high prevalence of poor sleep.

In contrast to the male cohort, poor sleep quality in women was primarily driven by psychological and socioeconomic factors rather than lifestyle habits. After adjusting for age, BMI, and clinical comorbidities, anxiety was identified as the strongest independent predictor of poor sleep quality. Women who screened positive for anxiety symptoms were 11.49 times more likely to experience poor sleep compared to those without anxiety (aOR 11.486; 95% CI: 1.371–96.213; $p=0.024$). Additionally, women in the combined B40 and T20 income groups had 3.46 times higher odds of reporting poor sleep quality compared to those in the M40 category (aOR 3.460; 95% CI: 1.232–9.719; $p=0.019$).

While descriptive trends suggested higher odds of poor sleep among women with a risk of OSA (aOR 2.748), stress (aOR 3.785), and physical inactivity (aOR 2.099), these variables did not achieve statistical significance in the final adjusted model. Similarly, age, duration of hypertension, and the presence of other medical

Table 3 Association between socio-demographic factors, clinical characteristics and sleep quality among participants with hypertension using chi-square or independent student t-test ($n = 335$)

Variables	Male ($n = 124$)			Female ($n = 211$)		
	Good sleep quality	Poor sleep quality	*p*-value	Good sleep quality	Poor sleep quality	*p*-value
Marital status						
Single	1 (10.0)	9 (90.0)		3 (13.6)	19 (86.4)	
Married/ Divorcee/ Widow(er)	10 (8.8)	105 (91.2)	0.896	29 (15.3)	160 (84.7)	0.833
Ethnicity						
Malay	8 (8.7)	84 (91.3)		23 (14.1)	140 (85.9)	
Chinese	2 (8.0)	23 (92.0)		7 (18.4)	31 (81.6)	
Indian	1 (14.3)	6 (85.7)	0.869	2 (20.0)	8 (80.0)	0.728
Education level						
None	1 (6.7)	14 (93.3)		1 (4.8)	20 (95.2)	
Primary school	4 (9.3)	39 (90.7)		12 (16.2)	62 (83.8)	
Secondary school	3 (5.8)	49 (94.2)		13 (14.9)	74 (85.1)	
Tertiary education	3 (21.4)	11 (78.6)	0.327	6 (20.7)	23 (79.3)	0.471
Occupation						
Self-employed or unemployed	3 (20.0)	12 (80.0)		14 (19.7)	57 (80.3)	
Public or private employee or retiree	8 (7.3)	101 (92.7)	0.106*	18 (12.9)	122 (87.1)	0.224
Income categories						
M40	4 (19.0)	17 (81.0)		11 (27.5)	29 (72.5)	
B40 and T20	7 (6.8)	96 (93.2)	0.072*	21 (12.3)	150 (87.7)	0.016**
Smoking						
Yes	3 (4.9)	58 (95.1)		0 (0.0)	3 (100)	
No	8 (12.7)	55 (87.3)	0.128*	32 (15.4)	176 (91.1)	0.461
Alcohol consumption						
Yes	2 (12.5)	14 (87.5)		0 (0.0)	3 (84.6)	
No	9 (8.3)	99 (91.7)	0.584	32 (15.4)	176 (84.6)	0.461
Exercise						
≥ 150 min/week	9 (15.3)	50 (84.7)		25 (18.0)	114 (82.0)	
< 150 min/week	2 (3.1)	63 (96.9)	0.017*	7 (9.7)	65 (90.3)	0.113
Obese with BMI ≥ 27.5 kg/m2						
Yes	4 (6.1)	62 (93.9)		14 (11.3)	110 (88.7)	
No	7 (12.1)	51 (87.9)	0.240*	18 (20.7)	69 (79.3)	0.061
Risk of obstructive sleep apnoea						
Yes	8 (6.9)	108 (93.1)		4 (5.6)	67 (94.4)	
No	3 (37.5)	5 (62.5)	0.003*	28 (20.0)	112 (80.0)	0.006
Presence of depression						
Yes	0 (0.0)	10 (100.0)		0 (0.0)	12 (100.0)	
No	11 (9.6)	103 (90.4)	0.303	32 (16.1)	167 (83.9)	0.132
Presence of anxiety						
Yes	0 (0.0)	38 (100.0)		1 (1.9)	53 (98.1)	
No	11 (12.8)	75 (87.2)	0.021*	31 (19.7)	126 (80.3)	0.002
Presence of stress						
Yes	0 (0.0)	41 (100.0)		1 (2.3)	43 (97.7)	
No	11 (13.3)	72 (86.7)	0.015*	31 (18.6)	136 (81.4)	0.007
Comorbidities						
Hypertension only	5 (11.1)	40 (88.9)		10 (11.6)	76 (88.4)	
Hypertension with other comorbidities	6 (7.6)	73 (92.4)	0.508	22 (17.6)	103 (82.4)	0.235
Age	63 (21.0)	57.0 (12.0)	0.745	56 (13.0)	60 (16.0)	0.237
Systolic blood pressure, mean (SD)	132 (15.0)	129 (12.5)	0.065*	129 (16.3)	131 (16.0)	0.672
Diastolic blood pressure, mean (SD)	76 (9.0)	69 (13.5)	0.121*	76 (10.8)	74 (12.0)	0.368
Duration of hypertension, mean (SD)	4 (12.0)	6 (9.5)	0.874	3 (4.8)	6 (8.0)	0.028

**In Malaysia, household income is stratified into three categories: B40 (bottom 40%), M40 (middle 40%), and T20 (top 20%). The B40 group comprises households earning less than RM4,850 per month (approximately USD1,140), the M40 group includes those earning between RM4,850 and RM10,959, and the T20 group comprises households with a monthly income exceeding RM10,959 (approximately USD2,575)

Table 4 Predictors of poor sleep among men with hypertension using multiple logistic regression

Variables	adjusted OR	95%CI (LL, UL)		*p*-value
Income categories, (B40 or T20)	2.849	0.500	16.247	0.239
M40	1			
Obesity with BMI ≥ 27.5 kg/m^2, yes	1.360	0.297	6.229	0.692
No	1			
Smoking, yes	3.384	0.700	16.355	0.129
No	1			
Obstructive sleep apnoea, yes	7.262	0.852	61.891	0.070
No	1			
Occupation, public or private employee or retiree	0.689	0.151	3.151	0.631
Self-employed	1			
Exercise, < 150 min/week	6.278	1.085	36.320	0.040
≥ 150 min/week	1			
Systolic blood pressure	0.941	0.941	1.037	0.218
Diastolic blood pressure	0.984	0.901	1.075	0.718

Table 5 Predictors of poor sleep among women with hypertension: multiple logistic regression

Variables	adjusted OR	95%CI (LL, UL)		*p*-value
Occupation, public or private employee or retiree	0.567	0.241	1.335	0.194
Self-employed or unemployed	1			
Income categories (B40 or T20)	3.460	1.232	9.719	0.019
M40	1			
Risk of obstructive sleep apnoea, yes	2.748	0.773	9.769	0.118
No	1			
Anxiety, yes	11.486	1.371	96.213	0.024
no	1			
Age	0.994	0.940	1.052	0.838
Obesity with BMI ≥ 27.5 kg/m^2, yes	0.890	0.355	2.226	0.803
No	1			
Hypertension only	0.476	0.183	1.237	0.128
Hypertension with other comorbidities	1			
Stress, yes	3.785	0.413	34.665	0.239
no	1			
Exercise, < 150 min/week	2.099	0.769	5.729	0.148
≥ 150 min/week	1			
Duration of hypertension	1.087	0.967	1.222	0.162

comorbidities were not significant predictors of sleep quality within female group.

Sensitivity analysis using Firth's penalized logistic regression was conducted for the female cohort which showed consistency with the sensitivity analysis (refer appendix).

Discussion

Our study found an exceptionally high prevalence of poor sleep among older patients with hypertension (men: 91.1%, women: 84.8%), substantially higher than the rates observed in adults with hypertension in China (60.4%), Turkey (63.3%), and United States (52.4%) [13–15]. Previous study on the prevalence of poor sleep among Malaysian working adults during the COVID-19 pandemic was 59.4%, whilst another study among older adults found a prevalence of 53.4%, are lower compared to our study [16, 17]. These discrepancies may partly arise because previous studies did not focus exclusively on older individuals with hypertension to which hypertension has been linked to poor sleep in previous studies [4, 5]. Among patients with hypertension without limiting to older population, a meta-analysis found a pooled prevalence of 52.5% with poor sleep quality [18]. Nonetheless, the markedly higher rates of poor sleep in our sample (85–91%) may be attributed to the unique socio-cultural environment in Malaysia, characterized by a multi-ethnic landscape and a pervasive 24-hour food culture. The accessibility of late-night eateries encourages nocturnal eating habits which is associated with poor sleep quality [19]. Furthermore, the high prevalence of OSA in Malaysia, estimated at approximately 54%, could explain the high prevalence of poor sleep [20]. Asian populations often possess distinct craniofacial characteristics, including smaller

maxillofacial joints and narrower upper airways, which heighten the risk of airway collapse during sleep [21]. However, it must be acknowledged that the exceptionally high percentages recorded may also reflect the specific demographic profile of this single-centre primary care cohort. While our systematic sampling was designed to minimize bias, the potential for a localized clustering of high-risk individuals cannot be entirely excluded.

Our study found that men suffer poor sleep more than women, exhibiting higher mean PSQI scores (8.66 vs. 7.42). Although a trend is observed toward poorer sleep in men, it is not statistically significant. This in contrast with study from China which showed that the prevalence of poor sleep was higher in older women (39.2%) compared to older men (26.3%) and having hypertension was found to result in poor sleep quality [22]. Previous studies from the United States [23], England [24] and China [25] also reported that poor sleep quality were associated with higher risk of hypertension in women compared to men. However, these studies examined general populations, not individuals with established hypertension [23–25]. The focus of our study on only patients with hypertension may explain why our study did not observe the same gender-related differences in sleep quality.

The significant association between physical inactivity and poor sleep in our male cohort highlights a critical opportunity for lifestyle-based interventions within the Malaysian primary care system. The use of Firth regression allowed for a robust estimation that overcame the statistical challenges of complete separation, confirming that the high sleep burden in this population is inextricably linked to sedentary behaviour. Our findings align with a growing body of international evidence. One systematic review reported that frequent, consistent and moderate intensity exercise was associated with improved sleep quality [26]. This is directly reflected in our study, as participants who failed to meet the World Health Organization (WHO) threshold of ≥ 150 min of moderate-intensity physical activity per week were over four times more likely to experience poor sleep [27]. Recent study from Korea also found that sedentary lifestyle is positively associated with poor sleep quality in both men and women [28]. The physiological mechanisms underlying this relationship may be particularly relevant for men with hypertension. Regular exercise helps to increase melatonin, reducing stress and anxiety while regulating the circadian rhythms for better sleep quality [29]. Promoting physical activity in primary care settings could serve a dual purpose, improving cardiovascular outcomes while simultaneously mitigating the high prevalence of sleep disruption.

Our findings demonstrate gender difference in the impact of socioeconomic status on sleep quality. For women, we observed a bimodal risk pattern where those at the lower and higher ends of the income spectrum experienced poorer sleep compared to the middle-income group (aOR = 3.46). This disparity may indicate that women are more susceptible to the specific stressors associated with financial insecurity. This finding contrasts with studies from the United States, where individuals with higher income tend to have optimal sleep durations (7–9 h), largely attributed to reduced financial strain, better mental health and improved living conditions [30–32].The possible explanation were that B40 group suffer from financial insecurity which may contribute to increased psychological stress and poor sleep [33]. On the other end, individuals in T20 group may experience higher work demands, longer working hours, greater job-related stress, all which can negatively affect sleep quality [34].

Interestingly, while psychological factors did not reach significance in the male cohort, anxiety symptoms in women were associated with over 11 times higher odds of poor sleep quality (aOR 11.486; $p = 0.024$). This gender-specific vulnerability suggests that women with hypertension may be more susceptible to the sleep-disrupting effects of emotional distress, necessitating a more integrated approach to mental health and sleep hygiene in primary care settings. Our finding is consistent with a cross-sectional study conducted in China which reported that women with hypertension were more likely to experience anxiety symptoms [35]. Additionally, meta-analyses have demonstrated a strong bidirectional association between anxiety and hypertension [36, 37]. While anxiety is known to negatively affect both blood pressure regulation and sleep quality, the observed gender disparity in sleep outcomes may be attributable to differences in coping styles and emotional regulation strategies. These differences are likely influenced by both biological predispositions and sociocultural expectations that shape emotional expression and stress responses between men and women [38].

The use of a PSQI global score of > 5 as the threshold for defining poor sleep quality is a well-established and validated criterion in international sleep research. However, the appropriateness of this specific cut-off in a population of older hypertensive patients in Malaysia warrants consideration. While the PSQI was not developed for a specific demographic, its application across diverse clinical groups has occasionally revealed inconsistencies in its internal factor structure(12). Furthermore, maintaining the PSQI > 5 threshold ensures direct comparability with existing Malaysian and international literature, which consistently utilizes this standard. While future research incorporating objective measures like polysomnography could further calibrate this cut-off for older hypertensive Asian cohorts, the current global PSQI score provides

a validated and reliable estimate of the significant sleep burden present in this population.

Strengths and limitations

This study offers valuable insight into sleep quality among patients with hypertension in a primary care setting by using validated and widely adopted assessment tools such as the PSQI, the DASS-21, and the STOP-BANG questionnaire. The use of bilingual (English and Malay) versions of these instruments strengthens the validity of the data in the Malaysian context. Moreover, the systematic random sampling method enhances the internal validity of our findings within the clinic population. However, several limitations should be acknowledged. First, the study was conducted in a single public primary care clinic in Malaysia, which may limit the generalizability of the findings to other regions or private healthcare settings. Second, the cross-sectional design restricts our ability to infer causal relationships between associated factors and poor sleep quality. A primary consideration is the potential for selection bias inherent in a clinic-based study design. As the participants were recruited from a public primary care facility, they represent a treatment-seeking population that may exhibit a higher prevalence of comorbidities or psychological distress compared to the general population in the community. Our findings may not be fully generalizable to suburban or rural areas of Malaysia as the study was conducted in Penang state which is a highly urbanized state with a significantly higher cost of living compared to the national average. This study provides valuable insights that can inform gender-sensitive approaches to managing sleep health among individuals with hypertension in urban areas in Malaysia.

Conclusion

In summary, the determinants of poor sleep quality exhibit distinct patterns across gender within the hypertensive population. These findings highlight the necessity for clinicians to adopt gender-sensitive diagnostic and therapeutic strategies when managing sleep disturbances in primary care. Among women, the risk of poor sleep is independently driven by psychological and socioeconomic factors, specifically the presence of anxiety and lack of middle-income stability. For men, the primary significant predictor is physical inactivity, suggesting that lifestyle-based interventions focusing on exercise may be particularly effective for men. This study suggests that tailored interventions addressing anxiety and socioeconomic stability for women, alongside physical activity promotion for men, are essential to improve sleep health in patients with hypertension. Future research utilizing longitudinal designs and objective sleep measures can further elucidate the causal mechanisms underlying these gender-specific associations.

Abbreviations

aOR	Adjusted Odds Ratio
B40	Bottom 40% income group in Malaysia
BMI	Body Mass Index
DASS-21	Depression, Anxiety and Stress Scale-21
EPV	Events Per Variable
HTN	Hypertension
IQR	Interquartile Range
LAR	Legally Authorised Representative
LL	Lower Limit (used in confidence intervals)
M40	Middle 40% income group in Malaysia
OSA	Obstructive Sleep Apnoea
PSQI	Pittsburgh Sleep Quality Index
RM	Ringgit Malaysia
SD	Standard Deviation
T20	Top 20% income group in Malaysia
UL	Upper Limit (used in confidence intervals)
USD	United States Dollar
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-026-27325-0.

Supplementary Material 1.

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Clinical trial registration

Not applicable.

Authors' contributions

L.H., S.F.L., and S.M.C. conceptualized and designed the study. L.H., H.W.L, and F.A.B. collected the data. S.F.L. and S.M.C. analysed the data and contributed to data interpretation. L.H. and S.F.L. drafted the initial manuscript. S.F.L and S.M.C edited the manuscript. S.M.C. supervised the project and finalized the manuscript. All authors reviewed and approved the final version of the manuscript.

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Data availability

Anonymised data will be available upon written request to corresponding author.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Malaysia Medical Research and Ethics Committee (ID: 23-01029-UDQ). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and the Malaysian Good Clinical Practice guidelines. All participants were provided with a Participant Information Sheet and gave written informed consent prior to enrolment.

For participants who were illiterate, the study team obtained informed consent from their legally authorised representative (LAR), in line with ethical requirements.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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