The recognition of sleep apnea syndrome (SAS) as a common and serious public health problem has become widespread, and the prevalence of SAS in the Japanese male working population has increased during the past decade, being recently estimated at 22.3% (Hida 1998, Nakayama-Ashida et al. 2008). SAS has conventionally been divided into two categories: obstructive sleep apnea syndrome (OSAS) and central sleep apnea syndrome (CSAS) including Cheyne–Stokes respiration. Pure obstructive sleep apnea (OSA) events are caused by the reduction or cessation of respiration because of narrowing or occlusion of the upper airway during sleep. Pure central sleep apnea (CSA) events or Cheyne–Stokes respiration are thought to be induced by chemosensitivity to hypoxia or hypercapnia. Currently, a large majority of patients with SAS are diagnosed with OSAS. Continuous positive airway pressure (CPAP) application is the first-line noninvasive treatment for OSAS, and can almost completely suppress obstructive respiratory events. However, it has long been noted in sleep-disorder clinics that some patients presenting with predominately obstructive apneas at baseline experience accompanying CSA events after tracheostomy or application of CPAP (Guilleminault and Cummiskey 1982, Onal et al. 1982, Thomas et al. 2004).

Sleep apnea initially manifests as primarily an obstructive components, but the presentation of frequent central components or a predominant Cheyne–Stokes respiration pattern after the removal of upper airway obstruction has been defined as complex sleep apnea syndrome (CompSAS) (Gilmartin et al. 2005, Morgenthaler et al. 2006). The reported prevalence of CompSAS among patients with SAS in the USA and Australia ranged from 13.1% to 20.4% (Morgenthaler et al. 2006, Pusalavidyasagar et al. 2006, Lehman et al. 2007). However, there may be genomic, environmental, or cultural differences between Caucasian and Japanese patients with SAS both in upstream pathophysiological risk factors such as obesity or neurological respiratory control dysfunction, and downstream clinical events such as cardiovascular or cerebrovascular consequences (Villaneuva et al. 2005). The purpose of this study was therefore to retrospectively determine the prevalence of CompSAS and the clinical significance of the condition among Japanese patients with SAS.

Methods

Study Subjects

A retrospective study was performed in two sleep-disorder centers. Japanese subject patients who were 20 years or older were newly examined for SAS, diagnosed by clinical symptoms, and attended overnight polysomnography (PSG). None of the patients had been previously treated with CPAP. Patients were diagnosed with SAS if the sum of the apnea and hypopnea events per hour [apnea hypopnea index (AHI)] was 5 or more at diagnostic PSG. Patients were diagnosed with pure CSAS if the number of CSA events per hour [central apnea index (CAI)] was 5 or more and at least 50% of the total apneic events were CSA at diagnostic PSG (Shin et al. 1999). Patients with more than 5 events per hour of both obstructive AHI and CAI, and with percentages of CSA and/or Cheyne–Stokes respiration events less than 50% at diagnostic PSG, were defined as showing mixed breathing patterns. Standard CPAP titration was performed manually during attended overnight in-laboratory sleep within 1 month of the diagnostic PSG night on the patients having an AHI of 20 or more based on the criteria stipulated by Japanese health insurance. Standard CPAP titrations were performed except for those with CSAS, indications for surgeries or oral appliances, and those pretreated with auto-adjusted CPAP. Patients were considered to have pure OSAS if obstructive AHI included 5 or more events per hour at diagnostic PSG, and if CPAP titration was successful in decreasing total AHI to less than 5 events per hour (Pusalavidyasagar et al. 2006). Patients were considered to have CompSAS if CPAP titration eliminated events defined as part of OSAS but for whom the residual CAI was 5 or more per hour or the Cheyne–Stokes respiration pattern became prominent and disruptive (Morgenthaler et al. 2006). Among patients with mixed breathing patterns, those in whom both obstructive AHI and CAI decreased to less than 5 events per hour at the titration were defined as [diagnosis(+) titration(−)].

Clinical complications including hypertension, cardiac diseases, and cerebrovascular diseases were investigated based on medical chart reviews. Cardiac diseases included left and right ventricular hypertrophy, chronic heart failure, mitral regurgitation, pulmonary stenosis, atrial fibrillation, and ischemic heart diseases (i.e., angina pectoris and myocardial infarction). Cerebrovascular diseases included stroke, subarachnoid hemorrhage, and cerebral infarction. The Institutional Review Boards of our institutes approved this study after reviews by the respective Ethics Committees.

Polysomnography and titration

Overnight sleep studies, diagnostic PSG, and manual CPAP titration were carried out as published previously (Suzuki et al. 2005). Briefly, we simultaneously performed electroencephalography (EEG, C4/A1, C3/A2), electrooculography (EOG), submental electromyography (EMG), and electrocardiography (ECG) using surface electrodes, and measured air flow at the nose and mouth using a thermistor, respiratory movements of the rib cage and abdomen by inductive plethysmography, and percutaneous arterial oxygen saturation (SpO_2) using a finger pulse oximeter. Apneas were identified as a near-flat airflow (< 10% of baseline; baseline amplitude was identified during the closest preceding period of regular breathing with stable oxygen saturation) for at least 10 sec. Hypopneas were identified as airflow or thoracoabdominal excursions of approximately < 70% of baseline for at least 10 sec, associated with either an oxygen desaturation of > 3% or an arousal.

On titration nights, technologists provided instructions on the use and adjustment of the CPAP apparatus, nasal mask adjustment, symptoms indicating an incorrect CPAP setting, and modes of hands-on intervention. The technologists increased CPAP pressure during sleep in a stepwise fashion (step size: 0.2–1.0 cm H_2O) to abolish respiratory events and associated arousals. The CPAP apparatus used for titration was a REMStar Pro fixed-type CPAP machine (Respironics; Pittsburgh, PA).

Statistical Analyses

All descriptive statistical data are presented as mean ± standard deviation. Descriptive statistical data were calculated for each variable. Variables were evaluated by the one-way factorial ANOVA test and the Yates Chi-squared test. A p value less than 0.05 was considered to indicate statistical significance. Statistical comparisons were performed using the Statistical Package for Social Sciences (SPSS) for Windows, version 11.01 (SPSS Inc.; Chicago, IL).

Results

In all, 3,694 patients were diagnosed with SAS at diagnostic PSG. Consecutive CPAP titration was performed on patients with AHI of 20 or more except for those with CSAS, indications for surgeries or oral appliances, and those pretreated with auto-adjusted CPAP. The total study population consisted of 1312 Japanese patients with SAS (1,217 male and 95 female). Schematic results of the study are outlined in Fig. 1. Fourteen patients exhibited pure CSAS, and 50 exhibited a mixed breathing pattern at diagnostic PSG. Sixty-six patients were diagnosed with CompSAS and 1,232

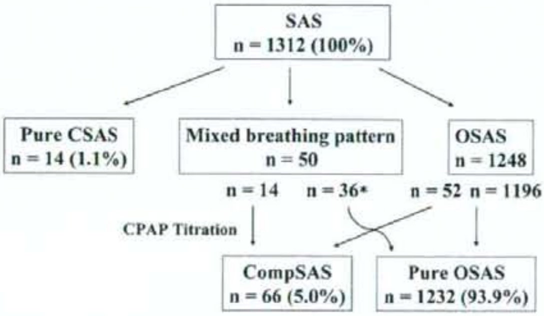

Fig. 1. Composition of the study population

SAS, sleep apnea syndrome; CSAS, central SAS; OSAS, obstructive SAS; CompSAS, complex SAS.

* [diagnosis(+) titration(−)], patients who showed mixed breathing patterns at diagnostic polysomnography and whose apnea/hypopnea indices at titration decreased to less than 5 events per hour.

with pure OSAS from the results of CPAP titration PSG. The overall prevalence of CompSAS was 5.0% (66 in 1,312 patients). The percentage of CompSAS as a proportion of all patients with mixed breathing patterns was 28.0% (14 in 50 patients). In all, 21.2% of patients with CompSAS had a mixed breathing pattern on their diagnostic PSGs (14 in 66 patients), compared with only 2.9% of patients with pure OSAS had a mixed breathing pattern (36 in 1,232 patients). The anthropometric and polysomnographic characteristics of the patients with CompSAS, OSAS, and CSAS are shown in Table 1. The prevalence of CompSAS among males and females with SAS was 5.3% (65 in 1218 patients) and 1.1% (1 in 94 patients), respectively. There were no significant differences in age among the three groups; however, there were significant differences in AHI values ($F = 17.0$, $p < 0.01$, ANOVA), and patients with CompSAS had a slightly but significantly higher value of AHI than patients with either OSAS or CSAS ($p < 0.01$, post-hoc). There were also significant differences in body mass index (BMI) among the groups ($F = 6.2$, $p < 0.01$, ANOVA). The patients with CSAS showed a significantly lower value of BMI than those with CompSAS or OSAS ($p < 0.01$, post-hoc), whereas there were no significant differences in BMI between patients with CompSAS and those with OSAS.

We then compared levels of clinical complications, such as hypertension, cardiac diseases, and cerebrovascular diseases, in the CompSAS, OSAS, and CSAS groups (Table 2). There was a tendency for higher levels of each complication in the CompSAS group compared with the OSAS group, but none of the between-group differences were statistically significant (hypertension, $p = 0.09$; cardiac diseases, $p = 0.06$; cerebrovascular diseases, $p = 0.69$).

Discussion

This is the first attempt to determine the prevalence of CompSAS among Japanese patients

TABLE 1. Anthropometric and polysomnographic characteristics of the CompSAS, OSAS, CSAS, and [diagnosis(+) titration(−)] groups.

	Number	Age	Males	BMI (kg/m^2)	AHI (events/h)
Overall	1,312 (100%)	46.9 ± 12.4	1,218 (92.8%)	28.2 ± 5.1	48.6 ± 24.6
CompSAS	66 (5%)	43.7 ± 12.1	65 (98.5%)	30.1 ± 6.7 †	58.7 ± 25.9 *†
OSAS	1,196 (91.2%)	47.0 ± 12.2	1,103 (92.2%)	28.4 ± 7.8	49.3 ± 23.9
CSAS	14 (1.1%)	40.8 ± 18.6	13 (92.9%)	22.3 ± 2.7 §	18.1 ± 13.4 §
[diagnosis(+) titration(−)]	36 (2.7%)	54.6 ± 12.8	36 (100%)	28.3 ± 3.7	58.7 ± 19.4

Data are presented as mean ± S.D. or number (%). BMI, body mass index; AHI, apnea/hypopnea index; CompSAS, complex SAS; OSAS, obstructive SAS; CSAS, central SAS; [diagnosis(+) titration(−)], patients who showed mixed breathing patterns at diagnostic polysomnography and whose apnea/hypopnea indices at titration decreased to less than 5 events per hour. * $p < 0.05$ between CompSAS and OSAS groups; † $p < 0.05$ between CompSAS and CSAS groups; § $p < 0.05$ between OSAS and CSAS groups.

TABLE 2. Comparisons of clinical complications in the CompSAS, OSAS, and CSAS groups.

	HTN	Cardiac Diseases	Cerebrovascular diseases
CompSAS $n = 66$	30 (44.5%)	9 (13.6%)	2 (3.0%)
OSAS; 1196 $n = 1,196$	502 (42.0%)	89 (7.4%)	20 (1.7%)
CSAS $n = 14$	1 (7.1%)	3 (21.4%)	0 (0%)

HTN, hypertension. Data are presented as the number of patients (%). There was no significant difference in clinical complications among the three groups.

with SAS. Clinicians and researchers should be aware of 'central apneas in disguise' (i.e., CompSAS), because such discrimination has clinical implications given that the diagnosis of pure OSAS cannot be achieved by diagnostic PSG but after the removal of upper airway obstruction.

SAS has two possible underlying causes: anatomically vulnerable airway and neurologically unstable breathing control. Central and obstructive features may co-exist in individuals with SAS. OSAS patients may demonstrate periodic breathing patterns, in which reduced and oscillating motor tone to the upper airway induces central apnea (Khoo et al. 1991), and CSAS patients may demonstrate intermittent obstructive apnea at the nadir of the respiratory cycle (Badr et al. 1995). CSA events may also originate from unstable breathing control arising from the sleep–awake transition, as well as from cardiac or neurogenic causes (Naughton et al. 1993). Periodic breathing patterns in patients with heart failure have been considered to be induced by instability of chemical control during sleep (Arzt et al. 2003, Dempsey et al. 2004). Unstable plant gain and controller gain cause a reduction in arterial CO_2 ($PaCO_2$) to a level below the apneic threshold, thereby resulting in central apnea. CompSAS is essentially chemoreflex-dependent or modulated sleep apnea. The more active the chemoreflex, the more likely that complex breathing patterns will emerge.

There was no significant difference in clinical complications between OSAS and CompSAS groups in the present study. This might reflect the fact that the study was performed in two sleep-disorder centers located in central Tokyo, being convenient facilities for the working population. The higher frequency of cardiac or cerebrovascular complications found in CompSAS groups in studies undertaken in the Mayo Clinic and Adelaide Institute might have contributed to the differences in the reported prevalence of CompSAS between these earlier studies and our own (Morgenthaler 2006, Pusalavidyasagar 2006, Lehman 2007).

Moreover, differences in titration protocol (i.e., overnight titration in this study and a split-night PSG in the Mayo Clinic and Adelaide Institute) might also reflect between-study discrepancies. Generally, SAS patients use the CPAP apparatus for the first time on titration night unless pretreated with an auto-adjusted CPAP instrument. Consequently, a certain number of patients cannot sleep well in a CPAP titration setting because of inconvenience and intolerance of the device, especially in the first few hours after titration starts. It may be that CSA events occur at arousals under such conditions. Dernaika et al. reported that most CSA events disappeared after continued CPAP use (2007). Patients with complex breathing patterns with the exception of pure CSAS could be categorized into CPAP-emergent CSA and CPAP-persistent CSA (Lehman 2007). CPAP-emergent CSA is defined as CompSAS in which CSA events emerge during CPAP titration, but with these events being so acute and transient that they disappear through continued CPAP use. In contrast, CPAP-persistent CSA is defined as CompSAS in which CSA events persist despite continued CPAP follow-up. What proportion of patients with CompSAS have CPAP-persistent CSAS is uncertain, but the work of Dernaika et al. suggests it may be only a small fraction. The majority of CSA events in patients with CPAP-emergent CSA could be a different manifestation of obstructive apnea, which represents instability of the respiratory drive at sleep–awake transitions, as described above. The other possible mechanism might be a maladaptive response to CPAP in which patients take larger than normal breaths producing "post-hyperpnea pauses". Some of these pauses might be prominent enough to meet the criteria for CSA.

In the present study, only 28.0% of patients with mixed breathing patterns were diagnosed as CompSAS cases at diagnostic PSG, indicating that the diagnosis of CompSAS can usually be made after CPAP titration. It was difficult to diagnose CompSAS by event-based scoring in diagnostic PSG. In the future, however, it will be important to diagnose most CompSAS cases from the diagnostic PSG (Thomas et al. 2007).

There are several limitations to this study. First, we were unable to perform second titrations on all patients with CompSAS to distinguish CPAP-persistent from CAP-emergent CSAS. Second, there exist potential limitations in the retrospective chart review in determining the presence or absence or the accuracy of data related to comorbidities. Echocardiography and/or Holter electrocardiogramphy would have provided better estimations of cardiac complications.

In conclusion, the overall prevalence of CompSAS was 5.0% among 1,312 Japanese patients with SAS, suggesting that the prevalence of CompSAS in Japanese SAS patients is lower than that in the USA and Australia. Thinking in a time series fashion considering all of the oscillatory pattern variants (periodic or episodic), cyclic time variants (short or long), and rhythmicity variants (rhythmic or arrhythmic) might be important in the recognition of CompSAS. Further prospective research is needed to determine whether CompSAS is associated with cardiac or neurogenic diseases and how central components of the condition are mediated by neurologically unstable breathing control in patients with the disorder.

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The Prevalence of Probable Delayed Sleep Phase Syndrome in Students from Junior High School to University in Tottori, Japan

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Delayed sleep phase syndrome (DSPS) is a circadian rhythm sleep disorder with a typical onset in the second decade of life. DSPS is characterized by the sleep-onset insomnia and the difficulty in waking at the desired time in the morning. Although DSPS is associated with inability to attend school, the prevalence has been controversial. To elucidate a change in the prevalence of DSPS among young population, epidemiological survey was conducted on Japanese students. A total of 4,971 students of junior high school, senior high school, and university were enrolled in this cross sectional study in Tottori Prefecture. They answered anonymous screening questionnaire regarding school schedule, sleep hygiene and symptomatic items of sleep disorders. The prevalence of probable DSPS was estimated at 0.48% among the total subject students without gender difference. In university, the prevalence of the last year students showed the highest value (1.66%), while that of the first year students showed the lowest value (0.09%) among all school years from junior high school to university. The prevalence increased with advancing university school years. Thus, a considerable number of Japanese students are affected with DSPS. Senior students of university are more vulnerable to the disorder than younger students. Appropriate school schedule may decrease the mismatch between the individual's sleep-wake cycle and the school schedule. Promotion of a regular sleep habit is necessary to prevent DSPS among this population. ——— delayed sleep phase disorder; circadian rhythms; adolescence; demography; epidemiology.
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Delayed sleep phase syndrome (DSPS) is a circadian rhythm sleep disorder in which the major sleep episode is delayed in relation to the desired clock time, resulting in both sleep-onset insomnia and difficulty in waking at the desired time in the morning (Weitzman et al. 1981; Thorpy et al. 1988; Schrader et al. 1993; American Academy of Sleep Medicine 2005). The disorder is known to occur in young generation, who in turn exhibit poor school performance (Thorpy et al. 1988; American Academy of Sleep Medicine 2005; Crowley et al. 2007). A transient increase in evening activities among this generation has been presumed to play an important role

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in the occurrence of DSPS (American Academy of Sleep Medicine 2005); in general, students have been shown to exhibit developmental changes in sleeping pattern. Older adolescents tend to have later bedtimes on both school and non-school nights compared to young adolescents, while wake-up times are reported to be later on weekends for older adolescents compared to younger adolescents (Crowley et al. 2007). In Japan, bedtime is linearly delayed with advancing age throughout adolescence, while rise time remains constant until high-school age and is delayed during university study period (Fukuda and Ishihara 2001). These findings give rise to the assumption that the frequency of DSPS is much higher in young generation—and especially university students—compared to other generations. However, the prevalence among students has not been conclusive (Schrader et al. 1993; Yazaki et al. 1999; American Academy of Sleep Medicine 2005).

In order to clarify this issue, we performed a questionnaire survey about the prevalence of DSPS among students in junior high school through to university age.

Methods

Public school students in Tottori Prefecture, Japan were the participants of this study. Tottori Prefecture lies in western Japan, covers a rural area of 3,500 km^2 and had a population of about 615,000 in 1998. The population is static, and extrinsic factors that tend to disturb sleep are much more uniform in this area compared to urban residential areas. The social time cues are also relatively uniform among these target students. These advantages, which enable us to reduce the influence of inter-individual factors, are appropriate for performing an epidemiological survey on DSPS.

Japan adopts a 6-3-3-4 single-track school system throughout country (Muta 2000): Six years in elementary school and three years in junior high school are compulsory education, while senior high school and university offer three and four years of education, respectively. The survey period was from May to June in 1998. The questionnaire was administered in the afternoon. A total of 5,356 students were contacted; and of these, 4,971 decided to answer the questionnaire (total response rate: 92.8%). Replies were obtained from 1,240 (614 males and 626 females) of the 1,314 junior high school students solicited (response rate: 94.4%), 1,205 (630 males and 575 females) of the 1,237 senior high school students solicited (response rate: 97.4%), and 2,526 (1,875 males and 651 females) of the 2,805 university students solicited (response rate: 90.1%).

The self-administered questionnaire consisted of items about bedroom environment, sleep habits, sleep hygiene, and sleep disorders, including DSPS. The questionnaire items pertaining to DSPS were based on the diagnostic criteria of the international classification of sleep disorders (ICSD) (American Academy of Sleep Medicine 1997), as follows: (i) inability both to fall asleep and to awaken spontaneously at the desired times; (ii) a phase delay of the major sleep episode in relation to the desired time for sleep (i.e., difficulty in falling asleep before 2 a.m. and awakening before 9 a.m.); (iii) impairment in maintaining regular school schedule (e.g., absence from school); (iv) during vacation time, maintenance of stable entrainment to a 24-hour sleep-wake pattern at a delayed phase, and awakening spontaneously; and (v) continuation of the above symptoms for at least six months. Students who had worked at a part-time job after 10 p.m. were excluded to prevent contamination of secondary DSPS. Students who fulfilled all these criteria were defined as having "probable" DSPS, because sleep-wake logs, which are necessary for the diagnosis of DSPS (American Academy of Sleep Medicine 2005), were not demonstrated in this study.

Statistically significant differences in school year or gender were estimated using a Yates Chi-square test with residual analysis. Differences were considered to be significant when p values were less than 0.05.

Results

Among a total of 4,971 subjects, 24 subjects were judged as having probable DSPS, and the prevalence was 0.48%. The rate in each school year is summarized in Table 1. Five subjects in each of junior and senior high school students were judged as having probable DSPS, and the rate in each school level was 0.40% and 0.41%, respectively. Among the university students, 14 had probable DSPS, and the prevalence was 0.55%. No statistically significant difference in prevalence was observed among these three school groups ($p = 0.8619$). When prevalence was compared according to school year, there was no sta-

TABLE 1. Prevalence of probable DSPS in Japanese students.[†]

	Male	Female	Total	
Junior High School (n = 1,240)				p = 0.0195 *
1st (n = 411) (n.s.)	1 (0.49)	1 (0.48)	2 (0.49)	
2nd (n = 391)	2 (1.08)	0 (0)	2 (0.51)	
3rd (n = 438)	0 (0)	1 (0.47)	1 (0.23)	
Subtotal (n.s.)	3 (0.49)	2 (0.32)	5 (0.40)	
Senior High School (n = 1,205)				
1st (n = 423) (n.s.)	1 (0.44)	1 (0.51)	2 (0.47)	
2nd (n = 388)	0 (0)	0 (0)	0 (0)	
3rd (n = 394)	1 (0.52)	2 (1.00)	3 (0.76)	
Subtotal	2 (0.32)	3 (0.52)	5 (0.41)	
University (n = 2,526)				
1st (n = 1,129) (p = 0.0004 *)	1 (0.12)	0 (0)	1 (0.09)	
2nd (n = 464)	1 (0.28)	0 (0)	1 (0.22)	
3rd (n = 329)	2 (0.90)	0 (0)	2 (0.61)	
4th (n = 604)	9 (1.80)	1 (0.95)	10 (1.66)	
Subtotal	13 (0.69)	1 (0.15)	14 (0.55)	
Total	18 (0.58)	6 (0.32)	24 (0.48)	

[†] Values are numbers (percentages).

n.s., not significant

* Significance value: $p < 0.05$

tistically significant difference between the prevalence in junior high school (p = 0.7461) and senior high school (p = 0.2915). However, the difference among school years was significant in university students (p = 0.0004). The prevalence of the first year was lowest (0.09%) among all school years in university, and the value increased with advancing school year. Among fourth-year students, 10 subjects (1.66%) were estimated to have DSPS, and the rate of occurrence was highest. A statistically significant difference in prevalence was also found among 10 school years from the first year of junior high school to the fourth year of university (p = 0.0195). The rate in the fourth year of university was significantly higher than that in any of the other school years by residual analysis with an adjusted residual of 4.44.

No gender difference in prevalence was observed within each school year.

DISCUSSION

This is the first report to reveal the prevalence of probable DSPS among students in every school year from junior high school to university. As a whole, the prevalence of DSPS in this population was 0.48%. The prevalence has not yet been conclusive. According to the ICSD, the prevalence in the general population and adolescence was found to be unknown and 7% to 16%, respectively (American Academy of Sleep Medicine 2005). In contrast, Schrader et al. (1993) show that the value is 0.17% among adults (18-67 years of age) and 0.25% among adolescents (18-22 years of age) in Norway. In Japan, 0.13% of subjects aged 15-59 years have been estimated to have DSPS (Yazaki et al. 1999). In the present study, the rates of occurrence among Japanese students were higher than those of the past studies, despite the age distribution of target population being different from the two studies. However, the value was clearly lower than that noted in the ICSD manual. Although no explanation is possible at present for the differences of prevalence, we speculate that the looser social time cues in students than in adults contribute to the relatively high prevalence.

A most interesting finding was the increase in prevalence with advancing school years in university. The reason for the increase is not clear. However, the highest prevalence—among fourth-year students—may be attributed to a loosening of social time cues in this generation. Many Japanese university students do not attend school regularly after having earned enough credits for graduation (Muta 2000).

This study has some limitations. First, sleep-wake logs, which are obligatory to the definitive diagnosis of DSPS, were not performed, and so DSPS prevalence in this study is restricted to being "probable." Second, the subjects were only students. The prevalence in non-student's group as well as in the other age groups remains unclear. Third, the subjects consisted of students who attend school regularly; therefore, our data does not consider DSPS in students who avoid school (Thorpy et al. 1988; American Academy of Sleep Medicine 2005; Crowley et al. 2007). Fourth, our questionnaire is an original one, as its items were crafted by the authors; thus, it is not standardized. The development of a standard diagnostic questionnaire for DSPS is necessary to elucidate true prevalence.

In conclusion, senior university students are more vulnerable to DSPS compared to other student populations. The present findings emphasize the importance of both promoting a regular sleep habits and reconsidering the school schedule of university students. To evaluate the real condition of DSPS, additional studies will be required to investigate sleep-wake schedules of students using a standardized questionnaire such as morningness-eveningness scale (Horne and Ostberg, 1976).

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Bedtime Activities, Sleep Environment, and Sleep/Wake Patterns of Japanese Elementary School Children

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Bedtime activities, sleep environment, and their impact on sleep/wake patterns were assessed in 509 elementary school children (6–12 years of age; 252 males and 257 females). Television viewing, playing video games, and surfing the Internet had negative impact on sleep/wake parameters. Moreover, presence of a television set or video game in the child's bedroom increased their activity before bedtime. Time to return home later than 8 p.m. from after-school activity also had a negative impact on sleep/wake patterns. Health care practitioners should be aware of the potential negative impact of television, video games, and the Internet before bedtime, and also the possibility that late after-school activity can disturb sleep/wake patterns.

Sleep/wake patterns are strongly influenced by sleep habits, and sleep habits are largely influenced by social backgrounds and cultural standards. Therefore,

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understanding the factors related to sleep habits is important for the prevention of sleep disturbance. The demands of today's "24-hour society" have increased nighttime activity and affected sleep/wake patterns of not only adults but also children. In addition, sleep/wake patterns may also be influenced by usage of video games, cell phones, and the Internet.

A nationwide lifestyle survey in Japan, which has been conducted every 5 years by the Broadcasting Culture Research Institute, showed that mean sleep duration has decreased about 40 minutes on weekdays and about 30 minutes on Sundays within the past 25 years (Broadcasting Culture Research Institute, 2005). This dramatic decrease of sleep duration may largely be attributed to the aforementioned change of lifestyle of the Japanese population.

Children's sleep is affected by changes of lifestyle or the social system. For example, abolition of Saturday classes all over Japan resulted in a more than 40-min increase in mean sleep duration of teenagers on Saturdays (Broadcasting Culture Research Institute, 2005).

Cultural differences could produce a huge difference in sleep habits and sleep/wake parameters (e.g., bedtime, wake time, and sleep duration). Previous reports indicated that sleep duration is shorter among adolescents in Japan than in the United States or European countries (Fukuda & Ishihara, 2001; Tynjala, Kannas, & Valimaa, 1993; Wolfson & Carskadon, 1998). The percentage of 3-year-old children who go to bed later than 10 p.m. was reported to be very high (52%) in Japan compared to that in Australia (4.1%; Japanese Society of Child Health, 2001; see also Armstrong, Quinn, & Dadds, 1994). These reports indicate that children's sleep/wake patterns can vary significantly between cultures.

Decreased nocturnal sleep among children may be due to (a) the sleep/wake pattern of their parents; or (b) the influence of distractions such as television, videos or DVDs, the Internet, video games, and cell phones, which may monopolize the child's attention for a long time. Playing video games and Internet surfing are becoming more prevalent among children. In the United States, 81% of American youths reported playing video games at least once a week, and video game playing could be considered pathological in 8.5% of youths (Martin & Oppenheim, 2007). In Japan, 92% of fifth-grade children have video or portable games (Japanese Parent Teacher Association, 2007). Use of the Internet is also becoming prevalent among adults and children. A recent survey revealed that the percentage of Internet users was higher among teenagers (16%–20%) than the community at large (13%–15%; Broadcasting Culture Research Institute, 2005). Moreover, most cell phones currently available in Japan are equipped with Web browsing and e-mail transmission capability. Use of this device at bedtime may increase the likelihood of disturbing sleep.

Van den Bulck (2004) reported that television viewing, computer game playing, and Internet use significantly affects sleep among adolescents. Although the use of video games, cell phones, and Internet among smaller children has increased, the usage of these items before bedtime has not yet been correlated with sleep/wake patterns of elementary school children.

The aims of the study were first to identify activities that elementary school children do frequently before bedtime, and second, to elucidate the relationship between these activities and sleep/wake patterns of Japanese children.

METHOD

Participants

The study was conducted at a public elementary school located in the suburbs of Osaka, the second-largest city in Japan, in a middle-class residential district. A questionnaire was given to all students ($N = 582$) of the school. Our study included 509 participants (252 males, 257 females), who responded to the questionnaire and answered the questions properly (response rate: 86.9%). The mothers in 484 (95.1%) cases, fathers in 18 (3.5%) cases, both the mother and father in 5 (1.0%) cases, and grandparents in 2 (0.4%) cases completed the questionnaire.

Measures

The questions asked about bedtime activities, the environment of the bedroom, bedroom sharing, after-school activities, and sleep/wake patterns. Parents were asked to assess their child's sleep and behavior during an average week.

Bedtime activities. Bedtime activities including television viewing, playing video games, talking over the telephone, and use of the Internet were examined. Watching videos or DVDs was included with television viewing; playing portable games was combined with playing video games. Use of the Internet included Web browsing and e-mail transmission either on a personal computer or via the Internet on a cell phone. Parents were asked to check if their child engaged in these activities more than twice a week. More than twice weekly (the median frequency of media use found in a previous national study) was chosen as the threshold of activity (Japanese Ministry of Internal Affairs and Communication, 2007).

Bedroom facilities. Parents were asked whether items such as television sets, personal computers, cell phones or telephones, and video games or portable games were present or taken into the bedroom.

Bedroom sharing. Parents were asked whether the child slept with other members of the family in the same bedroom (room sharing). If so, the member who shared the bedroom was specified.

After-school activity. Questions were asked about after-school activities including extra schooling, music lessons (such as piano and violin lessons), and sports lessons.

Sleep measures. Questions were asked about bedtime, wake time, and estimated duration of sleep for both average weekdays and weekends.

Procedure

The questionnaire was given to all the children of the school. Parents or guardians were asked to fill out the questionnaire, which was collected at school. The 1-week survey was conducted in October 2006 when the climate is mild and no major school activities (such as sports events, school festivals, or national holidays) were scheduled, so that we could avoid the influence of seasonal or event-related factors.

Statistical Analyses

Comparison of categorical variables (sex difference in bedtime activities and bedroom environment, and relationship between bedtime activities and bedroom environment) was made using a chi-square test. Two group comparisons were done using the Mann–Whitney *U* test for continuous variables.

A series of multivariate logistic regression analyses were performed to examine the factors associated with sleep/wake parameters. Six logistic models regarding sleep/wake parameters both on weekdays and weekends as response variables (bedtime after 10 p.m., wake time after 8 a.m., and sleep duration of less than 9 hr) were created. In addition, three logistic models regarding sleep/wake parameters between weekdays and weekends as response variables (later bedtime of more than 1 hr, later wake time of more than 2 hr, and longer sleep duration of more than 2 hr on holidays) were also created. As covariates, sex, school grade (lower grade or higher grade), bedtime activities, bedroom environment, and time to return home from after-school activity were used in common. All variables were initially examined in univariate models, then we performed multivariate logistic regression analysis for all variables that showed a significant correlation in univariate models. Odds ratios (ORs) and their 95% confidence intervals (CIs) are presented to show the association. All the statistical analyses were conducted using SPSS 11.5 for Windows. Significance levels were set at $p < .05$.

RESULTS

Demographics of the Participants

The number of participants in each school grade was 85 (45 males, 40 females) in the first grade, 96 (50 males, 46 females) in the second grade, 84 (37 males, 47 females) in the third grade, 93 (45 males, 48 females) in the fourth grade, 77 (43 males, 34 females) in the fifth grade, and 74 (32 males, 42 females) in the sixth grade. The children ranged in age from 6 years old (1st-grade student) to 12 years old (6th-grade student), and their mean age was 9.0 ± 1.8 years.

The percentage of children who slept with family members in the same bedroom (room sharing) was 85.3% including 21.8% who slept with siblings, 22.0% who slept with parents, and 40.5% who slept with both siblings and parents. The rate of room sharing decreased with advancing grade (Figure 1).

Activities Before Bedtime

The percentage of children who watched television before bedtime was 80.9%. As shown in Figure 2, television viewing was the most prevalent bedtime activity, and the rate of television viewing did not vary significantly with school grade. The percentage of children who played video games or portable games before bedtime was 30.6%. Use of the Internet was seen in 7.1% of children, and its rate of use increased with advancing age (Figure 2). Although there was no sex difference in television viewing ($p = .262$), playing video games was

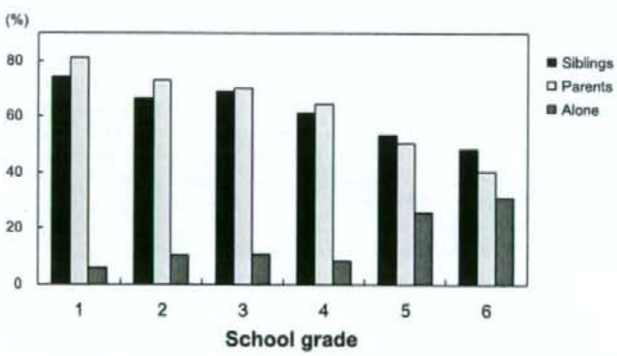

FIGURE 1 Percentage of children who slept with other family members in the same room (bedroom sharing).

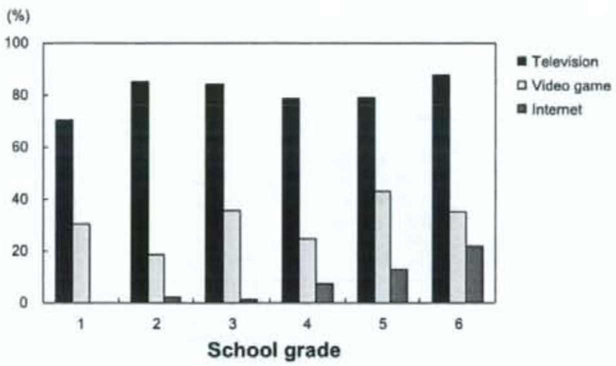

FIGURE 2 Percentage of children who watched television, played video games, or used the Internet.

significantly more common in males (36.9% vs. 24.5%, $p = .003$), whereas use of the Internet was more common in females (9.3% vs. 4.8%, $p = .032$).

Table 1 shows the comparison of sleep/wake parameters after dividing children on the basis of bedtime activities. Children who watched television had significantly later bedtimes on weekends and later wake times on weekdays. Children who played video games before bedtime had significantly later bedtimes and shorter sleep duration both on weekdays and weekends, and later wake time on weekends than children who did not play video games. Children who used the Internet before bedtime had significantly later bedtimes both on weekdays and weekends than children who did not use the Internet. Moreover, Internet users woke up significantly later on weekends and had shorter sleep duration on weekdays. Considering the fact that there was a statistically significant difference in age between users and nonusers of the Internet before bedtime, the same analysis was made focusing on fifth- and sixth-grade students who used the Internet more often than the others. Although bedtimes were similar, wake time on weekends (8:29 min $\pm$ 91 min vs. 8:01 $\pm$ 60 min, $p = .008$) and sleep duration on weekdays (494 $\pm$ 45 min vs. 518 $\pm$ 44 min, $p = .009$) were significantly different between frequent and infrequent Internet users.

Bedroom Facilities

Figure 3 shows how often television sets, video games, cell phones or telephones, and personal computers were in the child's bedroom. Totally, 29.1% of the

TABLE 1
Relationship Between Bedtime Activities and Sleep Parameters

Watching Television	+ (*n* = *412*)	− (*n* = *97*)	*P value*
Age (years)	9.1 ± 1.7	8.8 ± 1.7	.134
Bedtime on weekdays	21:42 ± 45 min	21:40 ± 51 min	.433
Bedtime on weekends	22:07 ± 51 min	21:52 ± 54 min	.007
Wake time on weekdays	6:56 ± 23 min	6:50 ± 22 min	.019
Wake time on weekends	7:46 ± 56 min	7:42 ± 51 min	.387
Sleep duration on weekdays	541 ± 43 min	544 ± 53 min	.909
Sleep duration on weekends	563 ± 49 min	575 ± 55 min	.180
Playing Video Games	+ (*n* = *156*)	− (*n* = *353*)	*P value*
Age (years)	9.2 ± 1.8	9.0 ± 1.7	.060
Bedtime on weekdays	21:50 ± 45 min	21:38 ± 46 min	.005
Bedtime on weekends	22:20 ± 55 min	21:58 ± 59 min	<.001
Wake time on weekdays	6:57 ± 24 min	6:54 ± 22 min	.490
Wake time on weekends	7:56 ± 58 min	7:41 ± 54 min	.022
Sleep duration on weekdays	529 ± 46 min	547 ± 44 min	<.001
Sleep duration on weekends	557 ± 52 min	569 ± 50 min	.039
Using the Internet	+ (*n* = *36*)	− (*n* = *473*)	*P value*
Age (years)	10.8 ± 1.3	8.9 ± 1.7	<.001
Bedtime on weekdays	22:09 ± 47 min	21:40 ± 45 min	<.001
Bedtime on weekends	22:36 ± 56 min	22:02 ± 50 min	.001
Wake time on weekdays	6:54 ± 23 min	6:55 ± 23 min	.938
Wake time on weekends	8:13 ± 84 min	7:43 ± 52 min	.002
Sleep duration on weekdays	511 ± 51 min	544 ± 44 min	<.001
Sleep duration on weekends	559 ± 64 min	566 ± 49 min	.663

Note. Bedtime and wake time: M ± SD (in minutes); sleep duration: M ± SD (in minutes).

bedrooms had televisions, 20.0% had video or portable games (with video games being more common in the bedrooms of older students), 14.3% had cell phones or telephones, and 4.3% had personal computers.

Cell phones or telephones were more commonly present in bedrooms among females than among males (17.1% vs. 11.5%, $p = .046$), whereas there was no sex difference in television sets ($p = .284$), video games ($p = .582$), and personal computers ($p = .544$). The percentage of the participants who watched television before bedtime was significantly higher among children with television sets in the bedroom than among children without television sets in the bedroom

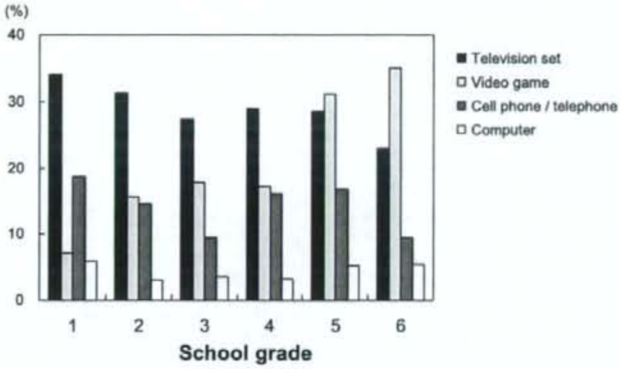

FIGURE 3 Percentage of children who slept in a bedroom with a television set, video game, cell phone, or telephone, or computer.

(87.2% vs. 78.4%, $p = .031$). The percentage of children who played video games before bedtime was significantly higher among children with video games in the bedroom than in those without video games in the bedroom (48.0% vs. 26.3%, $p < .001$).

Children who had televisions in the bedroom showed significantly later bedtimes on weekends (10:13 ± 53 min vs. 10:01 ± 51 min, $p = .008$). Children who had video games in the bedroom showed significantly later bedtimes on weekdays (9:54 ± 48 min vs. 9:39 ± 45 min, $p = .009$) and weekends (10:18 ± 4 min vs. 10:01 ± 51 min, $p = .008$) and shorter sleep duration on weekdays (529 ± 49 min vs. 545 ± 44 min, $p = .006$). Children who had cell phones or telephones in the bedroom showed significantly later bedtimes on weekends (10:15 ± 58 min vs. 10:03 ± 50 min, $p = .014$).

After-School Activities

Most of the children (81.3%) attended after-school activities including extra coursework, sports lessons, and music lessons at least once a week. There were no differences in the percentage of children attending after-school activities among the school grades. Of the students engaged in after-school activities, those in more advanced grades came home later than those in earlier grades.

There was no statistical difference in sleep/wake parameters between children with and without after-school activity. Sleep/wake parameters were then compared between children (5th- and 6th-grade students only) who returned

TABLE 2
Relationship Between Time to Return Home From School on Days With After-School Activity and Sleep Parameters Among Fifth- and Sixth-Grade Students

Time to Come Home	*After 8 p.m.* (*n* = *28*)	*Before 8 p.m.* (*n* = *123*)	*P value*
Age (years)	11.3 ± 0.7	11.2 ± 0.7	.351
Bedtime on weekdays	22:47 ± 43 min	22:06 ± 40 min	<.001
Bedtime on weekends	22:40 ± 52 min	22:34 ± 45 min	.324
Wake time on weekdays	7:10 ± 29 min	6:56 ± 24 min	.301
Wake time on weekends	8:27 ± 67 min	8:01 ± 66 min	.740
Sleep duration on weekdays	492 ± 43 min	519 ± 44 min	.006
Sleep duration on weekends	558 ± 52 min	552 ± 58 min	.891

Note. Bedtime and wake time: M ± SD (in minutes); sleep duration: M ± SD (in minutes).

before 8 p.m. and those who returned after 8 p.m. Children who returned after 8 p.m. had significantly later bedtimes on weekdays and shorter sleep durations on weekdays than children who returned before 8 p.m. (Table 2).

Logistic Regression Analyses

Multivariate logistic regression analysis revealed that bedtime after 10 p.m. on weekdays was significantly associated with being female (OR = 1.54, 95% CI: 1.03–2.32), higher school grade (OR = 3.65, 95% CI: 2.77–4.80), and time to return home after 8 p.m. (OR = 5.80, 95% CI: 2.05–16.44). Sleep duration of less than 9 hr on weekdays was significantly associated with higher school grade (OR = 3.13, 95% CI: 1.90–5.15) and using the Internet before bedtime (OR = 3.08, 95% CI: 1.02–9.17). Bedtime after 10 p.m. on weekends was significantly associated with higher school grades (OR = 3.14, 95% CI: 2.34–4.21), watching television before bedtime (OR = 2.09, 95% CI: 1.24–3.50), television in the bedroom (OR = 2.30, 95% CI: 1.42–3.72), and time to return home after 8 p.m. from after-school activity (OR = 6.71, 95% CI: 1.53–29.56). Wake time after 8 a.m. on weekends was significantly associated with being female (OR = 2.52, 95% CI: 1.74–3.66) and higher school grades (OR = 1.51, 95% CI: 1.18–1.92).

The results of multivariate logistic regression analyses regarding the difference of sleep parameters between weekdays and holidays are shown in Table 3. Bedtime delay of more than 1 hr on weekends was significantly associated with watching television and playing video games before bedtime and having a cell phone or telephone in the bedroom. Wake time delay of more than 2 hr

TABLE 3
Univariate and Multivariate Logistic Regression Results for Prediction of Sleep–Wake Patterns Between Weekdays and Weekends

	Univariate Relative Risk (95% CI)	*P Value*	*Multivariate Relative Risk (95% CI)*	*P Value*
	Bedtime delays more than 1 hr on weekends			
Sex (female/male)	0.93 (0.61–1.42)	.740		
Grade (4–6/1–3)	1.07 (0.82–1.38)	.632		
Bedtime activities				
Watch television	2.54 (1.30–4.95)	.006	2.45 (1.25–4.80)	.009
Play games	2.11 (1.37–3.25)	.001	1.96 (1.26–3.04)	.003
Use Internet	1.62 (0.77–3.41)	.202		
Bedroom facilities				
Television set	1.73 (1.12–2.69)	.015	*ns*	
Video game	1.19 (0.71–1.97)	.495		
Telephone	1.94 (1.13–3.33)	.017	1.83 (1.05–3.19)	.033
Computer	1.12 (0.44–2.89)	.805		
Time to return home[a]	2.61 (0.91–7.52	.075		
	Wake time delays more than 2 hr on weekends			
Sex (female/male)	2.62 (1.45–4.76)	.001	2.93 (1.55–5.53)	.001
Grade (4–6/1–3)	2.23 (1.54–3.24)	<.001	1.89 (1.21–2.71)	.002
Bedtime activities				
Watch television	1.32 (0.63–2.79)	.467		
Play games	2.76 (1.59–4.81)	<.001	2.66 (1.45–4.87)	.001
Use Internet	5.38 (2.55–11.34)	<.001	2.38 (1.04–5.47)	.041
Bedroom facilities				
Television set	0.92 (0.50–1.70)	.791		
Video game	2.59 (1.44–4.66)	.001	*ns*	
Telephone	1.67 (0.84–3.33)	.146		
Computer	2.03 (0.73–5.64)	.173		
Time to return home[a]	1.14 (0.39–3.32)	.816		
	Sleep duration increases more than 2 hr on weekends			
Sex (female/male)	2.61 (1.22–5.55)	.013	2.66 (1.17–6.03)	.019
Grade (4–6/1–3)	3.30 (1.93–5.62)	<.001	2.35 (1.33–4.17)	.003
Bedtime activities				
Watch television	1.15 (0.46–2.84)	.765		
Play games	3.77(1.86–7.62)	<.001	2.87 (1.31–6.30)	.008
Use Internet	8.23 (3.63–18.68)	<.001	2.73 (1.05–7.12)	.040
Bedroom facilities				
Television set	0.97 (0.46–2.08)	.946		
Video game	4.32 (2.14–8.73)	<.001	*ns*	
Telephone	2.61 (1.20–5.69)	.016	*ns*	
Computer	1.93 (0.55–6.78)	.307		
Time to return home[a]	0.46 (0.16–1.27)	.135		

Note. Results are presented as adjusted odds ratios (and 95% confidence intervals [CI]) from univariate and multivariate logistic regression analysis adjusting for all the factors in the table.
[a]Time to return home before or after 8 p.m. from after-school activity.

on weekends was significantly associated with being female, higher school grades, playing video games, or using the Internet before bedtime. Longer sleep durations of more than 2 hr on weekends was also significantly associated with being female, higher school grades, playing video games, or using the Internet before bedtime.

DISCUSSION

In this study, we investigated the relationship between bedtime activities and sleep/wake patterns in Japanese elementary school children. As bedtime activities are largely culturally dependent, understanding the culture-related lifestyle of children is necessary to improve their sleep quality.

For example, houses are usually smaller in Japan than in the West. This may lead to a higher rate of bedroom sharing with other family members. In addition, traditional Japanese houses usually have a multipurpose room with a "tatami mattress." This room is used as a living room during the day and a bedroom at night after the dining table is put away and a "futon mattress" is laid. In this study, we defined the bedroom as a room used for sleeping at night. Therefore, use of a multipurpose room for sleeping may be associated with placement of televisions in the bedroom at a higher rate.

Owens et al. (1999) reported that television viewing habits and the placement of televisions in the bedroom have a negative impact on children's sleep. In our study, television viewing seems to have a significant but small impact on both the delay of bedtime on weekends and wake time on weekdays. The reason for the difference in the result between our study and Owens et al.'s study is unclear, but it may be due to possible cultural differences in television viewing habits. For example, cable television is very common in the United States and provides hundreds of television programs, but it is present in only 35.9% of houses in Japan (Japanese Ministry of Internal Affairs and Communication, 2005). There may be a difference between cable television and terrestrial broadcasting that can explain the difference in the attitude of children toward television viewing before bedtime.

As for the relationship between sleep parameters and sex/age difference, being female and having higher school grades were shown to be independently associated with delayed bedtime on weekdays, later wake time on weekends, and longer sleep duration on weekends compared to weekdays.

Children in all grades played video games or portable games before bedtime, and older children in the higher grades played these games in the bedroom more frequently. One of the most striking results of our study was that playing video games and using the Internet before bedtime had a larger negative impact on