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Original Article

Predictors of insomnia onset in adolescents in Japan

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ABSTRACT

Objective: The objective of this study was to clarify the incidence rate and predictive factors of insomnia in Japanese junior and senior high school students.
Methods: We conducted a baseline survey on first year junior and senior high school students (seventh and 10th graders) throughout the nation. A follow-up survey was then conducted two years later. For both surveys, we used self-administered questionnaires inquiring about sleep, mental health status, lifestyle, participation in club activities, and study hours.
Results: A total of 3473 students (776 junior high and 2697 senior high) were suitable for analysis. During the two years leading to the follow-up study, the incidence rate of newly developed insomnia was 7.8% among junior high and 9.2% among senior high school students. Multiple logistic regression analyses revealed that factors associated with new insomnia onset were 'sleep paralysis experience' and 'poor mental health status' in junior high school students, and 'being woken by a nightmare', 'poor mental health status', '≥2 h of extracurricular learning per day' and 'mobile phone use for ≥2 h per day' in senior high school students.
Conclusions: In junior and senior high school students, parasomnias such as nightmares and sleep paralysis, and mental health status can be predictors of insomnia onset. For senior high school students, longer use of mobile phones can be a predictor of insomnia onset. The present findings suggest that sleep health must be promoted among junior and senior high school students in the future.
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1. Introduction

Previous studies have demonstrated that sleep plays a crucial role in the healthy development of adolescents, especially the development of important psychosomatic functions such as behavior, emotion, and attention [1–7]. However, qualitative or quantitative disturbance of sleep is common among adolescents, and is now considered a serious school health problem. Studies in various countries have indicated that 4–39% of adolescents have insomnia symptoms [8–25], although the definitions of insomnia used in these studies vary. A few longitudinal studies have clarified the factors associated with the onset of insomnia symptoms in adolescents. Our cohort study of 698 Japanese junior high school students revealed that sleep disorders are associated with future development of poor mental health. In addition, poor mental health increases the risk of onset of sleep disorders [26]. A longitudinal study that was announced later, confirmed the bidirectional association between sleep disorders and onset of a number of neurological symptoms [27,28]. In the United States, Robert et al. reported a similar finding in a longitudinal study of 3134 youths aged 11–17 years conducted between 2000 and 2001 [29]. It is also known that chronic insomnia is a predictor of future problems related to somatic health and interpersonal and psychological function, including poor mental health, lower subjective life satisfaction, and depressive mood [30]. Thus, insomnia is a predictor of poor mental and somatic health, and of alcohol and drug abuse among adolescents. However, the factors that affect insomnia onset among adolescents have not yet been fully elucidated due to the limited number of longitudinal studies completed to date [31,32]. As described above, limited predictors for insomnia onset have been identified to date. We postulated that predictors of insomnia onset can be identified in the lifestyle of junior high and high school students and that these may be useful for developing preventive measures for insomnia.

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Therefore, we conducted an epidemiological, self-administered questionnaire-based survey of junior and senior high school students sampled nationwide to examine the factors affecting the sleep of adolescents. The objectives of this study were (1) to clarify the incidence rates of insomnia among junior and senior high school students in Japan, and (2) to elucidate the factors predicting the onset of insomnia in adolescents.

2. Material and methods

2.1. Study population and design

In 2008, we conducted a cross-sectional nationwide survey evaluating the lifestyle habits of 170 Japanese junior and senior high school students who were selected by random sampling [33]. In January 2010, we invited the head teachers of 170 schools to participate in the present longitudinal-epidemiological survey. The following documents were sent to the schools: (1) a document seeking cooperation in the study, (2) a research plan describing the study's purpose and methodology, and (3) a sample of the questionnaire. With regard to the survey process, we explained that a baseline survey involving students in the seventh and 10th grades would be conducted, and that a follow-up survey would be conducted two years later, when these students had advanced to the ninth and 12th grades, respectively. Furthermore, we explained that the data collected from the self-administered questionnaires would not be used or made available for any purposes other than for this study and that the privacy of the respondents would be safeguarded. Out of the 170 schools contacted, a total of 10 and 14 junior and senior high schools, respectively, agreed to participate in this study.

The 24 schools consisted of 5687 students (1304 and 4383 students in the seventh and 10th grades, respectively) who participated in the study. The baseline survey was conducted between October and November 2010, and the follow-up survey of the same cohort of students was conducted two years later over the same months in 2012. Each survey adopted the same methodology with the homeroom teacher delivering the following information to each student during class: (1) the instructions, (2) the self-administered questionnaire, and (3) an envelope. After completing the questionnaire, each student placed and sealed the forms in the envelopes. The sealed envelopes were collected and opened for the first time at the investigating institution. Permission to conduct the study was obtained from the Ethics Committee of the institution to which the authors are affiliated (Nihon University School of Medicine Ethics Committee, Faculty of Medicine, Oita University Ethics Committee).

2.2. Measurement

The following five categories of data were included in the questionnaires used for each survey. (1) Personal data, including, school name, class name, student name, sex, and birth date. (2) Sleep status, including sleep duration, time of going to bed, time of getting out of bed, difficulty initiating sleep (DIS), difficulty maintaining sleep (DMS), early morning awakening (EMA), subjective sleep assessment, disorders of arousal, nightmares, sleep paralysis, self-treatment to aid sleep onset, and the Japanese version of the Epworth Sleepiness Scale (JESS) [34,35], comprising eight questions designed to measure subjective daytime sleepiness. The total JESS score (0–24) is obtained by summing the scores (0–4) for each question. Individuals with a JESS score of ≥11 points were considered to have excessive daytime sleepiness. This cutoff point was also adopted in the present study. (3) Lifestyle factors, including, eating habits, exercise habits, club activities, study time, commuting time, attendance at cram schools or after-school lessons, coffee or tea intake, time spent watching television, playing electronic games, and using mobile phones, respectively, incidences of bullying, reasons for bullying, personal worries, presence of an advisor, and days spent in the school nurse's office. (4) Physical status such as height and weight. (5) Mental health status, including, contentment with daily life, and the Japanese version of the 12-item General Health Questionnaire (GHQ-12) consisting of 12 questions [36]. The total GHQ-12 score (0–12) was obtained by summing the scores (0–1) for each question. Higher scores were considered to indicate poorer mental health status. Although the GHQ was developed for surveys targeting adults, it is known that valid results can also be obtained when administered to adolescents [26,37]. In previous studies conducted by our research group, the GHQ-12 was used for the measurement of poor mental health, and reasonable results could be obtained even at puberty [26,33,37]. Therefore, the GHQ 12 was also used in this study.

The students were provided with the following instructions: (1) this survey is part of a medical study, and their answers for the questionnaire would not affect the participant's academic performance or result in penalties, (2) Participation in the survey must be voluntary, and subjects not opting to participate would not be penalized, (3) The completed questionnaires would not be seen by the participants' teachers, (4) The participants' privacy would be strictly protected.

Participation in the study was voluntary and written informed consent was obtained from all of the participating students.

2.3. Definition

We questioned the participants about the following three issues: (1) difficulty initiating sleep, (2) difficulty maintaining sleep, and (3) early morning awakening, for which the respective questions were phrased as follows: “Over the past month, have you had difficulty falling asleep at night?”, “Over the past month, have you woken up during the night after going to sleep?”, and “Over the past month, have you woken up too early in the morning and had difficulty getting back to sleep?” Each question had five possible replies: “never,” “seldom,” “sometimes,” “often,” or “always.” “Often” and “always” were interpreted as affirmative answers to each question, and such responses were considered to indicate that students had DIS, DMS, or EMA. Insomnia was defined as the presence of one or more of these symptoms.

We also questioned participants about nightmares and sleep paralysis. Regarding nightmares, the question was phrased as “Over the past month, have you been woken by a nightmare?” There were five possible replies: “never,” “seldom,” “sometimes,” “often,” and “always.” “Often” and “always” were taken as affirmative answers, and these responses were considered to indicate that the student suffered from nightmares. Regarding sleep paralysis (*kanashibari* in Japanese), the question was phrased as: “Over the past month, have you suffered a sensation characterized by not being able to move your hands, feet and body when waking up or falling asleep?” There were two possible replies: “yes” or “no.” Students with GHQ-12 scores of ≥4 were defined as having poor mental health status.

2.4. Statistical analyses

All analyses in this study were performed separately for the junior and senior high school students. First, the prevalence of insomnia at baseline was calculated. Second, individuals did not demonstrate baseline insomnia, but those who had insomnia at the time of the follow-up survey were defined as subjects developing insomnia during the survey period. The incidence rate of insomnia onset was then calculated. Third, the factors associated with insomnia onset were examined using the chi-square test and multiple logistic regression analysis. Only participants who did not have insomnia at baseline were included in the multiple logistic regression analysis. The presence of insomnia at the time of the follow-up survey was used as a target variable, and the following items at baseline were used as covariates: sex, sleep duration, extracurricular learning (studying at home or at a cram school, a specialized private school that trains students to pass entrance examinations, after regular school hours), hours of mobile phone use per day, and presence or absence of nightmares, sleep paralysis, poor mental health status, breakfast, coffee or tea intake, exercise habits, and availability of an advisor. The forced entry method was used for multiple logistic regression analyses. SPSS for Windows version 22 (IBM Corp., Armonk, NY, USA) was used for statistical analyses.

3. Results

At the time of the baseline survey, 5687 students (1304 juniors and 4383 seniors) agreed to participate in the study, however, only 3473 students (776 juniors and 2697 seniors) agreed to participate in the follow-up survey. The overall response rate was 61.1% (59.5% and 61.5% for junior and for senior high school students, respectively). Subject characteristics at baseline are shown in Table 1. Individuals with a sleep duration <6 h per night accounted for 8.4% and 25.8% of junior and senior high school students, respectively. The proportion of junior high school students who undertook ≥2 h per day of extracurricular learning was higher than that for the senior cohort. In contrast, nearly half of the senior cohort used their mobile phones for ≥2 h per day. The proportions of individuals with poor mental health, those who skipped breakfast, and who habitually consumed caffeine were higher in the senior cohort than in the junior cohort. The proportions of students who suffered from nightmares and sleep paralysis, and who had access to an advisor were comparable between junior and senior high school students.

The prevalence rate of insomnia at baseline, shown in Table 2, was 9.3% (72 out of 776) and 10.2% (275 out of 2697) among junior and senior high school students.

The incidence rate of insomnia, shown in Table 3, over the two years between the baseline and follow-up surveys was 7.8% and 9.2% in the junior and among senior high school students, respectively.

The results of the chi-squared analysis to examine the factors associated with insomnia onset are shown in Table 4. Sleep paralysis, poor mental health status, and the presence/absence of an advisor were significantly associated with insomnia onset among junior high school students. Among senior high school students, hours of extracurricular learning, hours of mobile phone use, nightmares, poor mental health status, and the presence/absence of an advisor, were significantly associated with insomnia onset.

The results of multiple logistic regression analyses of the factors associated with insomnia onset among each cohort of junior and senior high school students are shown in Table 5. The presence of sleep paralysis experiences and poor mental health status at baseline facilitated insomnia onset among junior high school students. Four factors facilitated insomnia onset among senior high school students: the presence of nightmares, poor mental health status, extracurricular learning for ≥2 h per day, and mobile phone use for ≥2 h per day.

Table 1
Subject characteristics at baseline.

	Junior high school students		Senior high school students	
	N	%	*N*	%
Sex				
Male	372	47.9	1556	57.7
Female	404	52.1	1141	42.3
Sleep duration (h/day)				
<6	65	8.4	697	25.8
≧6	708	91.2	1994	73.9
Unknown	3	0.4	6	0.2
Extracurricular learning (h/day)				
<2	592	76.3	2531	93.8
≧2	172	22.2	153	5.7
Unknown	12	1.5	13	0.5
Mobile phone use (h/day)				
<2	660	85.1	1520	56.4
≧2	106	13.7	1165	43.2
Unknown	10	1.3	12	0.4
Nightmares				
No	747	96.3	2614	96.9
Yes	26	3.4	81	3.0
Unknown	3	0.4	2	0.1
Sleep paralysis				
No	678	87.4	2247	83.3
Yes	30	3.9	156	5.8
Unknown	68	8.8	294	10.9
Poor mental health (GHQ score ≥4)				
No	557	71.8	1595	59.1
Yes	215	27.7	1093	40.5
Unknown	4	0.5	9	0.3
Skipped breakfast				
No	727	93.7	2325	86.2
Yes	44	5.7	367	13.6
Unknown	5	0.6	5	0.2
Habitually consumed caffeine				
No	669	86.2	2101	77.9
Yes	103	13.3	590	21.9
Unknown	4	0.5	6	0.2
Exercise habits				
No	108	13.9	981	36.4
Yes	666	85.8	1703	63.1
Unknown	2	0.3	13	0.5
Advisor				
No	99	12.8	407	15.1
Yes	672	86.6	2250	83.4
Unknown	5	0.6	40	1.5

4. Discussion

In this study, we performed longitudinal epidemiological surveys of junior and senior high school students, and examined predictors of insomnia onset in each cohort. This study had a number of strengths. First, the sample size was sufficient. Second, participants were sampled from schools across Japan. Third, predictive factors for insomnia onset were examined by performing two surveys of the same cohort using a longitudinal design. This was also the first study to have evaluated predictors of insomnia onset in junior and senior high school students in Japan. To date, predictors of insomnia in puberty have not been sufficiently elucidated. The novel finding of this study is the identification of a predictor of insomnia in the normal lifestyle of junior and high school students selected from across Japan. The predictor identified in this study will contribute to the development of preventive

Table 2
The prevalence rate of insomnia at the baseline.

Insomnia at the baseline	Junior high school students		Senior high school students		Total	
	N	%	*N*	%	*N*	%
No	695	89.6	2407	89.2	3102	89.3
Yes	72	9.3	275	10.2	347	10.0
Unknown	9	1.2	15	0.6	24	0.7

Table 3
The incidence rate of insomnia during the 2 years between the baseline and follow-up surveys.

Insomnia at follow up	Junior high school students		Senior high school students		Total	
	N	%	*N*	%	*N*	%
No	638	91.8	2174	90.3	2812	90.7
Yes	54	7.8	221	9.2	275	8.9
Unknown	3	0.4	12	0.5	15	0.5

Table 4
The incidence rate of insomnia and the factors associated with insomnia onset.

	Junior high school students			Senior high school students		
	%	N	*p*	%	N	*p*
Overall	7.8	692		9.2	2395	
Sex			0.54			0.76
Male	8.5	331		9.1	1378	
Female	7.2	361		9.4	1017	
Sleep duration (h/day)			0.62			0.94
<6	6.0	50		9.2	600	
≧6	8.0	639		9.3	1791	
Extracurricular learning (h/day)			0.14			<0.01
<2	8.8	525		8.8	2252	
≧2	5.1	156		16.5	133	
Mobile phone use (h/day)			0.64			<0.01
<2	7.4	596		7.8	1381	
≧2	8.8	91		11.2	1005	
Nightmares			0.81			<0.01
No	7.9	673		8.7	2342	
Yes	6.3	16		34.6	52	
Sleep paralysis			<0.01			0.07
No	7.3	606		9.1	2011	
Yes	24.0	25		14.0	121	
Poor mental health (GHQ score ≥ 4)			<0.01			<0.01
No	5.4	520		7.1	1473	
Yes	15.4	169		12.8	915	
Skipped breakfast			0.66			0.12
No	8.0	653		8.9	2093	
Yes	5.9	34		11.7	299	
Habitually consumed caffeine			0.72			0.44
No	8.0	601		9.0	1887	
Yes	6.9	87		10.1	504	
Exercise habits			0.94			0.92
No	7.6	92		9.3	845	
Yes	7.8	599		9.2	1539	
Advisor			0.01			0.02
No	15.0	80		12.7	347	
Yes	6.9	608		8.7	2017	

Subjects with missing data were excluded from the analysis. *p* was calculated by χ^2 test.

Table 5
Multiple logistic regression analyses of the factors associated with insomnia onset among each cohort (junior high school students, senior high school students).

	Junior high school students			Senior high school students		
	AOR	95% CI	*p*	AOR	95% CI	*p*
Sex			0.44			0.54
Male	1.00			1.00		
Female	0.78	0.41–1.48		0.90	0.65–1.25	
Sleep duration (h/day)			0.44			0.33
<6	1.00			1.00		
≧6	0.60	0.16–2.20		0.84	0.59–1.19	
Extracurricular learning (h/day)			0.24			0.01
<2	1.00			1.00		
≧2	0.61	0.27–1.39		2.10	1.23–3.60	
Mobile phone use (h/day)			0.58			0.03
<2	1.00			1.00		
≧2	1.27	0.55–2.96		1.39	1.03–1.89	
Nightmares			0.41			<0.01
No	1.00			1.00		
Yes	0.39	0.04–3.72		4.46	2.36–8.42	
Sleep paralysis			0.02			0.31
No	1.00			1.00		
Yes	3.59	1.19–10.83		1.34	0.76–2.36	
Poor mental health (GHQ score ≥ 4)			<0.01			<0.01
No	1.00			1.00		
Yes	2.69	1.41–5.15		1.62	1.18–2.21	
Skipped breakfast			0.54			0.19
No	1.00			1.00		
Yes	0.63	0.14–2.82		1.32	0.87–1.99	
Habitually consumed caffeine			0.64			0.98
No	1.00			1.00		
Yes	0.79	0.29–2.12		1.00	0.69–1.43	
Exercise habits			0.91			0.97
No	0.95	0.38–2.36		1.01	0.73–1.39	
Yes	1.00			1.00		
Advisor			0.05			0.32
No	2.17	0.98–4.78		1.22	0.82–1.82	
Yes	1.00			1.00		

Subjects with missing data were excluded from the analysis. *p* was calculated by the multiple logistic regression analysis. AOR, adjusted odds ratio; CI, confidence interval; GHQ, general health questionnaire.

measures targeting individuals going through puberty. Specifically, it is necessary for students with sleep paralysis, nightmares, or poor mental health status to be aware that there is a risk of developing insomnia in the following years. We suggest that it is important to recognize this predictor and provide health counseling and health guidance for students. For students with extensive mobile phone use time, it will be necessary to draw their attention to this habit. In our view, the results of this research will be valuable for the future development of health guidance aimed at students.

The incidence rate of insomnia among Japanese adolescents was 7.8% and 9.2% in the junior and senior high school students, respectively. In the United States, Robert et al. reported an annual incidence rate of insomnia of 14.0% among adolescents aged 11–17 years ($N = 3134$), based on the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) [32]. In China, Luo et al. reported an annual incidence rate of insomnia of 16.0% among adolescents aged 11–18 years ($N = 2787$), as defined by the Insomnia Severity Index [31]. While a direct comparison may not be appropriate because the definitions of insomnia used in these studies differed, the incidence rates of insomnia among the Japanese adolescents were lower than that reported for the Chinese and North American adolescents.

The multiple logistic regression analyses conducted in this study revealed a number of predictors of insomnia onset. First, poor mental health status at baseline appeared to be a predictor of insomnia onset for both high school cohorts. This result was consistent with those of previous studies investigating the association between sleep and mental health among adolescents [26,29]. Previously, Robert et al. suggested that symptoms of depression (a depressed mood, anhedonia, and irritability) could be predictive factors for insomnia [29]. Furthermore, in a two-year follow-up study of 516 Japanese junior high school students, Kaneita et al. indicated that poor mental health status could be a predictor of sleep disorders [26]. Similarly, other studies using a range of cohorts have also reported poor mental health status as a predictor of insomnia onset, suggesting that this factor may be a universal phenomenon [27,28,38,39]. Two explanations for this should be considered. First, insomnia symptoms are widely reported in the majority of patients diagnosed with depression, while improvement in depressive symptoms was reportedly correlated with an improvement in insomnia status. This supports the possibility that poor mental health status can cause insomnia. Second, despite the absence of a causal association between poor mental health status and insomnia, the presence of a confounding factor that is correlated with both of these factors may support the association.

Moreover, students incidentally recognized poor mental health status at an earlier stage than insomnia. While we adjusted for the effects of confounding factors by entering assumed models in our multiple logistic regression analyses, we could not rule out the possibility that some confounding factors were not adjusted for in our analysis.

This study revealed that sleep paralysis was a predictor of insomnia among Japanese junior high school students, i.e. students who did not have insomnia symptoms, but who had experienced sleep paralysis at baseline tended to become aware of having insomnia over the following two years. Sleep paralysis is a state in which a person is unable to move their limbs, body, and head, although he/she is subjectively awake. It is known to be one of the symptoms of narcolepsy [40]. Takeuchi et al. conducted a physiological experiment using polysomnography on 1314 Japanese university students who had neither cataplexy nor narcolepsy. They investigated the sleep phase during which sleep paralysis occurred by intentionally interrupting the sleep of these participants. They found that once sleep had been interrupted, REM sleep occurred upon resuming sleep without a non-REM sleep phase, and that sleep paralysis was induced during this REM sleep after sleep resumption [41]. This study indicated that sleep paralysis and DMS (one of the symptoms of insomnia) were closely associated. The results of our study suggested that participants had first become aware of their sleep paralysis before becoming aware of insomnia symptoms by the time of the follow-up survey. Therefore, sleep paralysis may be recognized earlier than symptoms of insomnia.

This study also revealed that having nightmares could be a predictor of insomnia onset among senior high school students. Nightmares are defined as awakening from a frightening dream and rapidly becoming oriented and alert, according to the DSM-IV [42], and this is known to be a phenomenon incidental to DMS. Our previous study showed that experiences of sleep paralysis were significantly more frequent among adolescents in whom the frequency of nightmares was higher, and an association between these factors was identified [43]. The key finding in the present study is that the experience of nightmares tended to be recognized before insomnia, as with sleep paralysis. Sleep paralysis and nightmares are both classified as 'REM-related parasomnia' in the third edition of the International Classification of Sleep Disorders (ICSD-3), and are considered to be linked physiologically [44]. The present study revealed that sleep paralysis and nightmares could be potential predictors of DMS. Accordingly, they are important signs that may appear before individuals become aware of insomnia. DMS tends to occur under conditions of physical and mental stress, in individuals exhibiting unhealthy lifestyles, or who experience disturbances in their normal sleep rhythm [45]. Treatment of sleep paralysis or nightmares as soon as such disorders are recognized may help to prevent DMS onset. Therefore, such disorders need to be taken into consideration in the context of student health.

This study revealed that extracurricular learning for $\geq$2 h per day could be a predictor of insomnia onset in senior high school students. This result was somewhat unexpected, as initially, it would appear more likely that reduced sleep duration resulting from longer extracurricular learning would increase sleepiness and, therefore, promote sleep. This result needs to be interpreted carefully. One possible explanation is that another factor promoted both longer extracurricular learning and insomnia, and that longer extracurricular learning was the first 'symptom' to develop. For instance, it could be postulated that strong psychological stress due to the preparation for entrance exams may increase the motivation for longer extracurricular learning, leading to insomnia. Another possible mechanism is that studying until just before bedtime may disturb the mechanism for sleep regulation. Around a few hours before the time of sleep onset, the level of arousal (state of excitement) becomes maximal, therefore overriding any increased need to sleep. Sleepiness then increases rapidly, and changes appear in different sleep-promoting physiological parameters. The appropriate phase associations among these parameters are sustained, allowing sleep to be initiated and maintained [46]. However, it can be inferred that studying during this time zone may maintain the high level of arousal until immediately before sleep [47,48]. Previous studies have indicated that a higher arousal level before sleep onset prevents sleep, and that allowing at least 1 h of relaxation before bedtime effectively provides good sleep [47,48]. However, considering that in contemporary Japanese society, many junior and senior high school students are pressured with heavy homework loads, it is quite common for these students to continue studying until bedtime. It is highly probable that the resulting brain activation during this period may induce insomnia. To mitigate the risk of insomnia onset, it is essential for students to consider these results, and adjust their study schedule accordingly, after returning home from school.

This study revealed that $\geq$2 h of mobile phone use per day by senior high school students could be a predictor of insomnia onset. In recent years, studies on the association between the use of electronic devices, such as mobile phones, and insomnia among adolescents have been conducted from different perspectives [33,49,50]. A cross-sectional study of 95,680 junior and senior high school students in Japan by Munezawa et al. in 2008 indicated that the number of students displaying insomnia symptoms increased significantly with the frequency of mobile phone usage after switching off their bedroom light [33]. In 2010, Aora et al. conducted a cross-sectional study of 738 youths aged 11–13 years in the United Kingdom to investigate the association between the frequent use of technology, including, mobile phones, and the quality/quantity of sleep. The authors reported that the odds ratios (ORs) of insomnia symptoms (DIS, DMS, EMA) for students who used their devices every night were significantly higher [49]. Hysing et al. performed a cross-sectional study in 2010 involving 9846 Norwegian youths aged 16–19 years to investigate the association between the use of electronic devices with a display (including, personal computers, mobile phones, tablets, game consoles, televisions) and sleep. The results indicated that students who used the devices for $\geq$2 h during the day or before the time of sleep onset had a sleep onset latency of at least 60 min [50]. However, all of these studies were cross-sectional and a causal association between electronic device usage and insomnia in adolescents could not be determined. Our study was longitudinal and the results indicated that longer mobile phone usage increased the risk of insomnia onset after a two-year period.

A number of studies have investigated the association between use of electronic devices, such as mobile phones, and melatonin [51–53]. The blue light emitted from the display of electronic devices has been reported to have the strongest suppressive effects on melatonin secretion, compared to lights in other parts of the visual spectrum [51,52]. Furthermore, the blue light was reported to prematurely advance the plasma melatonin rhythm phase. Even at a low illuminance level (8 lux [28 $\mu W/cm^2$]), blue light exerts the same degree of phase advancement as 12,000 lux of white light (4300 $\mu W/cm^2$) [53]. Meanwhile, a longitudinal study by Fossum et al., reported that using a mobile phone in bed, or before going to bed was a predictor of insomnia onset and evening chronotype onset [54]. Light exposure by the device displays may delay the sleep phase. It is important to conduct a comprehensive examination of the associations among factors such as the use of mobile phones, insomnia, DSPD, and chronotype. Furthermore, similarly to the effects of extracurricular learning, mobile phone use before bedtime may activate the user's brain and induce insomnia. In 2008, Foley et al. conducted a nationwide survey of 2107 children aged 5–18 years in New Zealand to investigate the association between their behaviors during the 90 min before sleep and after sleep onset. The authors reported that sleep onset was delayed in the screen-based sedentary behavior group [55]. Furthermore, adolescence is a period when sleep onset shifts towards more nocturnal patterns [2,4,56]. Specifically, sleep/wake patterns are reported to change among adolescents of senior high school age [1]. Therefore, adolescents need to be educated on sleep-related health issues so that they have a better idea of how to spend time before sleep onset.

This study had some limitations. First, the definitions of the insomnia symptoms we used were not the diagnostic criteria defined in the second edition of the ICSD (ICSD-2). The ICSD-2 stipulates that the following two features are essential for the diagnosis of insomnia: (1) complaints of insomnia symptoms during nocturnal sleep, and (2) daytime sleep-related mental and/or physical impairment [57]. Previous self-administered questionnaire surveys included questions regarding the presence of DIS, DMS, and EMA in order to identify the presence of insomnia symptoms [17,24,33,58]. The present study was consistent with previous studies in this aspect. Second, because of ethical considerations and space limitations in the questionnaire, questions regarding a number of items could not be included. Examples are socioeconomic status (family financial conditions, academic performance), problematic behavior (drinking alcohol and smoking), sleep environment (bedroom temperature and humidity), and reliability of anamnesis. We cannot exclude the possibility that these factors may affect the predictors found in the present study as well as insomnia onset, and should be considered in future studies. Third, this study used self-reported data. Fourth, we did not measure the Delayed Sleep Phase Disorder (DSPD) or chronotype. DSPD or chronotype may be a confounding factor in relation to lifestyle and insomnia. It is crucial to gather information on DSPD and chronotype for future research. Finally, the number of junior high school students who participated in this study was smaller than that of the senior students. This may have decreased the statistical power of the study. Future studies will need to include a sufficient number of schools and participants.

5. Conclusions

This study has obtained useful epidemiological data on predictors of insomnia onset among Japanese junior and senior high school students. We found that parasomnia, such as nightmares and sleep paralysis, as well as mental health status were associated with insomnia. We also found that the use of mobile phones for $\geq$2 h per day and extracurricular learning for $\geq$2 h per day affected the sleep of senior high school students. These results provide scientific evidence that will be useful for the development of public health strategies targeting adolescents. The present findings suggest that sleep health should be promoted among junior and senior high school students in the future.

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Conflict of interest

All authors declare no competing financial interest.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2017.06.028.

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