

Sleep quality and associated factors across four reproductive life stages in Japanese women: A cross-sectional study

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Abstract

Women go through distinct life stages, including pregnancy, childbirth, and menopause, each accompanied by changes in sleep quality; however, no study has performed a comprehensive comparative analysis of sleep quality across these stages in Japanese women. This cross-sectional research examined sleep quality using the Pittsburgh Sleep Quality Index and contributing factors among 1,213 Japanese women across 4 groups: premenopausal nulligravid women (n = 333), pregnant women (n = 245), mothers of infants (n = 338), and perimenopausal women (n = 297). Multiple regression analysis identified being a mother of an infant, body mass index, the Simplified Menopausal Index (SMI), morning fatigue, attribution of sleep problems to busyness, and avoidance of presleep screen use as significant predictors of sleep quality. Group-specific models revealed that the SMI was the only significant predictor in pregnant women, morning fatigue in mothers of infants, and both in perimenopausal women, indicating that sleep-related risk profiles differ across life stages. The poor sleep quality observed among mothers of infants underscores the need for interventions targeting sleep quality. The identification of modifiable factors (e.g., screen avoidance, cognitive reappraisal of busyness) provides concrete targets for public health.

Introduction

Throughout their lives, women go through distinct life stages, including pregnancy, childbirth, and menopause, each accompanied by substantial changes in hormonal balance and social roles. These transitions are known to exert multifaceted effects on sleep quality and sleep architecture [1–3]. Fluctuations in female sex hormones, particularly estrogen and progesterone, during reproductive years and perimenopause have been well documented to impact sleep [1].

Sleep disturbances during pregnancy and the postpartum period can be attributed to not only hormonal fluctuations but also physiological and psychosocial factors, including nocturia, gastroesophageal reflux, musculoskeletal discomfort, and nighttime awakenings for infant care [2]. A comprehensive review by Pengo et al. [3] systematically mapped the associations between hormonal changes across the female lifespan and sleep, highlighting the prominent roles of premenstrual syndrome, menopausal symptoms, and postpartum depression.

International studies across multiple countries have evaluated life-stage-specific sleep quality using various instruments, such as the Pittsburgh Sleep Quality Index (PSQI). Accordingly, their findings have shown that sleep quality deteriorates from the second to the third trimester of pregnancy, [4] that approximately 67% of postpartum women experience sleep disturbances [5], and that the prevalence of poor sleep quality among menopausal women is 50.8% [6].

Japan has one of the shortest average adult sleep durations worldwide [7], alongside a well-documented gender gap in domestic and childcare responsibilities. These sociocultural characteristics can disproportionately affect women's sleep, particularly during biologically vulnerable periods, such as pregnancy, the postpartum phase, and perimenopause. An actigraphy-based study in Japan reported

shorter sleep duration in women than in men, suggesting that unequal domestic burdens can contribute to this disparity [8]; however, the absence of life-stage stratification precluded the detailed evaluation of how sleep quality varies across these critical periods. To the best of our knowledge, no cross-sectional research has comprehensively and comparatively analyzed sleep quality across these life stages in Japanese women. Addressing this gap is essential given that the interaction between sociocultural and biological factors can produce the patterns distinct from those observed in Western populations.

Against this background, the present study aimed to (1) evaluate differences in sleep quality across life stages among four groups of Japanese women (premenopausal nulligravid women, pregnant women, mothers of infants, and perimenopausal women); (2) identify factors associated with sleep quality, thereby generating findings comparable with international data; and (3) explore whether and how predictors of sleep quality operate within each individual life stage, including the variables specific to that stage. Ultimately, this comprehensive evaluation aims to identify which life stages of Japanese women require prioritized interventions and practical solutions. To this end, we employed the two-tier analytical strategy: the overall model incorporating all four groups was estimated to address aims 1 and 2, while group-specific models were subsequently designed to address aim 3. Measures common to all groups spanned physical, psychological, and behavioral domains: physical symptom burden was assessed using the Simplified Menopausal Index (SMI); psychological distress was assessed using the Kessler Psychological Distress Scale (K6) and Perceived Stress Scale (PSS); and interoceptive awareness was assessed using the Multidimensional Assessment of Interoceptive Awareness—Japanese version (MAIA-J). Sleep-related attitudes, 29 daily health-behavior items, and perceived social support were also included in our analyses. Group-specific models additionally incorporated stage-specific variables, including menstrual cycle characteristics and premenstrual dysphoric disorder (PMDD) symptoms in premenopausal nulligravid women, gestational week in pregnant women, and infant sleep characteristics along with infant temperament in mothers of infants.

Methods

Study design and participants

This cross-sectional web-based research was conducted in December 2024. The participants were recruited from the general population through Macromill, Inc., the Japanese online research panel company, and allocated to one of four life-stage groups. (1) The premenopausal nulligravid group consisted of healthy menstruating women aged 20–44 years who engaged in day-shift work, with no current pregnancy and children. (2) The pregnant women group consisted of those aged 20–44 years during their first pregnancy, with approximately equal representation across the first, second, and third trimesters. (3) The mother group included those aged 20–44 years raising a first-born infant aged 0–12 months, with approximately equal distribution across four age bands (0–3, 4–6, 7–9, and 10–12 months). First-time pregnancies and first-born infants were specified to ensure sample homogeneity given that prior childbirth experience and the presence of older children may introduce confounding effects on sleep patterns that cannot be adequately controlled. (4) The perimenopausal group consisted

of healthy women aged 45–55 years who engaged in day-shift work. This age range was determined based on the reported mean age at menopause in Japanese women (49.33 years [9]) and the Japan Society of Obstetrics and Gynecology definition of perimenopause as the 10-year period spanning 5 years before and after menopause [10]. Individuals engaged in night-shift work and those receiving treatment for cardiac, respiratory, hepatic, neurological, or psychiatric conditions were excluded from the sample.

Among the 1,563 initial respondents, 350 were excluded owing to careless responses (e.g., uniform response patterns), internal inconsistencies, or implausible sleep parameters, yielding a final analytic sample of 1,213 (premenopausal nulligravid: $n = 333$; pregnant: $n = 245$; mother: $n = 338$; perimenopausal: $n = 297$). This study was approved by the Ethics Committee of the Graduate School of Informatics, Nagoya University (NUPSY-241204-G-01). All methods were performed in accordance with the relevant guidelines and regulations (e.g., the Declaration of Helsinki). Each participant provided electronic informed consent.

Measures

Sleep quality was assessed using the total PSQI score (range 0–21; higher scores indicate poorer sleep quality; clinical cutoff > 5.5) [11, 12]. Explanatory variables common to all groups included age, body mass index (BMI), living-alone status, the SMI [13, 14], K6 [15, 16], PSS [17, 18], MAIA-J [19, 20], Multidimensional Scale of Perceived Social Support (MSPSS [21, 22]), and Satisfaction with Life Scale (SWLS [23, 24]).

Sleep-related attitudes were assessed using four original items rated on a 5-point Likert scale: (1) taking proactive measures to improve sleep, (2) believing sleep problems can be resolved through effort, (3) prioritizing hobbies and personal time over sleep, and (4) feeling that busyness sacrifices sleep. These items were developed based on the Charlotte Attitudes Towards Sleep (CATS) Scale [25] and the concept of time-based conflict [26]. Additionally, daily health behaviors were evaluated using 29 original items covering the weekly frequency of habits across five domains (physical activity, dietary habits, stimulants and daytime habits, sleep environment, and presleep behaviors). These 29 items were adopted from the Guide for Health Promotion through Sleep 2023 published by the Japanese Ministry of Health, Labour and Welfare (2024) [27]. Full details regarding all items are presented in Supplementary Table S1. Descriptive statistics for all variables were computed for the total sample and for each group.

Group-specific variables were as follows: menstrual status, dysmenorrhea score [28], and PMDD scale [29] for the premenopausal nulligravid group; gestational week for the pregnant group; and the Revised Infant Temperament Questionnaire (RITQ) Regularity subscale [30, 31] together with five original nocturnal infant sleep items for the mother group. These items were evaluated to capture key dimensions of infant sleep known to affect maternal sleep quality, namely nocturnal awakening frequency and self-soothing capacity [32] and sleeping arrangements, such as room- and bed-sharing [33, 34]. A summary of all variables used in the analysis is presented in Table 1.

Table 1
Summary of variables used in the analysis

Dependent variable	Variable type	Variables
		Total PSQI score
Explanatory variables	Continuous	Age, BMI, sleep attitudes (four items), daily health behaviors (29 items), SMI, K6, PSS, SWLS, MSPSS, and MAIA-J
	Categorical	Assigned group, living alone, menopausal treatment, menstrual problems, and other disease treatment
Group-specific additional variables		
	Premenopausal nulligravid women	Living alone, menstrual status, dysmenorrhea score, and the PMDD scale
	Pregnant women	Living alone and gestational week
	Mothers of infants	Infant age, menstrual status, RITQ regularity, nighttime awakenings, bed-sharing, and room-sharing
<i>Note.</i> Full measure details are provided in Supplementary Table S1. PSQI = Pittsburgh Sleep Quality Index; SMI = Simplified Menopausal Index; MAIA-J = Multidimensional Assessment of Interoceptive Awareness; RITQ = Revised Infant Temperament Questionnaire		

Statistical analysis

Multiple linear regression models with the dependent parameter of total PSQI score were fitted to examine the influence of life stage and other possible factors on variability of sleep quality among Japanese adult women. Categorical predictors were entered into the regression model using dummy coding. For life-stage variables, premenopausal nulligravid women were used as the reference category, and regression coefficients were interpreted relative to this group. The overall model including all four groups (53 predictors) and separate group-specific models were analyzed. Cases with missing data on group-specific variables were excluded from the respective group-specific regression models via listwise deletion, resulting in reduced sample sizes for these models (premenopausal nulligravid: $N = 293$; mothers of infants: $N = 251$). Multicollinearity was evaluated using the variance inflation factor. When heteroscedasticity was detected (Breusch–Pagan test), HC3 robust standard errors were applied. Given that our exploratory regression analysis included a large amount of predictor variables, the p values obtained by null-hypothesis tests for the regression coefficients were corrected for the false discovery rate (FDR) using the Benjamini–Hochberg procedure ($\alpha = 0.05$, two-tailed). If necessary, pairwise group differences in the marginal means of the total PSQI score among life stage groups were determined using the Bonferroni correction ($\alpha = 0.05$, two-tailed).

To address the potential content overlap between the SMI sleep item and the PSQI, sensitivity analysis was conducted using an adjusted SMI score, with the sleep-related item (item 5) having been excluded

(SMI_adj). Spearman rank correlations between total PSQI score and all predictors were also determined (Supplementary Table S2). Similar to regression coefficients, the p values obtained during the null-hypothesis testing ($\alpha = 0.05$, two-tailed) for correlation coefficients were corrected for FDR.

All analyses were performed using R version 4.2.3 [35] with RStudio (v2023.06.0 + 421). The following R packages were used: psych (v2.3.6) [36] for Spearman rank correlations; performance (v0.16.0) [37] and olsrr (v0.6.1) [38] for model diagnostics, including the Breusch–Pagan test and GVIF; parameters (v0.28.3) [39] for coefficient standardization and FDR correction;ggeffects (v2.0.0) for estimated marginal means; marginaffects (v0.19.0) [40] for pairwise group contrasts; and rstatix (v1.1.0) [41] for non-parametric tests.

Results

Descriptive statistics

Descriptive statistics for age, BMI, and total PSQI scores according to group are presented in Table 2. The Kruskal–Wallis test revealed significant differences in age across the four groups ($H(3) = 689.9$, $p < .001$, $\eta^2_H = 0.57$). Post-hoc pairwise comparisons with Bonferroni correction showed that pregnant women were significantly younger than were premenopausal nulligravid women ($p < .001$, Cliff's $\delta = -0.25$), mothers of infants ($p = .002$, Cliff's $\delta = -0.17$), and perimenopausal women ($p < .001$, Cliff's $\delta = -1.0$). Perimenopausal women were significantly older than all other groups ($p < .001$, Cliff's $\delta = 1.0$ for all). No significant difference in age was found between mothers of infants and premenopausal nulligravid women ($p = .075$, Cliff's $\delta = -0.11$). Similarly, BMI differed significantly across groups ($H(3) = 19.7$, $p < .001$, $\eta^2_H = 0.01$), with post-hoc tests confirming that the pregnant group had significantly higher BMI values than did the premenopausal nulligravid ($p < .001$, Cliff's $\delta = 0.21$), mother ($p = .011$, Cliff's $\delta = 0.15$), and perimenopausal ($p = .037$, Cliff's $\delta = 0.14$) groups, with no significant differences observed between the latter three groups. Based on the clinical cutoff (PSQI > 5.5), a substantial proportion of women in the mother (64.2%, $n = 217$) and pregnant groups (46.5%, $n = 114$) were classified as poor sleepers, indicating a high prevalence of sleep disturbance in these two groups. Notably, mothers of infants exhibited the lowest habitual sleep efficiency among all groups (84.0%; Table 2), reflecting frequent nighttime awakenings. After stratifying the mother group according to the infant age, 76.9% of mothers of infants aged 0–3 months exceeded the clinical PSQI cutoff, whereas 59.3%, 57.1%, and 61.8% of mothers of infants aged 4–6 months, 7–9 months, and 10–12 months did the same (Supplementary Table S3-1). Among pregnant women, the proportion of poor sleepers increased from 40.8% in the first trimester to 52.5% in the third trimester (Supplementary Table S3-1). The psychosocial, health, and behavioral parameters are described and summarized in Supplementary Tables S3-2 and S3-3.

Table 2

Descriptive statistics for age, BMI, total PSQI score, subscales, and sleep parameters according to group

Variable	Total (<i>N</i> = 1,213)	Premenopausal nulligravid (<i>N</i> = 333)	Pregnant (<i>N</i> = 245)	Mothers of infants (<i>N</i> = 338)	Perimenopausal (<i>N</i> = 297)
Age (years)					
Mean (<i>SD</i>)	35.9 (9.5)	32.8 (6.7)	29.7 (4.3)	31.3 (5.2)	49.9 (3.0)
Median [Q1, Q3]	33.0 [28.0, 44.0]	32.0 [27.0, 39.0]	29.0 [27.0, 32.0]	30.0 [28.0, 34.0]	50.0 [47.0, 52.0]
Range	20–55	20–44	20–44	20–44	45–55
BMI					
Mean (<i>SD</i>)	21.1 (3.4)	20.8 (3.6)	21.6 (3.0)	21.1 (3.6)	21.0 (3.3)
Median	20.3	20.1	21.1	20.2	20.4
[Q1, Q3]	[18.8, 22.5]	[18.5, 22.2]	[19.5, 22.8]	[18.8, 22.5]	[19.1, 22.1]
Range	12.0– 39.2	12.0–38.5	15.8–32.3	15.2–38.7	15.4–39.2
Total PSQI score					
Mean (<i>SD</i>)	5.8 (3.0)	5.2 (2.9)	5.7 (2.9)	6.7 (3.0)	5.3 (2.7)
Median [Q1, Q3]	5.0 [4.0, 8.0]	5.0 [3.0, 7.0]	5.0 [3.0, 8.0]	7.0 [5.0, 9.0]	5.0 [4.0, 7.0]
Poor sleepers <i>n</i> (%) PSQI > 5.5	587 (48.4%)	129 (38.7%)	114 (46.5%)	217 (64.2%)	127 (42.8%)
PSQI subscales— Mean (<i>SD</i>), range 0–3					
C1 Subjective sleep quality	1.4 (0.7)	1.3 (0.7)	1.4 (0.7)	1.6 (0.7)	1.5 (0.7)
C2 Sleep latency	1.1 (1.0)	1.1 (0.9)	1.3 (1.0)	1.3 (1.0)	0.8 (0.9)
Note. <i>N</i> = 1,213. PSQI = Pittsburgh Sleep Quality Index. Higher PSQI scores stand for poorer sleep quality (clinical cutoff > 5.5).					
Poor sleepers = total PSQI score > 5.5. PSQI subscales range 0–3 each. Times in 24-hour format (HH:MM). Q1, Q3 = first and third quartiles					

Variable	Total (<i>N</i> = 1,213)	Premenopausal nulligravid (<i>N</i> = 333)	Pregnant (<i>N</i> = 245)	Mothers of infants (<i>N</i> = 338)	Perimenopausal (<i>N</i> = 297)
Age (years)					
C3 Sleep duration	1.1 (0.9)	1.1 (0.8)	0.8 (0.8)	1.2 (0.9)	1.4 (0.8)
C4 Habitual sleep efficiency	0.4 (0.8)	0.2 (0.5)	0.4 (0.7)	0.8 (1.1)	0.2 (0.5)
C5 Sleep disturbances	0.9 (0.6)	0.8 (0.6)	1.1 (0.6)	1.0 (0.5)	0.8 (0.6)
C6 Use of sleep medication	0.1 (0.5)	0.2 (0.6)	0.1 (0.5)	0.2 (0.6)	0.1 (0.4)
C7 Daytime dysfunction	0.6 (0.7)	0.6 (0.7)	0.5 (0.6)	0.6 (0.7)	0.5 (0.6)
Sleep Parameters (PSQI open-ended items)					
Bedtime—Mean (SD)	23:18 (± 1.3h)	23:36 (± 1.3h)	23:18 (± 1.1h)	23:06 (± 1.3h)	23:24 (± 1.3h)
Bedtime—Median [Q1, Q3]	23:00 [22:30, 00:00]	23:30 [22:48, 00:30]	23:00 [22:30, 00:00]	23:00 [22:00, 00:00]	23:18 [22:30, 00:00]
Wake time—Mean (SD)	06:54 (± 1.3h)	06:54 (± 1.3h)	07:18 (± 1.3h)	07:06 (± 1.3h)	06:12 (± 1.1h)
Wake time—Median [Q1, Q3]	06:48 [06:00, 07:30]	06:48 [06:00, 07:30]	07:00 [06:30, 08:00]	07:00 [06:30, 08:00]	06:00 [05:30, 06:42]
Time in bed (h)	7.5 (1.3)	7.3 (1.1)	8.0 (1.2)	8.0 (1.5)	6.8 (1.1)
Sleep duration (h)	6.7 (1.2)	6.8 (1.0)	7.2 (1.1)	6.6 (1.3)	6.3 (1.1)
Sleep latency (min)	27.0 (26.9)	26.9 (26.6)	31.2 (28.5)	30.7 (29.9)	19.5 (19.8)
Sleep efficiency (%)	90.1 (12.5)	93.4 (9.4)	90.5 (10.9)	84.0 (15.8)	93.2 (10.0)
<i>Note.</i> <i>N</i> = 1,213. PSQI = Pittsburgh Sleep Quality Index. Higher PSQI scores stand for poorer sleep quality (clinical cutoff > 5.5). Poor sleepers = total PSQI score > 5.5. PSQI subscales range 0–3 each. Times in 24-hour format (HH:MM). Q1, Q3 = first and third quartiles					

Correlation analysis

Spearman correlations with total PSQI score are presented in Supplementary Table S2. The strongest positive correlations were detected for the SMI ($\rho = 0.497$, 95% CI [0.454, 0.538]), morning fatigue ($\rho = 0.484$, 95% CI [0.439, 0.525]), K6 ($\rho = 0.357$, 95% CI [0.307, 0.405]), and attribution of sleep problems to busyness ($\rho = 0.345$, 95% CI [0.294, 0.393]; all FDR-corrected $p < .001$). Among the MAIA-J subscales, Noticing (f3; $\rho = 0.187$, 95% CI [0.132, 0.241]) showed a significant positive correlation with the total PSQI score, whereas Not-Distracting (f6; $\rho = -0.269$, 95% CI [-0.321, -0.216]) showed a significant negative correlation (both FDR-corrected $p < .001$). Avoiding presleep smartphone use ($\rho = -0.096$, 95% CI [-0.151, -0.040]) also showed a significant negative correlation with the total PSQI score after FDR correction (FDR-corrected $p = .002$).

Overall regression model

The overall model explained approximately 40% of the variance in total PSQI score (adjusted $R^2 = 0.396$, $R^2 = 0.424$, $N = 1,213$). Multicollinearity values were generally low (most GVIFs ≤ 5), although the life-stage variable revealed a higher value (GVIF = 7.6), whereas the social support factor 2 subscale exhibited a slightly elevated GVIF (5.3). After FDR correction, significant predictors included mothers of infant (vs. premenopausal nulligravid women; standardized $\beta = 0.256$, 95% CI [0.095, 0.416], FDR-corrected $p = .021$), BMI (standardized $\beta = 0.078$, 95% CI [0.026, 0.131], FDR-corrected $p = .034$), attribution of sleep problems to busyness (standardized $\beta = 0.140$, 95% CI [0.085, 0.196], FDR-corrected $p < .001$), morning fatigue (standardized $\beta = 0.220$, 95% CI [0.157, 0.284], FDR-corrected $p < .001$), the SMI (standardized $\beta = 0.250$, 95% CI [0.188, 0.312], FDR-corrected $p < .001$), and frequency of avoiding presleep electronic device use (standardized $\beta = -0.084$, 95% CI [-0.130, -0.038], FDR-corrected $p = .006$; Table 3). Pairwise group comparisons based on this model revealed significantly poorer sleep quality among mothers of infants, with the estimated marginal mean PSQI score being significantly higher in the mother group (6.50, 95% CI [5.66, 7.35]) than in the premenopausal nulligravid group (5.75, 95% CI [4.96, 6.54]) (estimated difference = 0.76, $SE = 0.24$, $z = 3.12$, Bonferroni-corrected $p = .011$; Fig. 1).

Table 3
Overall regression model: Significant predictors

Variable	Standardized β [95% CI]	Unstandardized β [95% CI]	<i>t</i>	<i>p</i>
Group: Mother of infant	0.256 [0.095, 0.416]	0.755 [0.281, 1.230]	3.12	.021
BMI	0.078 [0.026, 0.131]	0.068 [0.022, 0.113]	2.92	.034
Busyness attribution	0.140 [0.085, 0.196]	0.342 [0.206, 0.477]	4.95	< .001
Morning fatigue	0.220 [0.157, 0.284]	0.596 [0.425, 0.768]	6.82	< .001
SMI	0.250 [0.188, 0.312]	0.036 [0.027, 0.045]	7.90	< .001
Presleep screen avoidance	-0.084 [- 0.130, - 0.038]	-0.241 [- 0.374, - 0.108]	-3.55	.006
N = 1,213, df = 1,157, R ² = .424, Adjusted R ² = .396, AIC = 5,516, BIC = 5,807				

Full regression coefficients are summarized in Supplementary Table S4.

Group-specific models

No variable was significantly associated with total PSQI score among the premenopausal nulligravid group ($N = 293$, adjusted $R^2 = 0.419$). In the pregnant women group, a higher SMI was identified as the sole significant predictor (standardized $\beta = 0.226$, 95% CI [0.093, 0.358], FDR-corrected $p = .047$, $N = 245$, adjusted $R^2 = 0.400$). Among the mother group, morning fatigue was the only significant predictor (standardized $\beta = 0.234$, 95% CI [0.100, 0.369], FDR-corrected $p = .045$, $N = 251$, adjusted $R^2 = 0.327$). Among the perimenopausal women group, both morning fatigue (standardized $\beta = 0.308$, 95% CI [0.154, 0.462], FDR-corrected $p = .003$) and SMI (standardized $\beta = 0.355$, 95% CI [0.201, 0.509], FDR-corrected $p < .001$) were identified as significant predicts ($N = 297$, adjusted $R^2 = 0.465$; Table 4).

Table 4
Group-specific regression results: Significant predictors

Group	Variable	Standardized β [95% CI]	Unstandardized β [95% CI]	<i>t</i>	<i>p</i>
Premenopausal nulligravid					
	—	—	—	—	—
<i>N</i> = 293, Adjusted R^2 = .419, AIC = 1,356, BIC = 1,562					
Pregnant women					
	SMI	0.226 [0.093, 0.358]	0.032 [0.013, 0.050]	3.36	.047
<i>N</i> = 245, Adj. R^2 = .400, AIC = 1,138, BIC = 1,320					
Mothers of infants					
	Morning fatigue	0.234 [0.100, 0.369]	0.641 [0.272, 1.010]	3.43	.045
<i>N</i> = 251, Adjusted R^2 = .327, AIC = 1,241, BIC = 1,460					
Perimenopausal women					
	Morning fatigue	0.308 [0.154, 0.462]	0.754 [0.376, 1.132]	3.93	.003
	SMI	0.355 [0.201, 0.509]	0.044 [0.025, 0.063]	4.55	< .001
<i>N</i> = 297, Adjusted R^2 = .465, AIC = 1,289, BIC = 1,488					

Sensitivity analysis

To examine whether the content overlap between the sleep-related item in the SMI (item 5) and the PSQI influenced the association between the SMI and the PSQI, a sensitivity analysis was conducted using an adjusted SMI score excluding item 5 (SMI_adj). Details regarding the full results are presented in Supplementary Table S5.

In the overall model, SMI_adj remained a significant predictor (standardized β = 0.141, 95% CI [0.081, 0.202], FDR-corrected p < .001), with an effect size smaller than that observed in the primary analysis (standardized β = 0.250). All other significant predictors from the primary analysis were retained. Notably, K6 emerged as an additional significant predictor (standardized β = 0.109, 95% CI [0.040, 0.178], FDR-corrected p = .019), a pattern not observed in the primary analysis (N = 1,213, adjusted R^2 = .374).

In the group-specific models, SMI_adj did not reach significance in the pregnant women ($N = 245$, adjusted $R^2 = .379$) or perimenopausal groups ($N = 297$, adjusted $R^2 = .429$), with no significant predictor identified in the former. In the perimenopausal group, morning fatigue was identified as the sole significant predictor (standardized $\beta = 0.352$, 95% CI [0.194, 0.511], FDR-corrected $p < .001$). In the mother group, the pattern was unchanged, with morning fatigue remaining the sole significant predictor (standardized $\beta = 0.248$, 95% CI [0.116, 0.380], FDR-corrected $p = .045$, $N = 251$, adjusted $R^2 = .321$).

Discussion

To the best of our knowledge, this study is among the first to comprehensively assess multidimensional predictors of sleep quality across distinct life stages of the female lifespan in Japan. Mothers of infants demonstrated the highest PSQI scores, significantly exceeding those of the premenopausal nulligravid group. Notably, nearly two-thirds of this group (64.2%) exceeded the clinical cutoff for poor sleep. This finding is consistent with international studies, which showed a high prevalence of sleep disturbance during the postpartum period [5, 42].

Being a mother of an infant emerged as one of the strongest predictors of poor sleep quality, consistent with the well-documented sleep fragmentation associated with nocturnal feeding and infant care demands [43]. The finding that morning fatigue was the sole significant concurrent factor in the group-specific model for mothers suggests that repeated nighttime awakenings accumulate as next-day exhaustion, potentially reflecting a bidirectional relationship between poor sleep and fatigue that can perpetuate chronic sleep difficulties.

Higher BMI values were associated with poorer sleep quality, conforming to the well-established links between obesity and sleep-disordered breathing [44, 45]. Although the inclusion of pregnant women raises the possibility that gestational weight gain may have played an essential role in this association [4, 42], neither BMI nor gestational age remained significant after FDR correction in the model restricted to the pregnant subsample, suggesting that the overall BMI effect was more likely driven by the nonpregnant status and that its role during pregnancy should be interpreted with caution.

The attribution of sleep insufficiency to busyness can be understood within the framework of time-based conflict [26]. Specifically, women facing competing demands from work, childcare, and housework tend to sacrifice sleep, with this cognitive appraisal potentially perpetuating poor sleep habits. The disproportionate concentration of domestic responsibilities on women in Japan can render this variable particularly salient in the Japanese context. Avoiding presleep electronic device use was negatively associated with the total PSQI score, consistent with evidence that screen-emitted blue light suppresses melatonin secretion and increases presleep cognitive arousal, thereby impairing sleep onset and quality [46]. This finding identifies a readily modifiable behavioral target for sleep hygiene interventions.

The SMI was identified as a consistent significant predictor of sleep quality in both the overall and group-specific models for pregnant and perimenopausal women. In the perimenopausal group, the SMI–PSQI association was consistent with the well-established mechanism by which vasomotor symptoms

resulting from estrogen decline disrupt sleep architecture [1]. Notably, morning fatigue also emerged as a significant concurrent factor alongside the SMI in this group, suggesting that the sleep fragmentation associated with these physical symptoms translates into profound next-day exhaustion and highlights a compounding burden on perimenopausal women. Although the SMI was the sole significant predictor in the pregnant women group, the underlying mechanism likely reflects a different pathway. Notably, physical discomfort associated with hormonal and physiological changes during pregnancy, such as nausea, back pain, and nocturia, are prominent contributors to sleep fragmentation and quality deterioration [2, 42]. Given that the SMI includes a sleep-related item (item 5), however, the content overlap between the SMI and PSQI raises the possibility that the detected associations were partially inflated by measurement circularity. To address this concern, we carried out a sensitivity analysis using the adjusted SMI score without item 5 (SMI_adj; Supplementary Table S5). In the overall model, SMI_adj remained a significant predictor, albeit with a notably smaller effect size than the original SMI, confirming that symptom burden was independently associated with sleep quality beyond the shared sleep content. In the group-specific models, however, SMI_adj did not reach significance in either the pregnant or perimenopausal groups, indicating that the effect sizes observed in these subgroups can be partly attributed to the content overlap between the sleep item and the PSQI. These findings call for cautious interpretation of the group-specific SMI associations and highlight importance of assessing symptom burden using instruments free of sleep-related content in future research. In the sensitivity analysis, K6 also emerged as a newly significant predictor in the overall SMI_adj model, a pattern unnoticed in the primary analysis. This suggests that the sleep-related item in the original SMI may have shared variance with psychological distress, which reduced the apparent independent contribution of K6. The emergence of K6 further suggests that general psychological distress, as a construct distinct from the symptom burden captured by the SMI, is an independent contributor to sleep quality across life stages. This finding is consistent with the well-established associations between anxiety, depression, and sleep disturbance reported across populations [47, 48]. Taken together, although the sensitivity analysis tempers the interpretation of group-specific SMI effects, the overall association between symptom burden and poorer sleep quality remains robust. The specific symptoms and mechanisms driving this relationship, however, appear to vary across life stages and warrant further investigation using more refined measurement approaches.

While total PSQI scores in the present study were broadly consistent with the values reported for corresponding life stages in North American, Chinese, and European populations [5, 6, 42]—suggesting universal biologically driven mechanisms—our findings also highlight uniquely Japanese sociocultural challenges. Specifically, the strong association between the attribution of sleep problems to busyness and poor sleep quality is particularly noteworthy when considered against the backdrop of Japan's pronounced sociocultural risk factors (e.g., a concentrated domestic burden on women [49], and highly prevalent room- and bed-sharing practices that reflect a cultural emphasis on interdependence over independent sleep [50]). Together, these factors underscore the distinctive nature of sleep issues among Japanese women. This emphasizes the urgent need for culturally and stage-specific social interventions, particularly for mothers of infants, rather than relying solely on biologically focused approaches.

Some limitations need to be addressed. First, the cross-sectional design of the present study precludes causal inference; hence, longitudinal studies tracking women across life stages are required to define temporal relationships. Second, all measures were based on self-report, which is susceptible to recall and social desirability biases. The exclusive reliance on subjective sleep assessment (the PSQI) indicates that comparison with objective measures, such as polysomnography or actigraphy, remains an important priority for future research. Additional limitations include potential sampling bias due to online recruitment and the lack of direct hormonal measurements. Furthermore, given the exploratory nature of the multivariable models, FDR correction (Benjamini–Hochberg procedure) and Bonferroni correction for pairwise comparisons were employed to mitigate the risk of false positives. The smaller sample sizes for the group-specific models may have further limited statistical power. Nevertheless, our findings should be interpreted as hypothesis-generating rather than confirmatory, highlighting the need for future confirmatory studies with more targeted designs.

Despite these limitations, this study provides a novel and comprehensive perspective on sleep quality across distinct life stages in Japanese women. The elevated PSQI scores in mothers of infants, in whom sleep difficulties are often overlooked as an inevitable consequence of childcare, emphasize the clinical need for sleep-focused interventions and support to safeguard both maternal and infant health. The identification of modifiable behavioral factors, specifically the avoidance of presleep screen use and management of busyness-related attributional cognitions, offers preliminary evidence regarding potential targets for clinical and public health initiatives aimed at enhancing sleep across the female lifespan.

Declarations

Competing Interests

This study was funded by Unicharm Corporation. A.S. and A.T. are employees of Unicharm Corporation. H.O.'s affiliated institution has a joint research agreement with Unicharm Corporation and receives joint research funding from them. Data analysis was partially outsourced to IDEALAB Inc. by Unicharm Corporation; H.M. is an employee of IDEALAB Inc., and M.K. is a former employee of IDEALAB Inc. The remaining author (T.K.) declares no competing interests.

Ethics approval and consent to participate:

This study was approved by the Ethics Committee of the Graduate School of Informatics, Nagoya University (NUPSY-241204-G-01). All methods were performed in accordance with the relevant guidelines and regulations (e.g., the Declaration of Helsinki). Electronic informed consent was obtained from all participants.

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Author Contribution

AS designed the study, conducted the survey, managed the data, determined the analysis policy, discussed the results, and drafted the manuscript. HM and AS analyzed the data. MK and TK provided critical feedback and helped shape the research direction. AT and HO supervised the project. All authors reviewed the manuscript and agreed to its contents.

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Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

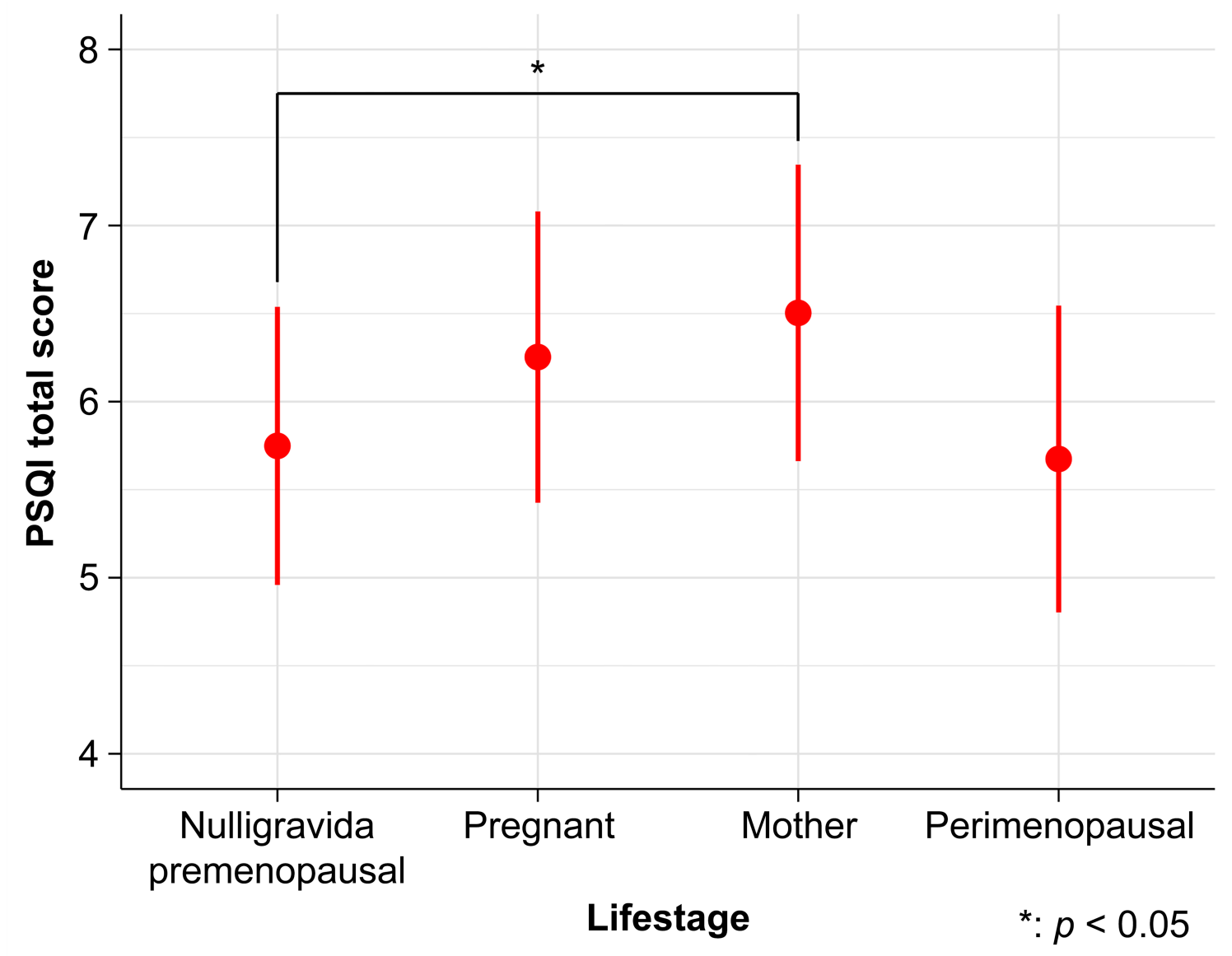


Figure 1

Estimated marginal means of the total PSQI score according to group. Error bars indicate 95% confidence intervals. * $p < .05$ (Bonferroni-corrected).

Supplementary Files

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