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Difficulty Falling Asleep, Nocturnal Awakening, Sleep Dissatisfaction, and Irritability in the General Population

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Sleep disturbance is characterized by problems with sleep quantity and quality. However, the exact mechanisms and factors underlying sleep dissatisfaction in the general population remains unclear. This cross-sectional study collected sleep data and irritability level from individuals who visited hospitals for medical checkups or with unexplained physical symptoms using self-report questionnaires. This study included 328 individuals (157 males and 171 females). Bivariate correlation analyses revealed that irritability (ρ = 0.420; p < 0.0001), short sleep length (ρ = 0.405; p < 0.0001), difficulty falling asleep (ρ = 0.443; p < 0.0001), and nocturnal awakening (ρ = 0.528; p < 0.0001) were strongly correlated with sleep dissatisfaction. Multiple linear regression analyses among the overall individuals, following bivariate correlation analyses, indicated that stress at home (β = 0.245; p < 0.0001), irritability (β= 0.172; p = 0.0021), difficulty falling asleep (β = 0.215; p < 0.0001), later bedtime (β = 0.140; p = 0.0331), and nocturnal awakening (β = 0.386; p < 0.0001) were independently correlated with sleep dissatisfaction, whilst short sleep length was not (β = 0.107; p = 0.1024). Further multivariable analyses revealed that difficulty falling asleep and nocturnal awakening were independently associated with each other. The obtained results were reproduced in the subgroup analyses among the 151 individuals taking medical checkups. In summary, major factors underlying sleep dissatisfaction in the general population included difficulty falling asleep and nocturnal awakening. Irritability was associated with difficulty falling asleep and sleep dissatisfaction. Carefully evaluating each of these sleep-related subscales and irritability may be beneficial in managing individuals with sleep problems.

Keywords: bedtime; difficulty falling asleep; irritability; nocturnal awakening; sleep satisfaction
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Introduction

Sleep problems are reported to affect approximately 20%-50% of the general population (Ohayon 1996; McArdle et al. 2020; Wang et al. 2023). Common specific sleep disorders include chronic insomnia, circadian rhythm sleep disorder, parasomnia, and sleep-related breathing disorders (Nobre et al. 2021; Peersmann et al. 2022; Jaqua et al. 2023). A recent nationwide database analysis revealed that direct healthcare for sleep disorders costs approximately $94.9 billion dollars annually in the United States (Huyett et al. 2021). They often cause productivity losses during the daytime, and negatively affect mental health and well-being in a large proportion of the general population (Barros et al. 2019). Many factors that may contribute to insomnia have been identified, such as excessive caffeine, frequent naps, nocturnal blue light exposure, workplace stress, a sedentary lifestyle, obesity with airway obstruction, and mental illness (Ting et al. 2005; Vernia et al. 2021). Despite these numerous risk factors that cause sleep problems, the exact relationships among sleep dissatisfaction, sleep duration, bedtime, wake-up time, difficulty falling asleep, nocturnal awakening, daily stress, and irritability in the general population remain uncertain. Therefore, the present study investigated sleep-related characteristics underlying sleep problems in the general population using a self-report questionnaire-based cross-sectional surveillance study design.

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Methods

Study design

This study was conducted at two hospitals (Kesennuma City Municipal Motoyoshi Hospital and Tohoku University Hospital) in Japan from April 2020 to March 2023. Individuals who visited Motoyoshi Hospital (Kesennuma, Japan) for a medical checkup and those who visited Tohoku University Hospital (Sendai, Japan) for detailed examinations of miscellaneous unexplained physical symptoms were recruited for this study. Self-report questionnaires on demographic background, lifestyle, and sleep-related information were also used. Data were collected at a single time point for each individual and the participants were not followed up. Data collected from those who agreed to participate and provided written informed consent were evaluated in subsequent analyses to identify factors underlying sleep dissatisfaction among the participants.

Collected variables

All participants from the two hospitals were administered the same self-report questionnaires. The individual characteristics obtained included age, sex, medical history, current daily tobacco use, and weekly alcohol consumption. The sleep dissatisfaction, irritability, and stress at home in the prior month subscales were measured using a numerical rating scale (NRS) ranging from 0 (no stress) to 10 (maximum stress). To understand the relationship between sleep disturbance and daytime functioning, fatigue during the daytime in the previous month was also collected using the NRS. The additional sleep-related data evaluated included (1) daily duration of lying in bed at night, (2) time needed to fall asleep in bed, (3) weekly average bedtime at night, (4) weekly average wake-up time in the morning, (5) total monthly days with nocturnal awakening, and (6) monthly total duration of afternoon sleep.

Statistical analyses

The distributions of continuous variables are described using median and interquartile range (IQR) (25th-75th percentiles). The distributions of continuous variables between the two independent groups were analyzed using the Mann–Whitney U test. Subsequent multiple linear regression analyses, using either of sleep dissatisfaction or required time to fall asleep in bed as the dependent variable, were performed by simultaneously entering the explanatory variables with p-values < 0.10 in the preceding bivariate correlation analyses into the models. Bivariate correlation analyses and subsequent multivariable analyses were initially performed with the overall participants, and they were further performed with the individuals visiting Motoyoshi Hospital for taking medical checkups as subgroup analyses. Potential risk of multicollinearity between the explanatory variables was assessed by calculating the variance inflation factors (VIF) for each variable. A VIF of > 5.0 was regarded as having a high risk of multicollinearity. A p-value threshold of $p < 0.05$ was used for both bivariate correlation analyses and subsequent multivariable analyses, and this level was not adjusted for multiple comparisons because of the exploratory nature of this study.

Ethics

This study was approved by the Institutional Review Board of Tohoku University Graduate School of Medicine (approval number: 20201063). Written informed consent was obtained from all participants. The study was performed in accordance with the latest version of the Declaration of Helsinki, as revised in 2013.

Results

Participants

In total, 328 individuals (151 from Kesennuma Motoyoshi Hospital and 177 from Tohoku University Hospital) returned the questionnaires and agreed to participate. Among them, 157 (48%) were males and 171 (52%) were females. The median age of the participants at enrollment was 48 years (IQR 34-60 years). The age was significantly higher in those from Tohoku University Hospital compared to those from Kesennuma Motoyoshi Hospital (median 53 years [IQR 37-63 years] vs. 43 years [IQR 31-57 years]; $p = 0.0006$). The primary reasons for visiting the Division of General Medicine of Tohoku University Hospital of the 177 individuals were unexplained pain or paresthesia (n = 63), fatigue (n = 28), body weight loss (n = 10), chronic slight fever (n = 8), and other miscellaneous reasons (n = 68). There were two patients with the chief complaint of sleep problems, one with sleep disturbance and the other with REM sleep behavior disorder; they were not excluded to avoid the risk of selection bias.

Of the 328 participants, 319 (97%) answered the question about sleep dissatisfaction in the previous month, which was measured using the NRS. The median sleep dissatisfaction (range 0-10) for the previous month was 5.0 (IQR 2.0-8.0). The sleep dissatisfaction subscale was significantly higher in those from Tohoku University Hospital compared to those from Kesennuma Motoyoshi Hospital (median 6.0 [IQR 3.0-8.0] vs. 3.0 [IQR 2.0-6.0]; $p < 0.0001$). Sleep dissatisfaction was strongly correlated with daytime fatiguability in the prior month (Spearman's $\rho = 0.428$, $p < 0.0001$). The sleep dissatisfaction scale results were significantly worse for females (median 5.5 [IQR 2.5-8.0]) compared to those for males (median 5.0 [IQR 2.0-7.0]; $p = 0.0198$, Mann–Whitney U test). The average time required to fall asleep in bed did not differ between females and males (median 30 min [IQR 10-60 min] vs. 30 min [IQR 10-30 min]; $p = 0.1259$). The total monthly days with nocturnal awakening did not significantly differ between females and males (median 2 days [IQR 0-5.5 days] vs. 1 day [IQR 0-4 days]; $p = 0.1129$).

Bivariate correlation coefficients

The bivariate correlation coefficients, measured using Spearman's ρ, between the sleep dissatisfaction subscale (NRS 0-10) and each of the evaluated characteristics are listed in the two left columns of Table 1. Strong correlations with sleep dissatisfaction were observed for nocturnal awakenings ($\rho = 0.528$; $p < 0.0001$), irritability subscale in the previous month ($\rho = 0.420$; $p < 0.0001$), daily duration of lying in bed at night ($\rho = -0.405$; $p < 0.0001$) and time needed to fall asleep in bed ($\rho = 0.443$; $p < 0.0001$). Scatterplots of the sleep dissatisfaction subscale and each of the daily durations of lying in bed, time required to fall asleep, and days with nocturnal awakening are shown in Fig. 1.

Based on the finding that the time required to fall asleep and days with nocturnal awakening had the strongest correlation with sleep dissatisfaction, further bivariate correlation analyses were performed between each of these two sleep problems and the other characteristics. The results for the time required to fall asleep are summarized in the two middle columns of Table 1. Weak-to-moderate correlations were confirmed for the irritability subscale ($\rho = 0.256$; $p < 0.0001$), daily duration of lying in bed at night ($\rho = -0.211$; $p < 0.0001$), weekly average wake-up time in the morning ($\rho = 0.236$; $p < 0.0001$), and total monthly days with nocturnal awakening ($\rho = 0.376$; $p < 0.0001$).

The results of nocturnal awakening are summarized in the two right columns of Table 1. Weak-to-moderate correlations were confirmed for the daily duration of lying in bed at night ($\rho = -0.272$; $p < 0.0001$) and required time to fall asleep in bed ($\rho = 0.376$; $p < 0.0001$).

Because the present study enrolled the participants from two different hospitals with different distributions of age and sleep dissatisfaction level, the same analyses were

Table 1. Correlation matrix with each outcome in the overall 328 participants.

Characteristics	Sleep dissatisfaction*		Time to fall asleep in bed		Nocturnal awakening‡	
	Spearman's ρ	p	Spearman's ρ	p	Spearman's ρ	p
Age	−0.0147	0.7937	−0.1293	0.0224	0.1881	0.0009
Stress at home *	0.3549	< 0.0001	0.1432	0.0114	0.1498	0.0083
Irritability *	0.4202	< 0.0001	0.2556	< 0.0001	0.1843	0.0012
Daily length of lying in bed	−0.4047	< 0.0001	−0.2111	< 0.0001	−0.2723	< 0.0001
Time needed to fall asleep in bed	0.4429	< 0.0001	n.a.	n.a.	0.3758	< 0.0001
Bedtime at night†	0.1583	0.0050	0.1203	0.0339	−0.1363	0.0165
Wake-up time in the morning†	0.1205	0.0331	0.2363	< 0.0001	−0.0404	0.4797
Nocturnal awakenings‡	0.5281	< 0.0001	0.3758	< 0.0001	n.a.	n.a.
Monthly length of afternoon sleep	0.0164	0.7816	0.0956	0.1054	0.1143	0.0539
Weekly alcohol consumption	−0.1126	0.0695	−0.0222	0.7229	−0.0409	0.5148
Current daily tobacco use	−0.0045	0.9407	0.0014	0.9812	0.0418	0.4939
Weekly days of physical exercise	−0.0050	0.9307	−0.1567	0.0063	−0.0123	0.8313

*Rated with a numerical rating scale from 0 (no stress) to 10 (unbearable maximum stress) based on symptoms in the previous month.
†Bedtime and wake-up time were averaged for weekdays and holidays in one week.
‡Monthly days with nocturnal awakening rated from 0 (none) to 30 (everyday).

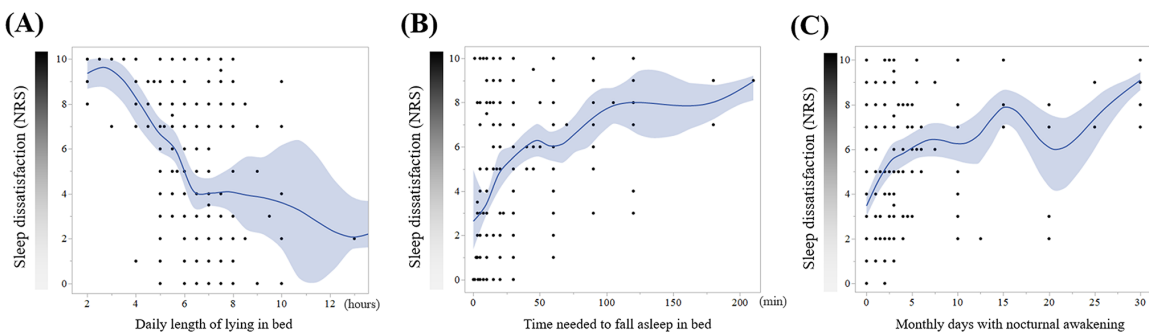

Fig. 1. Scatterplots of sleep dissatisfaction by sleep duration, required time to fall asleep, and nocturnal awakening.
(A) A strong negative correlation was confirmed between sleep dissatisfaction and daily duration of lying in bed at night. (B) A strong positive correlation was confirmed between sleep dissatisfaction and required time to fall asleep in bed. (C) A strong positive correlation was confirmed between sleep dissatisfaction and monthly days with nocturnal awakening.
NRS, numerical rating scale.

further performed for the 151 participants taking medical checkups (Table 2). Strong correlations with sleep dissatisfaction were observed for irritability subscale in the previous month ($\rho = 0.465$; $p < 0.0001$), daily duration of lying in bed at night ($\rho = -0.404$; $p < 0.0001$), time needed to fall asleep in bed ($\rho = 0.468$; $p < 0.0001$), and nocturnal awakenings ($\rho = 0.421$; $p < 0.0001$).

Factors influencing sleep dissatisfaction

To investigate the influence of each characteristic on sleep dissatisfaction independent from other characteristics, a multiple linear regression analysis was performed, using

Table 2. Correlation matrix with each outcome in the 151 participants taking medical check-up.

Characteristics	Sleep dissatisfaction*		Time to fall asleep in bed		Nocturnal awakening‡	
	Spearman's ρ	p	Spearman's ρ	p	Spearman's ρ	p
Age	−0.0532	0.5234	−0.1135	0.1786	0.1898	0.0227
Stress at home*	0.3735	< 0.0001	0.1971	0.0187	0.1303	0.1197
Irritability*	0.4646	< 0.0001	0.3342	< 0.0001	0.2211	0.0082
Daily length of lying in bed	−0.4042	< 0.0001	−0.2005	0.0167	−0.1684	0.0436
Time needed to fall asleep in bed	0.4684	< 0.0001	n.a.	n.a.	0.3694	< 0.0001
Bedtime at night†	0.1531	0.0679	0.0992	0.2402	−0.1316	0.1171
Wake-up time in the morning†	0.0560	0.5064	0.2168	0.0095	−0.0409	0.6275
Nocturnal awakenings‡	0.4214	< 0.0001	0.3694	< 0.0001	n.a.	n.a.
Monthly length of afternoon sleep	0.0625	0.4680	0.1817	0.0343	0.2204	0.0094
Weekly alcohol consumption	0.0094	0.9136	0.0345	0.6919	0.0475	0.5831
Current daily tobacco use	0.1510	0.0970	0.1248	0.1707	0.1663	0.0661
Weekly days of physical exercise	−0.0087	0.9199	−0.2278	0.0081	−0.0898	0.2987

No sex difference in sleep dissatisfaction ($p = 0.8021$), time needed to fall asleep ($p = 0.4377$), and nocturnal awakening ($p = 0.9364$).
*Rated with a numerical rating scale from 0 (no stress) to 10 (unbearable maximum stress) based on symptoms in the previous month.
†Bedtime and wake-up time were averaged for weekdays and holidays in one week.
‡Monthly days with nocturnal awakening rated from 0 (none) to 30 (everyday).

Table 3. Multiple linear regression analysis with sleep dissatisfaction as the outcome.

Characteristics	Unstandardized B	SEB	Standardized β	t	p	VIF
Among the overall 328 individuals						
Sex (male)	0.1933	0.1511	0.0637	−1.28	0.2020	1.1809
Stress at home*	0.2642	0.0590	0.2452	4.48	< 0.0001	1.4288
Irritability*	0.2203	0.0710	0.1715	3.10	0.0021	1.4535
Daily length of lying in bed	−0.2131	0.1300	−0.1071	−1.64	0.1024	2.0333
Time to fall asleep in bed	0.0196	0.0048	0.2150	4.07	< 0.0001	1.3282
Bedtime at night†	0.2576	0.1201	0.1403	2.14	0.0331	2.0396
Wake-up time in the morning†	−0.0785	0.1577	−0.0366	−0.50	0.6192	2.5734
Nocturnal awakening	0.1401	0.0187	0.3864	7.48	< 0.0001	1.2704
Weekly alcohol consumption	−0.0157	0.0213	−0.0359	−0.74	0.4628	1.1369
Among the 151 individuals for medical check-up (subgroup analysis)						
Stress at home*	0.1989	0.0839	0.1882	2.37	0.0195	1.3502
Irritability*	0.2949	0.1079	0.2314	2.73	0.0073	1.5372
Daily length of lying in bed	−0.5074	0.2447	−0.1696	−2.07	0.0404	1.4338
Time to fall asleep in bed	0.0246	0.0075	0.2467	3.26	0.0015	1.2246
Bedtime at night†	0.2060	0.1544	0.1030	1.33	0.1849	1.2775
Nocturnal awakening	0.1088	0.0408	0.2056	2.67	0.0088	1.2720
Current daily tobacco use	0.0280	0.0207	0.0953	1.35	0.1791	1.0642

Explanatory variable lists in the subgroup analysis were decided based on the bivariate correlation analyses among the 151 individuals taking medical-checkup.
*Rated with a numerical rating scale from 0 (no stress) to 10 (unbearable maximum stress) based on symptoms in the previous month.
†Bedtime and wake-up time were averaged for weekdays and holidays in 1 week. A positive coefficient for bedtime indicated that a later bedtime at night could be independently associated with sleep dissatisfaction.

Table 4. Multiple linear regression analysis with time needed to fall asleep in bed as the outcome.

Characteristics	Unstandardized B	SEB	Standardized β	t	p	VIF
Among the overall 328 individuals						
Age	−0.1104	0.1252	−0.0521	−0.88	0.3788	1.2729
Stress at home*	−0.5738	0.7261	−0.0483	−0.79	0.4300	1.3604
Irritability*	1.9631	0.8884	0.1396	2.21	0.0279	1.4517
Daily length of lying in bed	−3.9513	1.5254	−0.1799	−2.59	0.0101	1.7552
Bedtime at night†	−3.3138	1.4638	−0.1612	−2.26	0.0243	1.8456
Wake-up time in the morning†	8.7494	1.6833	0.3837	5.20	< 0.0001	1.9824
Nocturnal awakening	0.9001	0.2355	0.2252	3.82	0.0002	1.2631
Weekly physical exercise	−1.4720	0.9713	−0.0808	−1.52	0.1308	1.0329
Among the 151 individuals for medical check-up (subgroup analysis)						
Stress at home*	−0.3059	0.9297	−0.0294	−0.33	0.7427	1.2998
Irritability*	2.0092	1.0917	0.1686	1.84	0.0682	1.3647
Daily length of lying in bed	−4.9186	2.3306	−0.1851	−2.11	0.0369	1.2510
Wake-up time in the morning†	6.4658	2.0420	0.2498	3.17	0.0020	1.0117
Nocturnal awakening	1.1395	0.4469	0.2164	2.55	0.0121	1.1706
Afternoon sleep‡	0.0021	0.0058	0.0297	0.37	0.7142	1.0655
Weekly physical exercise	−0.0469	0.0206	−0.1846	−2.27	0.0248	1.0708

Explanatory variable lists in the subgroup analysis were decided based on the bivariate correlation analyses among the 151 individuals taking medical-checkup.
*Rated with a numerical rating scale from 0 (no stress) to 10 (unbearable maximum stress) based on symptoms in the previous month.
†Bedtime and wake-up time were averaged for weekdays and holidays in 1 week. A positive coefficient for wake-up time indicates that a later wake-up time in the morning could be independently associated with difficulty falling asleep at night.
‡Monthly total duration of afternoon sleep.

explanatory variables that had $p \geq 0.10$ from the preceding bivariate correlation analyses (Table 3). Statistically significant coefficients were observed in the stress at home (β = 0.245; $p < 0.0001$), irritability (β = 0.172; p = 0.0021), longer time to fall asleep in bed (β = 0.215; $p < 0.0001$), later bedtime at night (β = 0.140; p = 0.0331), and nocturnal awakening (β = 0.386; $p < 0.0001$). The duration of lying in bed at night did not show a significant coefficient with sleep dissatisfaction (β = −0.107; p = 0.1024).

When the required time to fall asleep in bed was removed from the explanatory variable list searching for the factors underlying the nocturnal awakenings and required time to fall asleep, the standardized coefficient (β) for the wake-up time in the morning became significant (β = 0.2166; p = 0.0027), whereas that for the bedtime at night did not (β = −0.1181; p = 0.0708).

The results of the subgroup analyses among the 151 participants taking medical checkups are listed in the lower half of the table. Irritability (β = 0.231; p = 0.0073), longer time to fall asleep in bed (β = 0.247; p = 0.0015), and nocturnal awakening (β = 0.206; p = 0.0088) were independently correlated with sleep dissatisfaction. Meanwhile, the statistical significance for the duration of lying in bed at night was marginal (β = −0.170; p = 0.0404).

Factors influencing difficulty falling asleep

To investigate the independent effect of each characteristic on the difficulty in falling asleep at night, a multiple linear regression analysis was performed using characteristics with $p \geq 0.10$ from the preceding bivariate correlation analyses (Table 4). Statistically significant coefficients were observed for the irritability (β = 0.1396; p = 0.0279), shorter sleep duration (β = −0.180; p = 0.0101), earlier bedtime at night (β = −0.161; p = 0.0243), later wake-up time in the morning (β = 0.384; $p < 0.0001$), and nocturnal awakening (β = 0.225; p = 0.0002). Based on the findings regarding the significance of bedtime and wake-up time in difficulty falling asleep, scatterplots of bedtime/wake-up time and sleep problem-related scales are depicted in Fig. 2. The scatterplots indicate that individuals with the wake-up time at approximately 05:30 AM had the highest sleep satisfaction and the shortest time to fall asleep in bed at night.

The results of the subgroup analyses among the 151 participants taking medical checkups are listed in the lower half of the table. Duration of lying in bed at night (β = −0.185; p = 0.0369), later wake-up time in the morning (β = 0.250; p = 0.0020), nocturnal awakening (β = 0.216; p = 0.0121), and shorter weekly physical exercise (β = −0.185; p = 0.0248) were independently correlated with difficulty falling asleep.

Factors influencing nocturnal awakening

To investigate the independent effect of each characteristic on the nocturnal awakening, a multiple linear

regression analysis was performed by using characteristics with $p \geq 0.10$ from the preceding bivariate correlation analyses (Table 5). Statistically significant coefficients were observed for shorter sleep duration ($\beta = -0.423$; $p < 0.0001$), longer time to fall asleep in bed ($\beta = 0.190$; $p = 0.0010$), earlier bedtime at night ($\beta = -0.215$; $p = 0.0003$), and afternoon sleep ($\beta = 0.250$; $p < 0.0001$). In this linear regression model, wake-up time in the morning was not included as an explanatory variable because it did not achieve statistical significance in the bivariate correlation analysis. However, when wake-up time in the morning was included among the explanatory variables, a later wake-up time had a significant coefficient with nocturnal awakening ($\beta = 0.204$; $p = 0.0116$).

The results of the subgroup analyses among the 151 participants taking medical checkups are listed in the lower half of the table. Duration of lying in bed at night ($\beta = -0.191$; $p = 0.0445$), difficulty falling asleep ($\beta = 0.248$; $p = 0.0106$) and nocturnal awakening ($\beta = 0.216$; $p = 0.0121$) were independently correlated with nocturnal awakening.

Discussion

In this cross-sectional study, sleep-related factors underlying sleep dissatisfaction, difficulty falling asleep, and nocturnal awakening were investigated using self-report questionnaires from 328 individuals living in Japan. Difficulty falling asleep at night and nocturnal awakening were suggested to be major independent components of sleep dissatisfaction, whilst the length of lying in bed at night showed a weaker statistical significance with sleep dissatisfaction. Moreover, stress at home and irritability were independently associated with sleep dissatisfaction and difficulty falling asleep. In view of the circadian rhythm, individuals with the bedtime at night around 22:00 PM and wake-up time in the morning around 05:30 AM were with the highest sleep satisfaction. Although the causal relationship between the bedtime/wake-up time and the other evaluated sleep-related subscales in this study was uncertain, close associations between daily stress, irritability, difficulty falling asleep, nocturnal awakening, and delayed circadian rhythm were suggested, possibly underlying sleep problems in the general population.

Humans have an endogenous circadian rhythm with a median longer than 24 hours (Zee et al. 2013). This misaligned circadian period can result in delayed sleep-wake phase disorders in some people (Sateia 2014; Nesbitt 2018), often accompanied by difficulty falling asleep in bed (Izuhara et al. 2021; Futenma et al. 2023). According to the

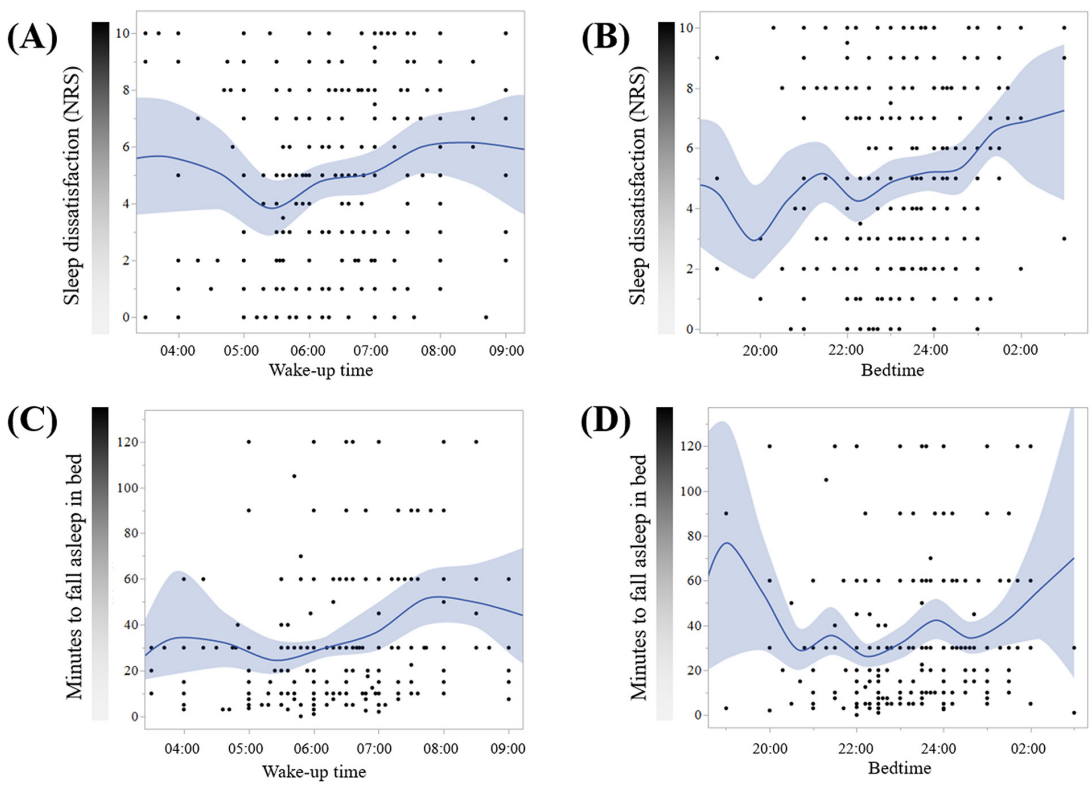

Fig. 2. Scatterplots of sleep problem-related scales by bedtime and wake-up time.
(A) A gradual worsening in sleep satisfaction was confirmed with a later wake-up time in the morning. The highest sleep satisfaction was observed with a wake-up time at approximately 05:30 AM. (B) A gradual worsening in sleep satisfaction was suggested with a later bedtime at night. (C) A gradual increase in the required time to fall asleep in bed at night was observed with later wake-up time. The shortest time to fall asleep was observed with a wake-up time at approximately 05:30 AM. (D) An association between bedtime at night and difficulty in falling asleep was not apparent in the bivariate scatterplot.

Table 5. Multiple linear regression analysis with nocturnal awakening as the outcome.

Characteristics	Unstandardized B	SEB	Standardized β	t	p	VIF
Among the overall 328 individuals						
Age	0.0226	0.0310	0.0426	0.73	0.4675	1.2541
Stress at home*	−0.0985	0.1749	−0.0340	−0.56	0.5739	1.3298
Irritability*	0.1689	0.2178	0.0488	0.78	0.4388	1.4455
Daily length of lying in bed	−2.2839	0.3262	−0.4227	−7.00	<0.0001	1.3320
Time to fall asleep in bed	0.0485	0.0146	0.1896	3.33	0.0010	1.1875
Bedtime at night†	−1.0827	0.2923	−0.2148	−3.70	0.0003	1.2290
Afternoon sleep‡	0.0024	0.0006	0.2503	4.15	<0.0001	1.3313
Among the 151 individuals for medical check-up (subgroup analysis)						
Age	0.0244	0.0379	0.0581	0.64	0.5216	1.1076
Irritability*	0.1509	0.2289	0.0627	0.66	0.5111	1.2289
Daily length of lying in bed	−1.0876	0.5351	−0.1914	−2.03	0.0445	1.2037
Time to fall asleep in bed	0.0489	0.0188	0.2484	2.60	0.0106	1.2398
Afternoon sleep‡	0.0024	0.0013	0.1652	1.89	0.0614	1.0365
Current daily tobacco use	0.0387	0.0496	0.0697	0.78	0.4375	1.0854

Explanatory variable lists in the subgroup analysis were decided based on the bivariate correlation analyses among the 151 individuals taking medical-checkup.

*Rated with a numerical rating scale from 0 (no stress) to 10 (unbearable maximum stress) based on symptoms in the previous month.

†Bedtime and wake-up time were averaged for weekdays and holidays in 1 week. A negative coefficient at bedtime indicated that an earlier bedtime at night could be independently associated with nocturnal awakening.

‡Monthly total duration of afternoon sleep.

latest version of the International Classification of Sleep Disorders (ICSD-3) (Sateia 2014), circadian rhythm sleep disorders include both delayed and advanced sleep-wake phase disorders, with the former having a higher frequency (Dagan et al. 1999; Kim et al. 2013; Sun et al. 2022). One of the characteristic findings of individuals with delayed sleep-wake phase disorder is difficulty falling asleep (Kim et al. 2013). Delayed sleep-wake phase disorders usually have their onset in adolescence or young adulthood (Kim et al. 2013), whereas advanced sleep-wake phase disorders are likely to occur in older individuals (Ando et al. 2002). The wake-up time in those with delayed sleep-wake phase disorders will shift to a later time, and they often experience difficulty at school and the workplace during the daytime. Multiple factors are considered to influence the circadian rhythm in humans. Light is among the most important ones (Blume et al. 2019). Blind people are more likely to experience sleep problems than sighted people (Leger et al. 1999; Lockley et al. 1999), suggesting the importance of ocular light exposure in the daytime for aligning the melatonin rhythm (Brown et al. 2022). In contrast, excessive presleep ocular light exposure in the evening and night suppresses melatonin production, potentially triggering delayed sleep-wake phase disorders by delaying the circadian cycle (Lewy 2003; Hunter et al. 2017). The current available therapeutic approaches for delayed sleep-wake phase disorders include chronotherapy and timed bright light exposure (Czeisler et al. 1981; Weitzman et al. 1981; Barion et al. 2007). Chronotherapy usually applies a phase-delay route of 5-6 days, and the exact implementation of this therapy in students and daytime workers is often difficult. More feasible approaches that can be performed by the patients themselves include appropriate ocular light exposure in the morning and maintenance of appropriate bedtimes and wake-up times on weekdays and holidays.

Daily stress at home and irritability were also shown to be closely linked with difficulty falling asleep in the present study. Excessive stress at home including work-family conflict and family caregiving can increase the risk of poor sleep quality (Byun et al. 2016; Güngördü et al. 2023; Seo et al. 2023). Irritability has been also reported to show a close association with impaired sleep quality (Whiting et al. 2023). A previous study that investigated the impact of experimental sleep restriction showed worsened irritability and negative emotion in healthy adolescents aged 14-17 years, suggesting that sleep problems will bring irritability and emotional problems (Baum et al. 2014). Other studies have demonstrated that mindfulness-based stress reduction, such as mindful breathing and sitting meditation, may improve the sleep quality (Morone et al. 2008; Hoge et al. 2013; Darehzereshki et al. 2022), suggesting that daily stress and irritability as the potential therapeutic target in people with difficulty falling asleep and sleep dissatisfaction. Meanwhile, a recent meta-analysis denied the benefit of mindfulness for improving sleep quality in people with chronic insomnia (Kim et al. 2022). Future studies to elucidate the therapeutic potential of managing stress and irritability in sleep disturbances are waited.

This study had several limitations. First, the sample size was relatively small for estimating the mechanisms underlying sleep dissatisfaction in the general population. Further studies with larger sample sizes are needed to verify the findings reported in this study. Second, the causal relationships between difficulty falling asleep, nocturnal awakening, bedtime/wake-up time, and sleep dissatisfaction could not be determined because of the cross-sectional nature of this study. Further studies are needed to causal relationships between the evaluated sleep-related factors in this study. Third, this study defined sleep problems based on subjective sleep satisfaction level using the NRS. The used NRS-based questionnaire was not verified for its validity and reproducibility in assessing the severity of sleep disturbance. Careful interpretation of the obtained results is needed, and it should be remembered that the evaluated primary outcome of this study was a subjective self-reported sleep satisfaction level measured by the NRS. Finally, all participants were of Asian descent. Therefore, the generalizability of these findings to other races and ethnicities remains uncertain.

Conclusion

Major components of sleep dissatisfaction in the general population include difficulty falling asleep and nocturnal awakening. Sleep length also influence the sleep satisfaction level, but its impact was weaker. Irritability was associated with difficulty falling asleep and sleep dissatisfaction. Careful evaluation and management of these sleep-related factors, stress factors, and irritability may be beneficial in treating individuals with sleep problems.

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Author Contributions

T.A. designed the research, collected data, analyzed, and wrote the draft of the manuscript.

Conflict of Interest

The author declares no conflict of interest.

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