Recent studies have suggested that there are potential underlying psychophysiological factors on the diurnal fluctuations in human time production: (1) accumulation of fatigue or sleepiness according to the length of the wakefulness (Phillips, 1977; Rammsayer, 1989), (2) an effect of circadian rhythm that was synchronized to day–night transition (Aschoff and Daan, 1997; Aschoff, 1998; Campbell et al., 2001; Morofushi et al., 2001), and (3) differences in psychological status at the time production session, especially mood (Mischel et al., 1969; Watts and Sharrock, 1984).

We used an AAT to evaluate vigilance level at the time production test. The AAC, a ratio of EEG alpha power values with eyes-closed to that with eyes-opened, has been widely utilized in human psychophysiological studies and recognized as a robust measure to evaluate the vigilance level objectively (Saletu and Grunberger, 1984; Niedermeyer et al., 1989). Studies on diurnal fluctuations of vigilance have revealed that longer sustained wakefulness was associated with lower vigilance level (Higuchi et al., 2001). Our results showing that AAC did not have a significant correlation with produced time suggest that the diurnal fluctuation in produced time was unlikely to be a consequence of changes in vigilance level.

We conducted continuous measurement of rectal temperature throughout the study, and found that a significant negative correlation between the produced time and rectal temperature. Rectal temperature measured under the strictly controlled conditions, in which ambient temperature and illumination, body movement, and posture of the participant, and feeding were kept constant, was reported to represent an oscillation of the circadian pacemaker (Czeisler et al., 1990), suggesting that the diurnal fluctuations in produced time may reflect changes in the output of the circadian pacemaker. In the present study, the experimental protocol was carefully designed to minimize effects of non-circadian factors. Thus, the fluctuation of core body temperature obtained in the present study was likely to represent an output of the circadian pacemaker. Aschoff, conducting a time production test in human subjects exhibiting free-run in the temporal isolation unit, has stressed that there may be a circadian effect on short-term time perception, though his study was not completely free from non-circadian confounding factors that may have effects on short-term time perception, such as psychological status, or mental activities. In his experiments, longer or shorter produced times were associated with lower or higher core body temperatures, respectively (Aschoff, 1998). To further confirm those potential effects of the circadian pacemaker on short-term time perception which obtained in his study and the present study, a longer observation under the well-controlled condition is necessary.

In contrast, about 70 years ago, when knowledge in human circadian organization had not been established, Hoagland described that a pathologically high skin temperature in patients with various infectious diseases was associated with prolongation of time estimation, presumably regardless of circadian timing (Hoagland, 1933). Recently, a similar observation has been reported by Hancock (1993). He found a significant but weak negative correlation between manipulated intra-auricular temperature and produced times, though shortening of produced time was not marked even when the intra-auricular temperature was seriously elevated. These studies may indicate that there are possible direct effects of body temperature on time perception. However, produced time obtained from patients suffering from infectious diseases seemed to be influenced rather by multiple pathological conditions than head temperature alone, since infection may cause not only the elevation of body temperature but also the releases of cytokines that have marked effects on brain function (Dantzer, 2001; Owens and Babcock, 2002).

In the present study, participants were instructed to memorize numbers, words, and figures before the initiation of time production, and maintain them while the participants were producing time. This procedure was considered to provide a dual task loading. That is, maintaining these memory targets was likely to occupy the working memory areas in the brain (McCarthy et al., 1994; Manoach et al., 1997). In the present study, the simultaneous load on the working memory areas, however, did not alter the time interval that the participants produced. In contrast, Fortin et al. have conducted a similar dual task procedure in searching effects on produced time and found that memory tasks presented during time production test were associated with a prolongation of produced time as compared with trials without memory tasks (Fortin and Breton, 1995; Fortin and Masse, 1999). However, their results may have been due to uncontrolled chronobiotic effects and other behavioral confounding factors. Our results revealed that the time of day had a more robust effect on produced time in comparison with simultaneously loaded memory tasks, even though there could have been a scanty effect of such memory tasks that Fortin et al. have reported.

Recently, functional imaging techniques were utilized in identifying neural networks related to time production (Harrington et al., 1998; Pouthas et al., 1999; Schubotz et al., 2000). Maquet et al. have suggested that time production process would be related to the function of the prefrontal cortices (BA 10, 46) in their PET study (Maquet et al., 1996). These areas have been reported to have a functional relationship with working memory process (Clifford et al., 2000). These functional imaging studies suggested that time production process may be related to a working memory function. Our results that

working memory loads have no significant effect on an accuracy of produced time suggest that the prefrontal cortices might not be the interval timing clock itself, though it played an important role as a part of neural networks that were involved in participant's attempt to produce time, since their study did not concern the accuracy of produced time due to different objectives of their studies.

Mood had been believed as an important factor in considering subjective passage of time. As one may imagine, in one's daily life time is likely to pass faster in a pleasant situation than in an unpleasant situation. Mischel et al. and Watts et al. have reported that subjective passage of time ran slower in the condition in which an emotionally uncomfortable task was provided, in comparison with that without such a task (Mischel et al., 1969; Watts and Sharrock, 1984; Angrilli et al., 1997). In the present study, we did not find any effects of mood and other psychological measures on time production. A possible explanation for the different results may be attributed to our study design in which the behavioral and psychological conditions were strictly controlled, giving minimal changes in the psychological statuses across 4 sessions. Moreover, enforced motivation for accuracy of produced time using economical rewards did not affect the accuracy, providing another explanation that produced time may be beyond volitional control.

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ORIGINAL ARTICLE

Sleep habits and factors associated with short sleep duration among Japanese high-school students: A community study

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Abstract

To clarify the sleep habits, and predictors thereof, in Japanese high-school students, a community study was conducted. A total of 3833 students were selected randomly from the 34 full-time high schools in two suburban cities in Japan. The response rate was 90.7% (n=3478). The students completed the Japanese version of the Pittsburgh Sleep Questionnaire Index (PSQI-J), the Japanese version of the 12-item General Health Questionnaire (GHQ12-J), and a questionnaire on sociodemographic characteristics, daily life, domestic situations, and perceived physical health. Mean bed and rise times were found to be 00:03 and 06:33 h, respectively, resulting in a sleep duration of 380.0 min. A multivariate logistic regression analysis revealed that a short sleep duration (i.e. less than 6 h; prevalence: 25.6%) was significantly associated with a later bedtime, a higher global PSQI-J score, an earlier rise time, being female, a longer study duration outside school hours, and a longer commuting duration, but not with a higher GHQ12-J score. Short sleep duration in Japanese high-school students is associated with their lifestyle as well as sleep problems, but not with psychosomatic problems.

Key words: adolescents, community survey, high-school students, insufficient sleep, lifestyle.

INTRODUCTION

During adolescence, the sleep-wake pattern changes dramatically. Previous epidemiological studies on the sleep habits of adolescents have reported that older teenagers sleep less than younger teenagers, the timing of sleep is delayed in older versus younger teenagers, and there is an increasingly large discrepancy between school night and weekend sleep schedules with age in teenagers.[1] Biologically, it is believed that the human sleep-wake pattern is determined by an interplay between sleep debt and circadian sleep propensity.[2] It has been reported that the required sleep duration of adolescents for optimal daytime alertness is between 8.25 and 9.2 h,[3] and that the intrinsic circadian timing system shows a phase delay that is associated with puberty.[4–6] Socially, the sleep duration of adolescents seems to be shortened by various social constraints, interactions with peers, academic obligations, extracurricular activities, employment, and school start time.[1] Consequently, shortened sleep in adolescents leads to insufficient sleep,[7,8] daytime sleepiness,[7,8] and habitual naps.[9–12]

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Some cross-sectional surveys on sleep habits have demonstrated that in Japan, changes in the sleep pattern during adolescence are consistent with the results of surveys conducted in other countries.[13–16] However, three of them[13,14,16] have not investigated the relationship between sleep habits and lifestyles, and the rest[15] have not selected their sample properly.

To determine the sleep patterns of Japanese high-school students in detail, a community survey was carried out. The sleep habits and factors associated with short sleep duration (i.e. less than 6 h per night) were studied among a cohort of Japanese high-school students.

METHODS

Participants and procedure

This epidemiological study was carried out in the cities of Chiba and Yotsukaido, which lie in typical suburban areas of Japan, and are located approximately 40 km east of the center of Tokyo. The area has a population of approximately 950 000. We explained the aims of the study to the educational committee of the appropriate local governments and obtained their permission to carry out the survey.

The survey was performed between 26 June and 1 July 2000. One class in each grade from all of the 34 full-time high schools in these cities was randomly sampled (Fig. 1). Well-trained school nurses administered the anonymous questionnaire to the students during a health education class. Students were informed about the aim of the study, and were then asked whether they were willing to participate. All of the students who attended the class gave their consent. Before rating the questionnaire, the students were told to read the instructions carefully, and were given the opportunity to ask questions about the study and the questionnaire. The school nurses monitored the session and answered questions as needed to ensure that all questionnaires would be completed correctly. Approximately 30 min were required to complete the questionnaire.

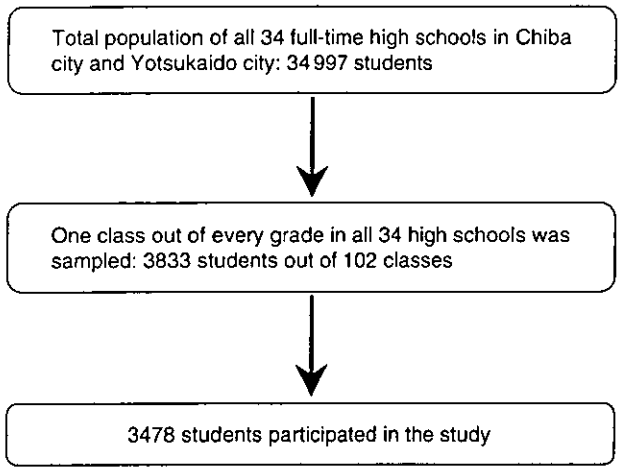

Figure 1 Sampling procedures. The 34 high schools in Chiba and Yotsukaido had a total student population of 34 997. Of the 3833 students sampled from that population (102 classes), 3478 (90.7%) participated in the survey and returned the questionnaires.

Measures

A self-administered anonymous questionnaire, which is described below, was developed to investigate sleep habits, sleep problems, physical and mental status, and lifestyle. The questionnaire consisted of three sections: the modified Japanese version of Pittsburgh Sleep Questionnaire Index (PSQI-J),[17,18] the Japanese version of the 12-item General Health Questionnaire (GHQ12-J),[19,20] and a questionnaire on sociodemographic characteristics, lifestyle, domestic situations, and perceived physical health. The PSQI-J assesses perceived sleep duration, perceived sleep latency, and the frequency and severity of specific sleep-related problems during the previous month.[17,18] To separate the sleep habits during weekdays and those on weekends, we added questions for sleep habits on weekends. The global PSQI-J score was calculated according to a standard method.[17]

The GHQ12-J is a widely used, self-administered questionnaire that was designed as a screening tool for mental illness. It assesses 12 symptoms of psychiatric disorders during the previous month. The responses are scored in a binominal fashion (symptom present: 'not at all' = 0, 'same as usual' = 0, 'more than usual' = 1, and 'much more than usual' = 1). The presence of psychiatric symptoms is indicated when the sum of the 12 responses exceeds six (i.e. when the GHQ12-J score exceeds 0.5).[20]

The personal characteristics comprised age, grade, gender, type of school attended (public/private and co-education/single-gender school), type of school course (general/vocational), and planning future course after graduation (college/junior college/vocational school/employment/'not decided'). The following items were embedded in the questionnaire on lifestyle; participation in extracurricular activities (yes/no), type of extracurricular activities (sports/cultural), duration of

extracurricular activities (hours per day), duration of study outside school hours (hours per day), duration of watching television and/or playing PC games (hours per day), duration of commuting between home and school (hours per day), duration of part-time work (hours per day), family size, existence of a night worker in the family (yes/no), perceived bedroom situation (good/fair/poor), and number of people sharing the subject's bedroom. Perceived physical health was assessed by using a Likert scale (good/fair/bad).

Statistical analysis

In order to assess the effects of grade and gender on: (i) bedtime; (ii) rise time; (iii) perceived sleep duration; (iv) duration of extracurricular activity; (v) duration of study outside school hours; (vi) duration of watching television and/or playing PC games; (vii) duration of commuting between home and school; and (viii) duration of part-time work, we performed analyses of variance (ANOVAs), with gender and grade as independent variables.

The factors associated with short sleep duration were examined with the aid of a series of logistic regression analyses. Independent variables were converted into binominal factors: bedroom situation and perceived physical health ('good' or 'fair'=0 and 'bad'=1); parametric values were dichotomized at 25 or 75 percentile values. All variables were initially examined in univariate models. To control confounding factors and to determine the main correlates, we then performed multivariate logistic regression analyses for all variables that showed a significant correlation in univariate models. Statistical tests of the regression estimates or odds ratios (ORs) were based on Wald statistics. Odds ratios and their 95% confidence intervals (CIs) are presented to show the association.

All of the analyses were performed by using StatView, Version 5.0.1 for Macintosh (SAS Institute, Cary, NC, USA). The level of statistical significance was set at $P<0.05$.

RESULTS

Sample characteristics

The 34 high schools in Chiba and Yotsukaibo had a student population of 34 997. Of the 3833 students sampled from this population, 3478 (90.7%) participated in the survey and returned valid questionnaires (Fig. 1). The sociodemographic characteristics of the sample are shown in Table 1. The sample consisted of 1639 male students (47.1%) and 1839 female students (52.8%) whose mean (SD) age was 16.5 (1.0) years (range 15–18 years). The number of students who attended a private school was 795 (22.5%), 283 (8.1%) attended a girls' school,

Table 1 Sociodemographic characteristics of the study sample

	n	%
Grade		
First	1219	35.0
Second	1185	34.1
Third	1074	30.9
Sex		
Male	1639	47.1
Female	1839	52.9
Public or private school		
Public school	2693	77.4
Private school	785	22.6
Course		
General course	3075	88.4
Vocational course	403	11.6
Type of school		
Co-education	3195	91.9
Girls' school	283	8.1
Extracurricular activity		
Yes	1816	52.2
Athletic club	1162	33.4
Cultural club	552	15.9
Missing data	102	4.1
No	1637	47.1
Missing data	25	0.7
Future course		
College/junior college	2142	61.6
Other	1319	37.9
Missing data	17	0.5
Part-time work		
Yes	383	11.0
No	3072	88.3
Missing data	23	0.7
Size of family		
<5	2912	83.7
≥5	542	15.6
Missing data	24	0.7
Night workers in family		
Yes	468	13.5
No	2983	85.8
Missing data	27	0.8
Bedroom sharing		
Not sharing	2784	80.0
Sharing	670	19.3
Missing data	24	0.7

and 403 (11.6%) majored in a vocational course. Eighteen hundred and sixteen students (52.2%) participated in an extracurricular activity; 1162 students (33.4%) participated in athletic activities and 552 (15.9%) participated in cultural activities. Among all of the participants, 2142 students (61.6%) planned to proceed to college or junior college, and 383 students (11.0%) were working part-time. The mean family size in this cohort was 4.6 (1.1), 468 students (13.5%) had family members who were night workers, and 670 students (19.3%) shared a bedroom with other family members.

Habitual sleep and daily life

Table 2 shows the sleep habits and lifestyle of the participants. The mean bedtime (SD) was 00:03 (01:06) hours, and it was later for the male students than for the female students ($F_{1,2}=10.4$). The mean bedtime was later as the grade went up ($F_{1,2}=109.5$). The mean rise time was 06:33 (00:47) hours, and it was later for the male students than for the female students ($F_{1,2}=285.6$). The mean rise time was also later as the grade went up ($F_{1,2}=30.5$). The mean perceived sleep duration was 380.0 (66.0) min, and it was shorter for the female students than for the male students ($F_{1}=59.4$). The mean perceived sleep duration reduced as the grade went up ($F_{1,2}=73.8$). The mean perceived sleep latency was 16.8 (19.4) min. In 1665 students (47.8%), the global PSQI score exceeded the cut-off value[15] and was larger for female students than for male students ($F_{1,2}=10.8$), and increased as the grade went up ($F_{1,2}=21.9$).

The students spent 68.9 (77.8) min studying outside school hours, 133.5 (94.0) min watching television and/or playing PC games, and 75.5 (47.2) min commuting every day. There was a significant main effect of gender on the duration of study outside school hours and commuting, and a significant main effect of grade on the duration of study outside school hours and watching TV and/or playing PC games.

Health problems

The GHQ12-J score was higher for the female than for the male students, and increased as the grade went up. Analysis of variance revealed a significant main effect of gender ($F_{1,2}=55.6$) and grade ($F_{1,2}=7.3$). Psychiatric problems, as defined by the GHQ12-J questionnaire, were recognized in 802 students (23.1%), and 728 students (20.9%) reported that their perceived physical health was bad.

Table 2 Sleep habits and lifestyle of the sample

		Male			Female			Significant effects		
	Overall	First	Second	Third	First	Second	Third	Grade	Gender	Interaction
Bedtime (hours)	00:03 ± 01:06	23:46 ± 01:04	00:07 ± 01:08	00:24 ± 01:09	23:50 ± 01:05	00:03 ± 01:05	00:11 ± 01:01	**		**
Rise time (hours)	06:33 ± 00:47	06:36 ± 00:48	06:43 ± 01:06	06:49 ± 00:42	06:20 ± 00:36	06:28 ± 00:38	06:25 ± 00:39	**	**	*
Sleep duration (min)	380.0 ± 66.0	401.5 ± 62.0	383.3 ± 68.3	372.6 ± 67.1	381.7 ± 64.9	375.9 ± 67.0	363.8 ± 60.5	**	**	*
Sleep latency (min)	16.8 ± 19.4	15.8 ± 14.5	17.4 ± 18.4	18.4 ± 19.6	17.9 ± 24.4	14.6 ± 14.4	16.9 ± 22.4			**
Global PSQI score	5.7 ± 2.5	5.1 ± 2.3	5.7 ± 2.5	5.9 ± 2.5	5.5 ± 2.4	5.9 ± 2.4	6.1 ± 2.5	**	**	
Sum of GHQ-12 score	4.2 ± 3.1	3.6 ± 2.9	3.9 ± 3.1	4.1 ± 3.2	4.3 ± 3.2	4.8 ± 3.0	4.7 ± 3.1	**	**	
Study outside school hours (min/day)	68.9 ± 77.8	51.2 ± 60.5	40.6 ± 50.0	95.7 ± 97.2	70.1 ± 78.2	50.9 ± 55.1	109.9 ± 92.2	**	**	
TV and/or PC games (min/day)	133.5 ± 94.0	129.3 ± 93.8	141.3 ± 106.3	132.5 ± 95.3	137.2 ± 86.2	140.8 ± 93.1	118.3 ± 88.1	**		*
Commuting (min/day)	75.5 ± 47.2	68.5 ± 45.2	73.9 ± 49.3	69.7 ± 46.0	81.9 ± 47.9	78.4 ± 48.7	78.8 ± 44.3		**	

Results are presented as mean ± SD. *P<0.05; **P<0.01.

Table 3 Prevalence of short sleepers (perceived sleep duration of less than 6 h)

	Total	Short sleeper		
	n	*n*	%	95% CI
Males				
First grade	573	85	14.8	(13.7–16.0)
Second grade	537	119	22.2	(20.8–23.5)
Third grade	529	155	29.3	(27.8–30.8)
Females				
First grade	646	159	24.6	(23.2–26.0)
Second grade	648	189	29.2	(27.7–30.7)
Third grade	545	184	33.8	(32.2–35.3)
Overall	3478	891	25.6	(24.2–27.1)

Short sleeper

Eight hundred and ninety-one students (25.6%) were categorized as short sleepers (i.e. their perceived sleep duration was less than 6 h; Table 3). The prevalence of short sleepers was 14.8–29.3% for the male students and 24.6–33.8% for the females.

Factors associated with short sleep duration

Univariate logistic regression analyses were performed for 37 independent variables, 15 of which exhibited significant correlations with short sleep duration (Table 4). To control for confounding factors and to determine the main correlates of short sleep duration, all significant variables in the univariate models were submitted to a multivariate model. Adjusted ORs and their 95% CIs in the final model are shown in Table 4.

Multivariate logistic regression analysis revealed that short sleep duration was significantly associated with being female (OR=1.7, 95%CI: 1.4–2.2) and having a later bedtime (OR=22.5, 95%CI: 16.2–31.2), an earlier rise time (OR=3.8, 95%CI: 2.8–5.1), a high global PSQI-J score (OR=12.7, 95%CI: 9.6–16.7), a long study duration outside school hours (OR=2.0, 95%CI: 1.5–2.8), and a long commuting duration (OR=1.6, 95%CI: 1.2–2.2).

DISCUSSION

In this community survey, it was found that the average sleep duration of Japanese high-school students was 380 min, that older students slept less than younger students, and that female students slept less than male students. By using a multivariate logistic regression analysis, it was found that a short sleep duration was associated with sleep habits and lifestyle as well as a high global PSQI-J score, but not with a high GHQ12-J score or physical problems.

The sleep habits of adolescents in Japan have not been investigated until recently. There are some studies in which short sleep duration in Japanese adolescents has been examined,[15,16] however, in those studies, subjects were not sampled properly, their questionnaires were not standardized, or they did not take into account confounding factors in their analyses. In the first instance, the community study presented here documented the sleep habits among Japanese high-school students by using a random sampling procedure, standardized questionnaires, and multivariate statistical analyses.

It has been well acknowledged that a reduction in sleep duration, a delay in the sleep phase, and an increase in the discrepancy between sleep habits on school nights and on weekend nights are observed during adolescence.[1] These changes were reported to be caused by intrinsic biological changes[3–6] and environmental social factors.[1] The circadian system is likely to be susceptible to a phase delay during puberty, and social factors such as academic obligation, extracurricular activities, employment, and entertainment are known to suspend bedtime in adolescents, while the socially enforced school start time determines their rise time.[1] We suspect that the sleep duration among adolescents, which is under the influence of the pubertal circadian system as well as social constrains, may be shorter than what is required biologically, leading to insufficient sleep, daytime sleepiness, and habitual naps in these individuals.[21]

The mean sleep duration of the high-school students in the present study was 380 min. Previous surveys conducted in other countries have demonstrated that sleep duration is shorter in East Asia[9,22,23] (380–440 min in late teens) compared with Europe,[7,24–27] North America,[28] South America,[4] and Africa[11] (460–490 min in late teens). Te cultural difference between East Asia and other areas and different instruments may at least partially explain this difference. Another explanation may be drawn from the effect of naps on night sleep. Recent studies have suggested that taking a nap in the evening is a common occurrence among Japanese adolescents.[10,14] It has been shown that in an experimental setting, having an evening nap decreases the sleep debt,[2] so the late bedtime experienced by Japanese high-school

Table 4 Significant correlations of short sleep duration, as assessed by logistic regression analysis

	Total	Short sleep duration		Crude		Adjusted	
	n	*n*	%	OR	95% CI	OR	95% CI
Grade							
First	1219	244	20.2				
Second	1185	308	26.0	1.4	1.2–1.7*		
Third	1074	339	31.6	1.8	1.5–2.2*		
Gender							
Male	1639	359	21.9				
Female	1839	532	28.9	1.5	1.2–1.7*	1.7	1.4–2.2*
School type							
Co-educated	3195	799	25.0				
Girls' school	283	92	32.5	1.4	1.1–1.9*		
Bedtime							
Before 01:00 hours	3037	535	17.6				
After 01:00 hours	428	350	81.8	21.0	16.1–27.3*	22.5	16.2–31.2*
Perceived sleep latency							
≤20 min	2892	737	25.5				
>20min	502	138	27.5	1.3	1.1–1.5*		
Rise time							
After 06:00 hours	3021	697	23.1				
Before 06.00 hours	424	182	42.9	2.5	2.0–3.1*	3.8	2.8–5.1*
Global PSQI score							
≤7	2544	371	14.6				
>7	764	479	62.7	9.8	8.2–11.8*	12.7	9.6–16.7*
Sum of GHQ12-J score							
≤6	2656	637	24.0				
>6	802	249	31.1	1.4	1.2–1.7*		
Extracurricular activity							
Yes	1816	409	22.5				
No	1637	477	29.1	1.4	1.2–1.7*		
Duration of extracurricular activity							
≥1 h	1638	355	21.7				
<1 h	1690	492	29.1	1.5	1.3–1.7*		
Duration of study outside school hours							
≤2 h	2868	667	23.3				
>2 h	467	190	40.7	2.3	1.9–2.8*	2.0	1.5–2.8*
Commuting duration							
≤2 h	3039	753	24.8				
>2 h	383	127	33.2	1.5	1.2–1.9*	1.6	1.2–2.2*
Part-time work							
No	3072	763	24.8				
Yes	383	119	31.1	1.4	1.1–1.7*		
Bedroom environment							
Good	2589	631	24.4				
Bad	847	249	29.4	1.3	1.1–1.5*		
Perceived physical status							
Not bad	2727	627	23.0				
Bad	728	257	35.3	1.8	1.5–2.2*		

*$P<0.01$.

students might be influenced by the habit of taking naps in the evening.

Short sleep duration was associated with female students in the present study. A similar gender difference in perceived sleep duration has been reported in other community surveys in the USA,[29] Taiwan,[9] and in four of the European countries,[25] but not in Korea,[23] China[22] or Italy.[27] Further study is required to clarify the differences in the effect of gender on sleep duration among these countries.

In the present study, multivariate logistic regression analyses have revealed that short sleep duration in Japanese high-school students is associated with late sleep onset and poor sleep quality rather than an early rise time. We have also demonstrated that short sleep duration is not associated with psychiatric or physical problems. Insufficient sleep was reported to result in excessive daytime sleepiness and deteriorated daytime performance.[30,31] However, it remains unclear whether short sleep duration causes poor academic performance in adolescents. Eliasson *et al.* reported that academic performance in adolescents was not correlated with perceived sleep duration.[32]

Among environmental factors, the long commuting duration showed strongest association with short sleep duration. It has been reported that school start time is the strongest factor determining rise time in adolescents.[1] As this survey has been conducted in a homogenous community, the difference of school start times was minimal (less than 15 min) between schools. Our result indicates that commuting duration influences the rise time and sleep duration of adolescents, under equivalent school start times.

In conclusion, the sleep duration of Japanese high-school students was shorter compared with students from other countries in North and South America, Europe and Africa, but was comparable to that in East Asian countries. Short sleep duration was associated with multiple factors, and a late bedtime was the most significant predictor. Psychiatric and physical problems were not associated with short sleep duration.

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