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Relationships between sleep efficiency and lifestyle evaluated by objective sleep assessment: SLeep Epidemiology Project at University of Tsukuba

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ABSTRACT

Objectively measured sleep efficiency has recently been shown to be associated with health problems. Although several factors have previously been reported to be associated with sleep efficiency, most of these studies were conducted on older or younger adults, and the factors associated with sleep efficiency in healthy workers remain unknown. The aim of this study was to investigate the relationship between sleep efficiency and lifestyle factors using sleep measurement data recorded by an activity meter worn by workers. In total, 693 workers (male, 43.6%; mean age, 42.7 ± 11.3 years) were recruited from five offices in 2017. Sleep was measured over the period of 1 week by actigraphy. Workers' attributes, lifestyle habits, and occupational stress were identified using a questionnaire, and the association of sleep efficiency with lifestyle, occupational stress, and attributes was explored by logistic regression analysis. A logistic regression analysis using attributes and occupational stress as adjustment variables revealed that "longer sleeping hours on weekends than on weekdays" [odds ratios (OR), 0.66; 95% confidence interval (CI), 0.47–0.94], "water ingestion at bedtime" [OR, 2.09; 95% CI, 1.28–3.41], and "smartphone use at bedtime" [OR, 1.90; 95% CI, 1.28–2.83] were associated with decreased sleep efficiency. This study found that lifestyle habits were associated with sleep efficiency among workers. It is necessary to verify whether intervention in these lifestyle habits would contribute to the improvement of sleep efficiency in future studies.

Keywords: sleep, lifestyle, actigraphy, worker, sleep efficiency

Abbreviations:
OR: odds ratio
CI: confidence interval
WASO: wake time after sleep onset
SL: sleep latency

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INTRODUCTION

Poor sleep quality is a risk factor for health problems such as depression and other psychiatric disorders, as well as several physical diseases, including type 2 diabetes, hypertension, and coronary heart disease.[1-4] It is also known that poor sleep quality increases work injury and that good sleep quality improves work engagement.[5,6] Therefore, poor sleep quality in workers is an important concern from an occupational health perspective.

Many of these past studies regarding sleep were based on self-administered questionnaires. One study showed that sleep duration was underestimated or overestimated by the participants and that objective sleep efficiency and psychological factors influenced the subjective estimates.[7] Therefore, an increasing number of studies have focused on objectively measured sleep.

Objectively measured sleep efficiency [%, (total sleep time/bedtime) × 100] has been associated with sleep quality in all age groups.[8] Sleep efficiency is an actigraphic parameter that uses estimates obtained during wakefulness and sleep simultaneously. Wake time after sleep onset and sleep latency are included in the calculation, which enables accurate measurement of sleep quality.[9] Sleep efficiency is also thought to indicate sleep continuity.[10] Sleep fragmentation has been shown to be associated with cognitive decline and reduced insulin sensitivity in healthy adults.[11,12] Reductions in sleep efficiency have been associated with hypertension, with the results of noninvasive assessment of brachial artery flow-mediated dilation (FMD) in the general adult population, and with the risk of cardiovascular disease; however, the subjective questionnaires used in these studies did not include FMD.[13,14] One of these studies also identified discrepancies between subjective and objective sleep ratings and reported that low sleep efficiency can be a risk factor for new health problems.[14] Low sleep efficiency in older adults is also associated with poor cognitive performance.[15] Therefore, low sleep efficiency can be a risk factor for health problems and cognitive performance.

Lifestyle has been identified as a risk factor for low sleep efficiency in objectively measured sleep. In older adults, nocturia and sleeping pill intake have been associated with lower sleep efficiency,[16] and sleep efficiency has been related to daytime physical activity.[17] However, most previous studies were conducted in elderly subjects and students, and few were conducted on workers. Accordingly, there is little information on the sleep efficiency of workers. Workers spend most of their time during the day at work, and it is widely known that work-related stress can affect sleep.[18] Occupational stress has also been shown to have a negative impact on lifestyle, with increased stress inducing unhealthy lifestyle habits.[19] Occupational stress could be a confounding factor between sleep quality and lifestyle, but no research related to sleep efficiency has taken work-related stress into account. To overcome this issue, our study aimed to investigate the relationship between sleep efficiency and lifestyle habits in workers using objective sleep measurements obtained by actigraphy, to examine the impact of occupational stress, and to obtain insight into sleep hygiene guidance that would improve insomnia in healthy workers.

METHODS

Data collection

The SLeep Epidemiology Project at the University of Tsukuba (SLEPT study) was conducted between 2016 and 2017 as a cross-sectional study in four workplaces (one university, two research institutions, and one company in Ibaraki Prefecture and Tokyo, Japan). Participants were recruited using workplace advertisements, posters, and group emails. Eligible participants were asked to complete a self-administered questionnaire and to wear an actigraphy device and record their sleep/awake status in a sleep diary for 1 week. The Ethics Committee of the University of Tsukuba Medical School (approval number: 1065-10) approved the study protocol, and written, informed consent was obtained from all participants.

The items of the questionnaire answered by the participants were as follows: basic characteristics (ie, age, sex, height, and weight), exercise habits ("once a week or less" or "more than once a week"), smoking status ("current smoker" or "other responses (former and never"), nightcap ("yes" or "no"), longer sleeping hours on weekends than on weekdays ("yes" or "no"), smartphone use at bedtime ("yes" or "no"), TV watching in the bedroom ("yes" or "no"), ingestion of a caffeinated beverage ("less than one cup per day" or "one cup per day or more"), water ingestion at bedtime ("yes" or "no"), shift worker ("yes" or "no"), and commute time (minutes). These lifestyle items were selected from those identified in previous studies as related to insomnia.[20-22] Body mass index (BMI) was determined by a survey item regarding height and weight. Work-related stress was measured by the Brief Scale for Job Stress (BSJS).[23] The BSJS comprises 10 questions regarding three job stress-enhancing factors ("workload," "mental workload," and "problems in personal relationships") and another 10 questions regarding three job stress-relieving factors ("job control (job decision latitude)," "reward from work (job satisfaction)," and "support from colleagues and superiors"). Each question had four frequency-based response categories.

Participants

A total of 785 individuals were recruited for the study, of whom four withdrew their consent, and 34 were excluded after failing to meet the eligibility criteria (eg, missing sleep measurements and questionnaire data). Of the 747 remaining participants, a further 54 were excluded because of sleep disorders such as insomnia and sleep apnea, a history of psychiatric disorder, or ongoing psychotropic or sleep medication. A final total of 693 participants were included for analysis.

Actigraphy

Over the period of 1 week, each participant wore an actigraphy device (ACOS MTN-220) on the waist, which recorded sleep data automatically, and they recorded their bedtimes and wake times manually in a sleep diary. The actigraph recorded the total sleep time, sleep latency (SL), wake time after sleep onset (WASO), sleep effects, number of awakenings, and number of position changes. The longest sleep duration within 24 hours was also used as a variable. Agreement between the built-in sensor of the device and polysomnography is reported to range from 86.9% to 88.4%.[24,25] Sleep efficiency was defined as the ratio of the real to apparent sleep time, in which the real sleep time was measured using actigraphy and the apparent sleep time was calculated from the bedtimes and wake times recorded in the participant's sleep diary.

Statistical analysis

The participants were classified into high sleep efficiency (≥80%) and low sleep efficiency (<80%) groups according to weekly average sleep efficiency.[16] Attributes, lifestyle habits, and occupational stress were compared between the high sleep efficiency and low sleep efficiency groups using Student's unpaired *t*-tests for continuous data and chi-square tests for categorical data.

The effect of lifestyle habits on the two sleep efficiency groups was examined by binomial logistic regression analysis with high sleep efficiency (≥80%) as the objective variable. The explanatory variables were age, sex, BMI, lifestyle (exercise habits, smoking status, nightcap, longer sleeping hours on weekends than on weekdays, smartphone use at bedtime, TV watching in the bedroom, ingestion of a caffeinated beverage, water ingestion at bedtime, shift worker, commute time), shift work, commuting time (hours), and BSJS. Both univariate and logistic regression analysis schemes were used, and odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated. In addition, stratification was performed by sex, and binomial logistic regression analysis was performed.

SL, WASO, and number of awakenings were also analyzed. For sleep latency, total awake time, and number of awakenings, the mean values of the values measured for one week were classified into two groups based on the median values, and binomial logistic regression analysis similar to that for sleep efficiency was performed.

All statistical data were analyzed using IBM SPSS Statistics for Windows version 25 (IBM Corp., Armonk, NY, USA). A P value of <.05 was taken to indicate statistical significance.

RESULTS

Table 1 lists the participants' characteristics, sleep disturbance, lifestyle, and occupational stress variables. Mean age was 42.7 years, 302 (43.6%) were male, and mean BMI was 22.3 kg/m^2. Mean sleep efficiency was 80.8%. The low sleep efficiency group included 269 (38.8%) participants.

Table 1 Participants' characteristics

		n (%) or mean	± SD
Attribute			
Age		42.7	± 11.3
Sex	Male	302	(43.6)
	Female	391	(56.4)
Body mass index (kg/m^2)		22.3	± 3.4
Total sleep time (minutes)		323.8	± 58.4
Sleep efficiency		80.8	± 10.5
Sleep efficiency of less than 80%		269	(38.8)
Sleep latency		17.2	± 12.4
Wake time after sleep onset		53.9	± 37.7
Number of awakenings		4.0	± 2.3
Lifestyle			
Longer sleeping hours on weekends than on weekdays		285	(41.1)
Nightcap		179	(25.8)
Smoking		58	(8.4)
Exercise habits		135	(19.5)
Smartphone use at bedtime		435	(62.8)
TV watching in the bedroom		197	(28.4)
Water ingestion at bedtime		579	(83.5)

Ingestion of a caffeinated beverage		
Coffee	486	(70.1)
Green tea	320	(46.2)
Tea	136	(19.6)
Energy drink	18	(2.6)
Shift worker	63	(9.1)
Commuting time (hours)	0.56	± 0.5
Brief Scale for Job Stress		
Workload	2.2	± 0.8
Mental workload	2.1	± 0.8
Problems in personal relationships	1.9	± 0.8
Job control	2.9	± 0.7
Reward from work	2.9	± 0.8
Support from colleagues and superiors	3.0	± 0.7

n = 693

Table 2 shows the relationship between sleep efficiency and the participants' characteristics, lifestyle, and occupational stress variables. The high sleep efficiency group had significantly lower BMI, shorter commuting time, and lower mental workload and reward from work compared with the low sleep efficiency group. The low sleep efficiency group had significantly higher percentages of males, "smartphone use at bedtime," and "water ingestion at bedtime" than the high sleep efficiency group.

Table 2 Crosstabulation of sleep efficiency with demographic, lifestyle, and work factors

		Sleep efficiency		
		High SE n (%) or Mean ± SD	Low SE n (%) or Mean ± SD	p
Age		42.8 ± 11.0	42.8 ± 11.7	0.99
Sex	(Male)	147 (34.8)	155 (57.4)	<0.01
Body mass index (kg/m^2)		22.0 ± 3.4	22.8 ± 3.3	<0.01
Lifestyle habit				
Longer sleeping hours on weekends than on weekdays	(Yes)	186 (44.0)	99 (36.7)	0.07
Nightcap	(Yes)	104 (24.6)	76 (28.1)	0.34
Smoking	(Current smoker)	32 (7.6)	26 (9.6)	0.41
Exercise habits	(More than once a week)	76 (18.0)	59 (21.9)	0.25
Smartphone use at bedtime	(Yes)	251 (59.3)	183 (67.8)	0.03
TV watching in the bedroom	(Yes)	123 (29.1)	74 (27.4)	0.70
Water ingestion at bedtime	(Yes)	340 (80.4)	240 (88.9)	<0.01
Ingestion of a caffeinated beverage				
Coffee	(More than one cup per day)	304 (71.9)	182 (67.4)	0.24

Green tea	(More than one cup per day)	193 (45.6)	128 (47.4)	0.70
Tea	(More than one cup per day)	82 (19.4)	54 (20.0)	0.92
Energy drink	(More than one cup per day)	8 (1.9)	10 (3.7)	0.22
Shift worker	(Yes)	34 (8.0)	29 (10.7)	0.28
Commuting time (hours)		0.53 ± 0.38	0.61 ± 0.64	0.04
Brief Scale for Job Stress				
Workload		2.1 ± 0.8	2.2 ± 0.8	0.20
Mental workload		2.1 ± 0.7	2.3 ± 0.8	<0.01
Problems in personal relationships		1.9 ± 0.8	1.9 ± 0.8	0.61
Job control		2.9 ± 0.8	2.9 ± 0.7	0.58
Reward from work		2.9 ± 0.8	3.0 ± 0.8	0.04
Support from colleagues and superiors		3.0 ± 0.7	3.0 ± 0.7	0.20

Average and standard deviation (SD) for continuous data, percentage for categorical data and P-values are shown. Statistical analyses were conducted using the t test and chi-square tests.
SE: sleep efficiency
χ^2 test or *t*-test, n = 693.

Table 3 lists the results of logistic regression analysis with low sleep efficiency as the objective variable. Multivariate analysis revealed a significant propensity of female sex in the high sleep efficiency group [female: OR, 0.41; 95% CI, 0.28–0.59]. One lifestyle habit was significantly related to high sleep efficiency, "longer sleeping hours on weekends than on weekdays" [OR, 0.66; 95%, CI 0.47–0.94], whereas "water ingestion at bedtime" [OR, 2.09; 95% CI, 1.28–3.41] and "smartphone use at bedtime" [OR, 1.90; 95% CI, 1.28–2.83] were significantly associated with low sleep efficiency. In addition, the mental workload in the job stress category yielded significant effects on low sleep efficiency, but there were no significant effects of caffeine-containing beverage ingestion or shift work.

Table 3 Analysis of the effects of demographic, lifestyle, and work factors on low sleep efficiency

		Unadjusted			Adjusted		
		OR	95% CI	p	OR	95% CI	p
Age		1.00	0.99 – 1.01	0.99	1.01	0.99 – 1.03	0.40
Sex	(Ref: Male)	0.40	0.29 – 0.54	<0.01	0.41	0.28 – 0.59	<0.01
Body mass index		1.07	1.03 – 1.12	<0.01	1.04	0.99 – 1.10	0.12
Lifestyle habit							
Longer sleeping hours on weekends than on weekdays	(Ref: No)	0.74	0.54 – 1.01	0.06	0.66	0.47 – 0.94	0.02
Nightcap	(Ref: No)	1.20	0.85 – 1.70	0.30	1.04	0.71 – 1.53	0.83
Smoking	(Ref: Former and never)	1.30	0.76 – 2.24	0.34	0.97	0.53 – 1.77	0.92
Exercise habits	(Ref: Once a week or less)	1.28	0.87 – 1.87	0.21	1.22	0.79 – 1.87	0.37
Smartphone use at bedtime	(Ref: No)	1.44	1.05 – 1.99	0.03	1.90	1.28 – 2.83	<0.01
TV watching in the bedroom	(Ref: No)	0.92	0.66 – 1.29	0.63	0.93	0.64 – 1.35	0.71
Water ingestion at bedtime	(Ref: No)	1.95	1.25 – 3.06	<0.01	2.09	1.28 – 3.41	<0.01
Ingestion of a caffeinated beverage							

	OR	95% CI	p	OR	95% CI	p
Coffee (Ref: One cup per day or less)	0.81	0.58 – 1.13	0.21	0.89	0.62 – 1.29	0.53
Green tea (Ref: One cup per day or less)	1.07	0.79 – 1.46	0.65	1.18	0.84 – 1.65	0.34
Tea (Ref: One cup per day or less)	1.04	0.71 – 1.53	0.84	1.36	0.89 – 2.08	0.15
Energy drink (Ref: One cup per day or less)	2.00	0.78 – 5.12	0.15	1.50	0.55 – 4.05	0.43
Shift worker (Ref: No)	1.38	0.82 – 2.32	0.23	1.65	0.93 – 2.92	0.09
Commuting time (hours)	1.41	1.01 – 1.97	0.04	1.49	1.05 – 2.12	0.03
Brief Scale for Job Stress						
Workload	1.13	0.94 – 1.37	0.20	0.82	0.62 – 1.07	0.14
Mental workload	1.39	1.14 – 1.70	<0.01	1.53	1.14 – 2.05	<0.01
Problems in personal relationships	1.05	0.86 – 1.29	0.61	0.91	0.71 – 1.18	0.49
Job control	1.06	0.86 – 1.31	0.58	0.86	0.66 – 1.12	0.26
Reward from work	1.23	1.01 – 1.48	0.04	1.24	0.97 – 1.57	0.08
Support from colleagues and superiors	0.95	0.75 – 1.20	0.65	0.99	0.73 – 1.33	0.93

Statistical analyses were conducted using binomial logistic regression.
OR: odds ratio
CI: confidence interval
Logistic regression analysis, n = 693.

Table 4 lists the results of the logistic regression analysis stratified by sex. One lifestyle habit was significantly related to high sleep efficiency in males: “Longer sleeping hours on weekends than on weekdays” [OR, 0.55; 95% CI, 0.32–0.93]. Two lifestyle habits were significantly related to low sleep efficiency in males: “water ingestion at bedtime” [OR, 3.39; 95% CI, 1.64–7.02] and “smartphone use at bedtime” [OR, 2.00; 95% CI, 1.12–3.58]. No significant association was found for lifestyle habits in females.

Table 4 Analysis stratified by sex of the effects of demographic, lifestyle, and work factors on low sleep efficiency

	Male			Female		
	OR	95% CI	p	OR	95% CI	p
Age	1.02	0.99 – 1.05	0.16	1.00	0.97 – 1.02	0.74
Body mass index	1.03	0.95 – 1.12	0.48	1.06	0.99 – 1.13	0.10
Lifestyle habit						
Longer sleeping hours on weekends than on weekdays (Ref: No)	0.55	0.32 – 0.93	0.03	0.70	0.43 – 1.14	0.15
Nightcap (Ref: No)	1.28	0.74 – 2.19	0.37	0.82	0.44 – 1.54	0.54
Smoking (Ref: Former and never)	1.14	0.51 – 2.54	0.75	0.80	0.26 – 2.40	0.69
Exercise habits (Ref: Once a week or less)	1.56	0.85 – 2.87	0.15	0.94	0.48 – 1.85	0.86
Smartphone use at bedtime (Ref: No)	2.00	1.12 – 3.58	0.02	1.74	0.95 – 3.18	0.07
TV watching in the bedroom (Ref: No)	0.73	0.41 – 1.29	0.27	1.17	0.70 – 1.94	0.55
Water ingestion at bedtime (Ref: No)	3.39	1.64 – 7.02	<0.01	1.27	0.64 – 2.52	0.49
Ingestion of a caffeinated beverage						
Coffee (Ref: One cup per day or less)	0.91	0.52 – 1.59	0.74	0.97	0.57 – 1.66	0.92

Green tea	(Ref: One cup per day or less)	1.08	0.63 – 1.83	0.78	1.26	0.78 – 2.01	0.35
Tea	(Ref: One cup per day or less)	0.77	0.36 – 1.66	0.51	1.65	0.97 – 2.80	0.07
Energy drink	(Ref: One cup per day or less)	0.89	0.21 – 3.71	0.87	3.87	0.83 – 18.11	0.09
Shift worker	(Ref: No)	1.29	0.43 – 3.83	0.65	1.68	0.80 – 3.55	0.17
Commuting time (hours)		2.14	1.16 – 3.95	0.02	1.22	0.81 – 1.83	0.34
Brief Scale for Job Stress							
Workload		0.78	0.52 – 1.16	0.21	0.88	0.58 – 1.32	0.53
Mental workload		1.57	1.01 – 2.45	0.05	1.49	0.99 – 2.22	0.05
Problems in personal relationships		0.80	0.54 – 1.17	0.25	1.08	0.77 – 1.54	0.65
Job control		0.77	0.51 – 1.17	0.22	0.95	0.66 – 1.37	0.78
Reward from work		1.81	1.21 – 2.70	<0.01	0.97	0.70 – 1.35	0.84
Support from colleagues and superiors		0.80	0.50 – 1.28	0.35	1.17	0.77 – 1.78	0.47

Statistical analyses were conducted using binomial logistic regression.
OR: odds ratio
CI: confidence interval
Logistic regression analysis, male : n = 302, female : n = 391.

Table 5 lists the results of logistic regression analysis with SL as the objective variable. Multivariate analysis showed a significant relationship of BMI to SL [BMI: OR, 1.06; 95% CI, 1.01–1.11]. One lifestyle habit was significantly related to long SL: "water ingestion at bedtime" [OR, 2.38; 95% CI, 1.52–3.72].

Table 5 Analysis of the effects of demographic, lifestyle, and work factors on SL

		Adjusted		
		OR	95% CI	p
Age		1.00	0.98 – 1.01	0.69
Sex	(Ref: Male)	0.75	0.52 – 1.08	0.12
Body mass index		1.06	1.01 – 1.11	0.03
Lifestyle habit				
Longer sleeping hours on weekends than on weekdays	(Ref: No)	0.77	0.55 – 1.07	0.12
Nightcap	(Ref: No)	1.06	0.73 – 1.52	0.77
Smoking	(Ref: Former and never)	0.94	0.53 – 1.68	0.84
Exercise habits	(Ref: Once a week or less)	0.99	0.66 – 1.49	0.96
Smartphone use at bedtime	(Ref: No)	1.42	0.99 – 2.06	0.06
TV watching in the bedroom	(Ref: No)	1.40	0.99 – 1.99	0.06
Water ingestion at bedtime	(Ref: No)	2.38	1.52 – 3.72	<0.01
Ingestion of a caffeinated beverage				
Coffee	(Ref: One cup per day or less)	1.06	0.75 – 1.51	0.73
Green tea	(Ref: One cup per day or less)	1.21	0.88 – 1.67	0.24
Tea	(Ref: One cup per day or less)	1.06	0.71 – 1.58	0.77
Energy drink	(Ref: One cup per day or less)	0.50	0.18 – 1.35	0.17

Shift worker	(Ref: No)	1.19	0.68 – 2.08	0.55
Commuting time (hours)		1.04	0.76 – 1.42	0.82
Brief Scale for Job Stress				
Workload		1.01	0.78 – 1.31	0.95
Mental workload		1.18	0.89 – 1.55	0.25
Problems in personal relationships		0.96	0.76 – 1.22	0.74
Job control		1.10	0.86 – 1.41	0.45
Reward from work		1.10	0.88 – 1.38	0.39
Support from colleagues and superiors		1.06	0.79 – 1.41	0.70

Statistical analyses were conducted using binomial logistic regression.
OR: odds ratio
CI: confidence interval
SL: sleep latency
Logistic regression analysis, n = 693.

Table 6 lists the results of logistic regression analysis with WASO as the objective variable. Multivariate analysis showed that female sex was significant in the short WASO group [female: OR, 0.42; 95% CI, 0.29–0.61]. Two lifestyle habits were significantly related to long WASO: "water ingestion at bedtime" [OR, 1.89; 95% CI, 1.20–2.98] and "smartphone use at bedtime" [OR, 1.82; 95% CI, 1.25–2.67] were significantly associated with low sleep efficiency. One lifestyle habit was significantly related to short WASO: "longer sleeping hours on weekends than on weekdays" [OR, 0.71; 95%, CI 0.50–0.99]. In addition, the mental workload and reward from work in the job stress category had significant effects on long WASO, and job control in the job stress category had significant effects on short WASO.

Table 6 Analysis of the effects of demographic, lifestyle, and work factors on WASO

		Adjusted		
		OR	95% CI	p
Age		1.00	0.98 – 1.02	0.93
Sex	(Ref: Male)	0.42	0.29 – 0.61	<0.01
Body mass index		1.05	0.99 – 1.10	0.08
Lifestyle habit				
Longer sleeping hours on weekends than on weekdays	(Ref: No)	0.71	0.50 – 0.99	0.05
Nightcap	(Ref: No)	1.23	0.85 – 1.79	0.28
Smoking	(Ref: Former and never)	1.37	0.75 – 2.52	0.31
Exercise habits	(Ref: Once a week or less)	1.11	0.73 – 1.70	0.62
Smartphone use at bedtime	(Ref: No)	1.82	1.25 – 2.67	<0.01
TV watching in the bedroom	(Ref: No)	1.08	0.75 – 1.54	0.68
Water ingestion at bedtime	(Ref: No)	1.89	1.20 – 2.98	<0.01
Ingestion of a caffeinated beverage				
Coffee	(Ref: One cup per day or less)	0.97	0.68 – 1.39	0.87
Green tea	(Ref: One cup per day or less)	0.95	0.68 – 1.32	0.76
Tea	(Ref: One cup per day or less)	1.21	0.81 – 1.83	0.35

Energy drink	(Ref: One cup per day or less)	1.16	0.42 – 3.19	0.78
Shift worker	(Ref: No)	1.35	0.76 – 2.39	0.31
Commuting time (hours)		1.39	0.97 – 2.00	0.08
Brief Scale for Job Stress				
Workload		0.76	0.58 – 1.00	0.05
Mental workload		1.35	1.01 – 1.79	0.04
Problems in personal relationships		1.04	0.81 – 1.32	0.77
Job control		0.75	0.58 – 0.97	0.03
Reward from work		1.33	1.05 – 1.68	0.02
Support from colleagues and superiors		0.88	0.66 – 1.18	0.40

Statistical analyses were conducted using binomial logistic regression.
OR: odds ratio
CI: confidence interval
WASO: wake time after sleep onset
Logistic regression analysis, n = 693.

Table 7 lists the results of logistic regression analysis with number of awakenings as the objective variable. Multivariate analysis showed that female sex was significantly associated with a lower number of awakenings [female: OR, 0.49; 95% CI, 0.34–0.70], and high BMI was associated with more awakenings. One lifestyle habit was significantly related to more awakenings: "smartphone use at bedtime" [OR, 1.67; 95% CI, 1.14–2.44]. In addition, the mental workload and reward from work in the job stress category had significant effects on increased number of awakenings.

Table 7 Analysis of the effects of demographic, lifestyle, and work factors on Number of awakenings

		Adjusted		
		OR	95% CI	p
Age		1.00	0.98 – 1.01	0.73
Sex	(Ref: Male)	0.49	0.34 – 0.70	<0.01
Body mass index		1.06	1.01 – 1.12	0.02
Lifestyle habit				
Longer sleeping hours on weekends than on weekdays	(Ref: No)	0.80	0.57 – 1.12	0.20
Nightcap	(Ref: No)	1.40	0.96 – 2.03	0.08
Smoking	(Ref: Former and never)	1.50	0.81 – 2.75	0.19
Exercise habits	(Ref: Once a week or less)	1.31	0.86 – 1.99	0.21
Smartphone use at bedtime	(Ref: No)	1.67	1.14 – 2.44	<0.01
TV watching in the bedroom	(Ref: No)	1.07	0.75 – 1.54	0.70
Water ingestion at bedtime	(Ref: No)	1.53	0.98 – 2.40	0.06
Ingestion of a caffeinated beverage				
Coffee	(Ref: One cup per day or less)	0.98	0.68 – 1.41	0.91
Green tea	(Ref: One cup per day or less)	0.95	0.68 – 1.32	0.75
Tea	(Ref: One cup per day or less)	1.27	0.84 – 1.91	0.25
Energy drink	(Ref: One cup per day or less)	1.20	0.44 – 3.32	0.72

Shift worker	(Ref: No)	1.52	0.86 – 2.70	0.15
Commuting time (hours)		1.23	0.88 – 1.74	0.23
Brief Scale for Job Stress				
Workload		0.75	0.57 – 0.98	0.04
Mental workload		1.46	1.10 – 1.94	<0.01
Problems in personal relationships		1.09	0.85 – 1.39	0.49
Job control		0.86	0.67 – 1.11	0.25
Reward from work		1.26	1.00 – 1.59	0.05
Support from colleagues and superiors		0.78	0.58 – 1.05	0.10

Statistical analyses were conducted using binomial logistic regression.
OR: odds ratio
CI: confidence interval
Logistic regression analysis, n = 693.

DISCUSSION

The present study revealed that the lifestyle habits of longer sleeping hours on weekends than on weekdays, drinking water at bedtime, and smartphone use at bedtime were significantly associated with sleep efficiency in selected male workers in Japan. These results were significant even after adjusting for the effects of occupational stress. To the best of our knowledge, this is the first study to objectively measure sleep efficiency in workers and to investigate the effects of lifestyle habits on sleep efficiency.

The use of smartphones at bedtime was a statistically significant risk factor for decreased sleep efficiency. Similar results were reported by a previous study in young adults, which reported that those who used smartphones before bed often had the devices in their bedrooms and may have been awakened by text messages sent by others.[26] In the present study, significant associations were found for post-sleep onset indices such as sleep efficiency and total waking time, but no association was found for sleep latency. In a previous study of junior high school students, no significant association was found between smartphone use before bedtime and sleep latency.[27] The present study is consistent with that result, suggesting that the effects of smartphones are not related to sleep latency, but may be related to sleep after falling asleep. Light exposure at night decreases melatonin secretion, and some studies have reported that sleep efficiency improves after administration of oral melatonin.[28,29] A decrease in melatonin levels may also have affected sleep efficiency in the present study, although this was not tested. Further research is needed on the use of smartphones before bedtime.

The present finding of higher sleep efficiency in women than men is in agreement with the findings of a previous study.[30] Men were found to spend a greater percentage of time in the relatively shallow sleep 1 stage compared with women,[31] which may be the reason why it is more difficult for men to maintain sleep continuity. The association with lifestyle also lost its dominance in women when stratified by sex. For women, the cutoff value of 80% for sleep efficiency may have been inappropriate; it is possible that the cutoff for sleep efficiency should be considered according to sex.

Water ingestion at bedtime was a significant risk factor for reduced sleep efficiency. Nocturia is a major factor in sleep disorders, and limiting fluid intake before sleep is known to reduce nocturia and improve sleep efficiency.[32,33] However, no significant association was found between the number of mid-awakenings and fluid intake. This indicated that it was unlikely to have increased the frequency of toilet visits. Although the time spent in the toilet may be one of the causes of reduced sleep efficiency, other factors may have been relevant: for example, people who had difficulty sleeping drank water hoping it would help them sleep better, or the sleeping environment was so bad that they needed to prevent heat stroke by drinking water. However, in the present study, neither were behavioral aspects monitored nor was the number of toilet visits investigated, so the details are unknown. Quantitative analyses of fluid intake were not conducted, but they should be evaluated in future research.

Those who slept for longer hours on the weekends than on weekdays were more likely to have better sleep quality. Accumulated sleep debt due to lack of sleep on weekdays can cause workers to increase the time spent sleeping on weekend days. Longer hours sleeping on the weekends than on weekdays most likely reflects the lack of sleep on weekdays. It has been suggested that continued physiologically inadequate duration of sleep can increase sleep efficiency.[34] This result was most likely influenced by the lack of sleep on weekdays. Therefore, we do not recommend increasing the duration of sleep on weekends in order to improve sleep efficiency because of its possible association with problems such as sleep deprivation syndrome. However, the current questionnaire did not use quantitative questionnaires, such as the length of sleep on holidays. Therefore, future studies should include quantitative analyses.

We found no association between exercise habits and sleep efficiency. In younger and older adults, daytime activity was found to be associated with sleep efficiency, but exercise intervention did not improve sleep efficiency.[35] However, a meta-analysis of patients with sleep apnea syndrome revealed that exercise generally improved sleep efficiency.[36] Exercise has a positive impact on patients with a history of this condition, but it may not have a significant impact on healthy adults.

Of the occupational stresses, mental workload was associated with lower sleep efficiency, whereas workload was not significantly associated. This result was replicated in a survey using a subjective questionnaire.[37] The results suggest that the difficulty of the work content rather than the quantity of work may have an effect on the decrease in sleep quality. Interventions to improve sleep quality may be more effective when examining the content rather than the quantity of work.

No association was found between consuming a nightcap and sleep efficiency in the present study. Alcohol consumption has been reported to have an adverse effect on sleep efficiency, which is inconsistent with the present results.[38] In the present study, a single question was used to assess nightcap consumption over the whole week in which sleep efficiency was measured. There is a possibility that some participants may have refrained from a nightcap when measuring sleep, and our study may not have been able to adequately evaluate the effect on sleep of consuming a nightcap. This association could be evaluated by performing a survey that considers each day of the week individually, as well as the amount of alcohol consumed.

The present study has some limitations. The first limitation is that, due to the cross-sectional study design, all parameters were assessed only once, and the causal relationships between parameters were unclear. Prospective cohort studies and interventional studies (randomized, controlled trials) are required to determine whether improving these lifestyle habits can increase sleep efficiency and clarify the causal relationships. The second limitation is the difficulty in obtaining an actigraphy sample of the general workforce. The subjects were recruited from four establishments located in Ibaraki and Tokyo, but the number of subjects was much smaller than the total number of employees. It can be said that the subjects in this study only participated in the study because they were interested in the study of sleep. People who voluntarily participated in the study may have been more health-conscious and may have overestimated their lifestyle. In addition, people who are concerned about their sleep may have participated in the study, so they may have overestimated their sleep measurements (SL, WASO, number of awakenings) and underestimated their sleep efficiency. In addition, although there are more male than female workers in Japan, the participants in this study were more likely to be female.[39] This may indicate that the participants may not be representative of the general workforce due to selection bias. Although the average sleep efficiency was comparable between the present study and similar previous studies, caution should be exercised in applying the present results to other target populations.[40,41] Third, several relevant factors were not included in the present study. Although it is known to reduce sleep efficiency, sleep apnea syndrome was not included in the self-reported questionnaire.[42] It is likely that some people have sleep apnea but are unaware of it, but we did not take this into consideration. Sleep can be affected by factors related to work–life balance and interactions or conflicts between work and private environmental factors, such as family, community, or private activities.[43] Adjustment for these as potential confounding factors was not performed, and this aspect also requires further research. Fourth, all parameters except the actigraphy data were self-reported. Recall biases could exist in these parameters, and height and weight in particular may not have been recorded accurately. In future research, factors other than sleep should be measured in an objective manner. Therefore, further large-scale studies in randomly selected workplaces are required in the future. Fifth, the participants were drawn from four different workplaces and may have had different lifestyles and work shift patterns. We adjusted as much as possible for occupational factors such as shift work and occupational stress. However, due to the small number of workplaces, it is highly likely that we did not adjust for all possible factors. Finally, this study evaluated the quality of sleep only by sleep efficiency. Since there are no other objective data (eg, laboratory data such as blood test results), the reliability of this study needs to be considered in the future. In addition, the sleep efficiency used in the index of this study was calculated from the bedtime and waking time from the sleep diary and the sleep time measured from the actigraph. This is not a completely objective index and includes some subjective data, so one cannot say that recall bias was completely removed. In the future, more objective indicators should be added to ensure reliability of the study.

Despite these limitations, this study was able to identify three factors that were significantly associated with sleep efficiency and is the first to show the relationship between lifestyle factors and sleep efficiency in workers. These results suggest the possibility that optimizing these lifestyle habits could improve sleep efficiency. Sleep efficiency data were obtained by objective measurement of sleep duration by actigraphy. These results are more reliable than studies using questionnaires on workers' sleep quality. Workers spend much of their time at work during the day, and work-related factors affect their sleep.[44] In this study, workplace stress was also investigated and adjusted for in the statistical analysis. We consider that this study took work-related factors into account as much as possible. It is known that sleep hygiene education can improve sleep.[45] Further research is needed to determine whether sleep hygiene education can improve sleep efficiency by optimizing lifestyle habits.

CONCLUSIONS

Through objective measurement of sleep in workers via actigraphy, this study revealed that one lifestyle habit (longer sleeping hours on holidays than on weekdays) had a significant effect on high sleep efficiency, and two lifestyle habits (water ingestion at bedtime and smartphone use at bedtime) had a significant effect on low sleep efficiency in male workers.

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CONFLICT OF INTEREST STATEMENT

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