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ORIGINAL ARTICLE

The association between Internet usage and sleep problems among Japanese adolescents: three repeated cross-sectional studies

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Abstract

Study Objectives: Sleep problems and problematic Internet use have important implications for adolescent health; however, there have been no large-scale surveys using comprehensive measures. We examined the association between Internet use duration and sleep problems among Japanese adolescents.

Methods: We used data from the Lifestyle Survey of Adolescents collected in 2012, 2014, and 2017. We calculated the change in sleep status (insomnia, sleep duration, bedtime, and sleep quality) and Internet usage (screen time and services such as Internet surfing, social media use, streaming such as YouTube, and online gaming). A binary logistic model was estimated for insomnia. Generalized ordered logit models were employed for the ordinal outcomes (sleep duration, bedtime, sleep quality, and multidimensional sleep health). Sampling weights were constructed based on participation rate on survey years and selection rates from population statistics.

Results: We analyzed data from 248 983 adolescents. Sleep status was unchanged; however, many adolescents used more Internet services and for longer durations. The odds ratio of Internet screen time for all sleep problems (insomnia, shorter sleep duration, later bedtime, and worse sleep quality) gradually declined. Longer Internet screen time (>5 hours) was strongly associated with all sleep problems. Internet services were also associated with sleep problems; particularly, social media use and online gaming were linked to later bedtimes.

Conclusions: Despite the decreased strength in the association between Internet usage and sleep problems, longer Internet time was strongly associated with sleep problems. Public health interventions should consider Internet use as an intervention target to improve adolescents' health.

Statement of Significance

This was the first large-scale study to examine the association between Internet usage and sleep problems among Japanese adolescents. Longer Internet usage may have addictive associations, which leads to poor sleep health, particularly a later bedtime and worse sleep quality. Social networking and online gaming were both strongly related to a later bedtime and poorer sleep quality. The findings provide evidence for policymakers and teachers to educate adolescents on healthy Internet use to maintain their health.

Key words: adolescence; sleep; Internet; health surveys; insomnia

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Introduction

Adolescent sleep problems are a critical public health concern. A meta-analysis indicated that inadequate sleep is associated with obesity, negative somatic and psychosocial health, poor school performance, and risk-taking behavior [1]. Previous studies reported many factors that affect adolescent sleep such as unhealthy dietary behaviors [2], smoking [3], drinking alcohol [4], consuming caffeine [5], time spent with peers [6], involvement in extracurricular activities [7], poor mental health [8], having no intent to study at university [4], and the use of electronic media [9, 10].

Many studies have reported that technological developments, such as the Internet and cellular phones, and the rise of the "24-hour society" affect adolescents' sleep [9–13]. Increased new media screen time in 2009–2015 may be involved in the increasing trends of short sleep duration among US adolescents [14]. A systematic review involving data from 690 747 children from 20 countries identified a decline of 0.75 min/year in children's sleep duration over the last 100 years [15]. There was also an increased prevalence in the sleep-onset difficulties among European adolescents from 2002 to 2014 [16]. These changes were attributed to increases in electronic device use, including social media engagement and reading news online [17]. A meta-analysis showed a significant odds ratio (OR) for sleep problems and significant reduced sleep duration among individuals with Internet addiction [18]. Another meta-analysis showed that Internet, computer and phone use, and video games were all associated with late bedtime [11]. The use of electronic devices may have led to arousal, activation, and exposure to light before bedtime, affecting sleep duration and quality [10]. Thus, media use is associated with delayed bedtime and reduced total sleep duration.

Despite the association between the Internet and sleep problems, most previous studies did not investigate a dose–response relationship between Internet screen time and sleep problems. In Japan, the Cabinet Office reported that adolescent Internet users increased from 76.0% in 2012 to 93.2% in 2017, and the smartphone ownership rate among adolescents increased from 45.7% in 2012 to 72.8% [19]. In 2012, the estimated prevalence of problematic Internet use was 6.2% in boys, 9.8% in girls, and 7.9% in total among Japanese adolescents [20]. With the explosive spread of the Internet and smartphone ownership, the prevalence of problematic Internet users is likely to increase further. Previously, we reported that there were increasing trends toward shorter sleep duration and late bedtimes from 2004 to 2017 [21]. However, we also showed that the prevalence of insomnia and poor sleep quality among Japanese adolescents had decreased during that period [21]. There is no doubt that excessive Internet use has a negative impact on sleep; however, to our knowledge, no study has investigated why the prevalence of insomnia and sleep quality has decreased despite the increasing influence of the Internet in adolescence. In addition, few studies have evaluated which sleep problems are the most associated with Internet screen time.

We sought to explore the cross-sectional relationship between Internet screen time and sleep problems in three repeated large national studies of Japanese adolescents from 2012 to 2017. We also examined the association between Internet service and sleep problems. Previous findings showed that the prevalence of insomnia among Japanese adolescents decreased despite increased trends of adolescent Internet users [19, 21]. Thus, we hypothesized that the associations of Internet use with sleep problems would be modified by survey year. The results may provide new evidence to promote sleep-related education for adolescents.

Materials and Methods

Study sample

We used data from the Lifestyle Survey of Adolescents (aged 12–18 years) collected in 2012, 2014, and 2017. We obtained a representative sample of Japanese adolescents using a stratified single-stage standard cluster sampling procedure supported by the Japanese Ministry of Health, Labour and Welfare. The method involved dividing Japan into regional blocks and randomly selecting schools from each block. All students in selected schools were asked to respond to the survey. The respondents completed a self-administered anonymous questionnaire at their school. The study population was restricted to junior and senior high school students between grades 7 and 12. The distribution of the characteristics of schools (e.g. private vs. public) was selected to be representative of the study population. Detailed information about the design and content of these surveys can be found elsewhere [10, 21]. This study was exempted from full review by the Nihon University School of Medicine review board. It was conducted in accordance with the Declaration of Helsinki.

Variables

Four outcome variables on sleep problems were constructed from relevant survey questions. The sleep problems included questions about insomnia symptoms, sleep duration, and self-reported sleep quality. Insomnia symptoms were defined as answering "yes" to any of the following three questions during the previous month. (1) Did you have difficulty falling asleep at night? (2) Did you wake up during the night after you had gone to sleep? (3) Did you wake up too early in the morning and had difficulty getting back to sleep? Each question had five possible responses: *never*, *seldom*, *sometimes*, *often*, and *always*. "Often" and "always" were considered affirmative answers to the question [4]. For self-reported sleep duration, the survey asked, "How many hours did you sleep on average each day during the last month?" Each question had six possible responses: less than 5 hours, 5 hours or more but less than 6 hours, 6 hours or more but less than 7 hours, 7 hours or more but less than 8 hours, 8 hours or more but less than 9 hours, and 9 hours or more. As for self-reported sleep quality, the survey asked, "How do you assess the quality of your sleep during the previous month (*very good*, *good*, *poor*, or *very poor*)?" Regarding bedtime, the survey asked, "What time do you go to bed?" Bedtime was categorized into three levels: before 11 pm, from 11 pm to 1 am, and after 1 am.

Variables on Internet screen time were derived from the survey question, "How many hours on average did you spend using the Internet on a school day for the previous month?" Internet screen time was categorized into four levels: less than 1 hour, 1 or more but less than 3 hours, 3 or more but less than 5 hours, and 5 hours or more. Regarding Internet services, the survey asked, "What kind of Internet services have you used

in the previous month? Choose all services that apply (*Internet surfing to search for information and news*; *social media use*; *streaming services such as YouTube, Niconico, etc.*; or *online gaming*)?" Other explanatory variables included survey year, sex, school grade, type of school (junior high or senior high school), lifestyle behavior (eating breakfast, participation in extracurricular activities, smoking, drinking alcohol), having fun at school, future plans to study at a university, and mental health status.

Statistical analysis

First, we calculated participants' selection rate from statistics by survey year. Second, we calculated the status of sleep problems such as insomnia symptoms, sleep duration, bedtime, and sleep quality by survey year. In this study, sleep duration was categorized into three levels: less than 6 hours, 6 or more but less than 8 hours, and 8 hours or more to fit a uniform log cumulative odds of association across these three categories. Third, the status of Internet use was calculated by survey year. Fourth, we analyzed the association between Internet use duration and sleep problems. Fifth, a binary logistic model was estimated for insomnia. A generalized ordered logit model was employed for the three ordinal outcomes (sleep duration, bedtime, and sleep quality). This method relaxes the parallel lines assumption and thus allows the impact of each independent variable to differ across the ordinal outcome categories [22]. Both variable-specific and Wald tests indicated that there was no evidence of parallel lines assumptions violations [23]. Therefore, ordered logit models were deemed acceptable. Ordered logit models are more parsimonious and easier to interpret [24]. As the associations of survey year may vary with different levels of Internet usage, we combined the survey year and the Internet screen time as the explanatory variables. The final covariates in the logistic regression analysis included sampling weights, demographic characteristics (sex and school grade), lifestyle behaviors (having breakfast, participating in extracurricular activities, drinking alcohol, smoking status), student life such as having fun at school and future plans to study at a university, and mental health status. These covariates were selected because they have been associated with sleep problems in previous studies [2, 4, 10, 21]. We also analyzed these associations by gender to identify gender differences. Finally, we examined the associations between multiple sleep dimensions, Internet screen time, and Internet service using a generalized ordered logit model. A multidimensional index of poor sleep health scores was calculated as the sum of the number of the following four dimensions self-reported as "poor." Adolescents who reported insomnia symptoms and/or reported that their sleep hours were less than 6 hours were scored as "poor" in the sleep duration dimension; those who went to bed after 1 am were scored as "poor" on bedtime; those who reported poor or very poor sleep quality were scored as "poor" on sleep quality. Male participants who responded that it took 30 minutes or more to fall asleep were classified as "poor" on the sleep-onset latency dimension. In this study population, the distribution of total risks ranged from 0 to 4 with a median of 1. Weights were constructed based on participation rate by junior/senior high school and selection rate from matched national population statistics in each survey year. We set the significance level at $p < .01$ (two-tailed test) because of the large sample size. All analyses were performed using Stata 15 (Statacorp, College Station, TX).

Results

In 2012, 2014, and 2017, the response rates were 60.7%, 52.0%, and 54,4%, respectively. After excluding 2499 observations (0.99% of the original sample) with missing information regarding sex, inconsistent responses, or missing variables, the final sample included 248 983 complete cases.

The number of participants in each survey year varied from 100 050 in 2012 to 63 945 in 2017 (Table 1). The overall selection rates from population statistics were 1.45% in survey year 2012, 1.25% in survey year 2014, and 0.97% in survey year 2017. Almost twice as many participants were in grades 10–12 as compared to grades 7–9.

Table 2 shows the lifestyle behaviors of analyzed participants. Most adolescents ate breakfast daily and participated in extracurricular activities. The prevalence of smoking and drinking consistently declined over the survey years, whereas

Table 1. Participants' demographic characteristics

		2012		2014		2017	
		Participants	Selection rate (%)	Participants	Selection rate (%)	Participants	Selection rate (%)
Total Grade		100 050	1.45	84 988	1.25	63 945	0.97
7	Boy	6920	1.15	5467	0.92	3740	0.67
	Girl	6485	1.13	5061	0.89	3644	0.68
8	Boy	6556	1.08	5426	0.91	3687	0.65
	Girl	6328	1.08	5055	0.89	3642	0.67
9	Boy	6186	1.02	5320	0.89	3702	0.64
	Girl	6019	1.04	5145	0.90	3713	0.67
10	Boy	11 233	1.94	9058	1.57	7963	1.42
	Girl	10 247	1.82	9990	1.78	6238	1.14
11	Boy	10 477	1.92	8348	1.52	7903	1.44
	Girl	9549	1.77	9390	1.72	6309	1.17
12	Boy	10 215	1.84	7606	1.41	7470	1.39
	Girl	9835	1.80	9122	1.71	5934	1.12

The selection rate was calculated from the national population statistics of all junior and senior high school students in each survey year throughout Japan.

Table 2. Lifestyle behaviors of analyzed participants

	2012 (*N* = 100 050)		2014 (*N* = 84 988)		2017 (*N* = 64 329)	
	%	95% CI	%	95% CI	%	95% CI
Daily eating breakfast	87.7	87.5–87.9	87.0	86.8–87.3	86.5	86.2–86.7
Participating in extracurricular activities	86.3	86.1–86.5	86.2	85.9–86.4	85.7	85.4–86.0
Present smoking	2.3	2.2–2.4	1.6	1.6–1.7	1.0	0.9–1.0
Present drinking alcohol	9.4	9.2–9.5	7.3	7.1–7.5	4.6	4.4–4.8
Having fun at school	67.1	66.8–67.4	66.6	66.3–67.0	68.3	67.9–68.7
Future plans to study university	33.3	33.0–33.6	33.7	33.3–34.0	35.7	35.3–36.1
Poor mental health	38.3	38.0–38.6	55.6	55.2–56.0	53.8	53.4–54.3

CI, confidence interval. Participants for whom data were missing were excluded from the analyses. Weights were adjusted to ensure that the weighted proportions of students in each grade matched national population statistics.

Table 3. Estimated change status of sleep problems among Japanese adolescent from 2012 to 2017

			Sleep duration				Bedtime				Sleep quality				
Year	Insomnia		≥8 h	6–7.99 h	<6 h		Before 11 pm	11 pm–1 am	After 1 am		Very good	Good	Poor	Very poor	
2012	19.7	(*n* = 97 475)	12.5	61.4	26.2	(*n* = 98 120)	21.1	58.8	20.1	(*n* = 97 890)	15.0	48.3	32.1	4.7	(*n* = 97 615)
2014	21.0	(*n* = 82 129)	10.3	61.8	27.9	(*n* = 82 301)	21.7	59.0	19.4	(*n* = 82 333)	14.8	47.9	32.5	4.7	(*n* = 82 143)
2017	19.2	(*n* = 62 092)	10.2	63.1	26.7	(*n* = 62 280)	21.7	59.2	19.1	(*n* = 62 299)	14.6	50.4	30.5	4.4	(*n* = 62 192)

Status was expressed in percentages (%). Participants for whom data were missing were excluded from analyses. Insomnia: those who answered one or more of difficulty initiating sleep (DIS), difficulty maintaining sleep (DMS), and early morning awakening (EMA) as experienced "often" or "always." Weights were adjusted to ensure that the weighted proportions of students in each grade matched national population statistics.

Table 4. Demographics of Internet use among Japanese adolescent from 2012 to 2017

	Internet screen time					Internet service				
		<1 h	1–2.99 h	3–4.99 h	≥5 h		Internet surfing	Social media use	Streaming	Online games
2012	(*n* = 97 984)	30.4	43.1	14.6	11.9	(*n* = 100 050)	68.1	36.0	63.5	19.8
2014	(*n* = 83 701)	22.8	48.2	17.3	11.7	(*n* = 84 988)	71.2	53.4	69.5	32.6
2017	(*n* = 62 311)	17.3	49.4	20.7	12.6	(*n* = 63 119)	74.4	79.9	78.4	45.1

All values were expressed in percentages (%). Participants for whom data were missing were excluded from analyses. Questions about Internet service used were multiple-choice style. Weights were adjusted to ensure that the weighted proportions of students in each grade matched national population statistics.

the prevalence of mental health problems increased from 2012 to 2014.

Table 3 shows the percentage of sleep status in each survey year. The percentages for each survey year were similar. However, the percentage of insomnia was highest in 2014 (21.0% [*n* = 17 247]). The proportion of participants who got 8 or more hours of sleep decreased from 12.5% (*n* = 12 265) to 10.2% (*n* = 6353). The proportion that went to bed after 1 am decreased from 20.1% (*n* = 12 265) to 10.2% (*n* = 6353). The percentage of poor and very poor sleep quality was lowest in 2017, 30.5% (*n* = 18 969) and 4.4% (*n* = 2736), respectively. Female adolescents tended to have shorter sleep duration, later bedtime, and poor sleep quality across three surveys (Supplementary Table 1).

Table 4 shows the Internet usage status in each survey year. Regarding Internet screen time, the proportion that used the Internet for less than 1 hour decreased from 30.4% (*n* = 29 787) to 17.3% (*n* = 10 780), while the proportion that used the Internet for 1–2.99 hours and 3–4.99 hours increased from 43.1% (*n* = 42 231) to 49.4% (*n* = 30 782) and from 14.6% (*n* = 14 306) to 20.7% (*n* = 12 898), respectively. All Internet services increased during this period, especially social network services, from 36.0% (*n* = 36 018) to 79.9% (*n* = 50 432), and online gaming, from 19.8% (*n* = 19 810) to 45.1% (*n* = 28 467), indicating that the figure more than doubled in 2017 compared to 2012. Female adolescents tended to use social network services more and male adolescents tended to play online games more (Supplementary Table 2).

Figure 1 shows the relationship between Internet screen time and each sleep problem. Linear relationships were observed between Internet time and each sleep status across all survey years. In the group with the highest Internet time (5 hours or more), the prevalence of insomnia, short sleep duration (less than 6 hours), later bedtime (after 1 am), and very poor sleep quality were around 31%–33%, 39%–42%, 37%, and 11%–12%, respectively.

Figure 2 shows the association between Internet screen time and sleep problems. Longer Internet screen time (vs. the reference of less than 1 hour) was generally associated with a higher likelihood of all sleep problems in all survey years. Respondents who used the Internet for 5 or more hours had a higher OR for sleep problems than did their counterparts. Especially compared with those who has less than 1 hour of Internet screen time in 2012, those who used the Internet for 5 or more hours in 2012 had the highest odds of insomnia (adjusted OR [aOR] = 1.71; 95% confidence interval [CI] = 1.61% to 1.81%), a later bedtime (aOR = 2.44; 95% CI = 2.32% to 2.56%), and worsened sleep quality (aOR range = 1.62; 95% CI = 1.54% to 1.71%). The survey year (vs.

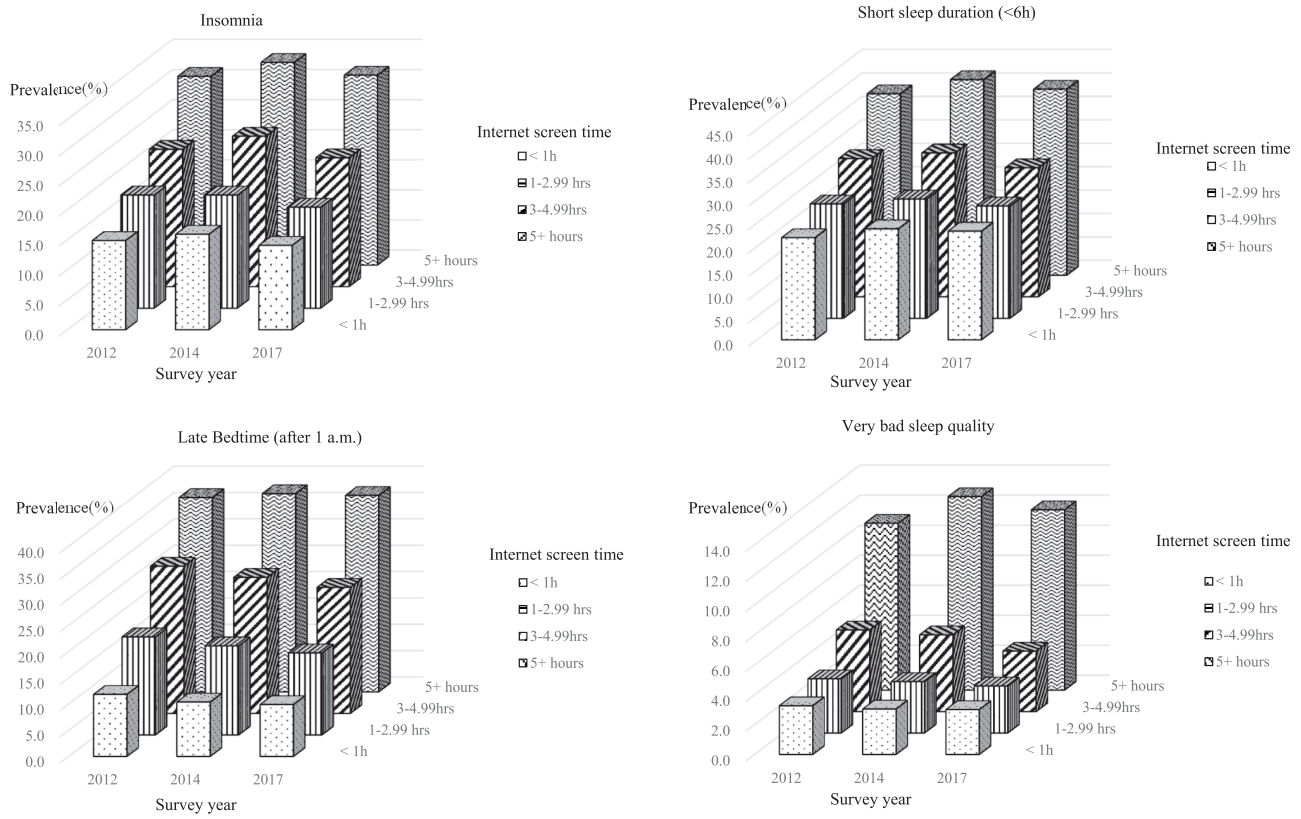

Figure 1. Prevalence of each sleep problem by Internet screen time.

the reference of 2012) was generally associated with a lower likelihood of insomnia, a later bedtime, and worse sleep quality except for shorter sleep duration. There were no gender differences in the association between Internet screen time and sleep problems.

Table 5 shows the association between Internet services and sleep problems. Those who used the Internet for surfing had lower ORs for all sleep problems except shorter sleep duration compared to those who used the Internet for other reasons. Those who used the Internet for online gaming (aOR = 1.26; 95% CI = 1.23% to 1.28%) and social media use (aOR = 1.27; 95% CI = 1.24% to 1.30%) had higher ORs for a later bedtime and worse sleep quality than did their counterparts. There were no gender differences in the association between Internet services and sleep problems.

Table 6 shows the association between Internet screen time, Internet services, and poor sleep health scores. Linear relationships can be observed between Internet screen time, Internet services, and sleep health. Thus, as poor sleep health score increases, the percentage of Internet screen time of 5 hours or more and all Internet services increases. Those who used the Internet for 5 or more hours had a higher OR for poor sleep health than did their counterparts.

Discussion

This study was the first nationwide representative study to examine the association between Internet usage and a variety of sleep problems among Japanese adolescents across recent three surveys. We revealed three main findings: (1) Internet screen time and Internet services were independently associated with sleep problems; (2) linear relationships existed between Internet screen time, multidimensional sleep health, and each sleep problem; and (3) the link between the Internet and sleep problems seemed to weaken over time. These findings have key implications for public health.

As expected, our study was similar to others in that longer Internet time was significantly associated with insomnia, shorter sleep duration, later bedtime, and worse sleep quality. A systematic review reported that 29 out of 31 studies found an association between computer use and sleep outcomes, particularly delayed bedtime and reduced sleep duration [25]. Our results showed further evidence that a linear relationship like dose–response Internet spent time was associated with all sleep problems. One study showed that computer/Internet use of at least 3 h/day (AOR = 2.56) was significantly associated with insomnia complaints among German adolescents boys [26], and a dose–response relationship emerged between sleep duration and use of electronic devices, especially computer use [27]. Another study addressed the association between Internet addiction and sleep problems worldwide [18]. A meta-analysis showed that the pooled OR of sleep problems for the Internet addiction group was 2.20 (95% CI = 1.77% to 2.74%), and the pooled standardized mean difference for sleep duration for the Internet addiction group compared to nonaddicted users was –0.24 (95% CI = –0.38% to –0.10%) hours [18]. Time spent on the Internet was also positively associated with Internet addiction [28].

To our knowledge, there have not been any previous surveys on the association between type of Internet use (e.g. streaming

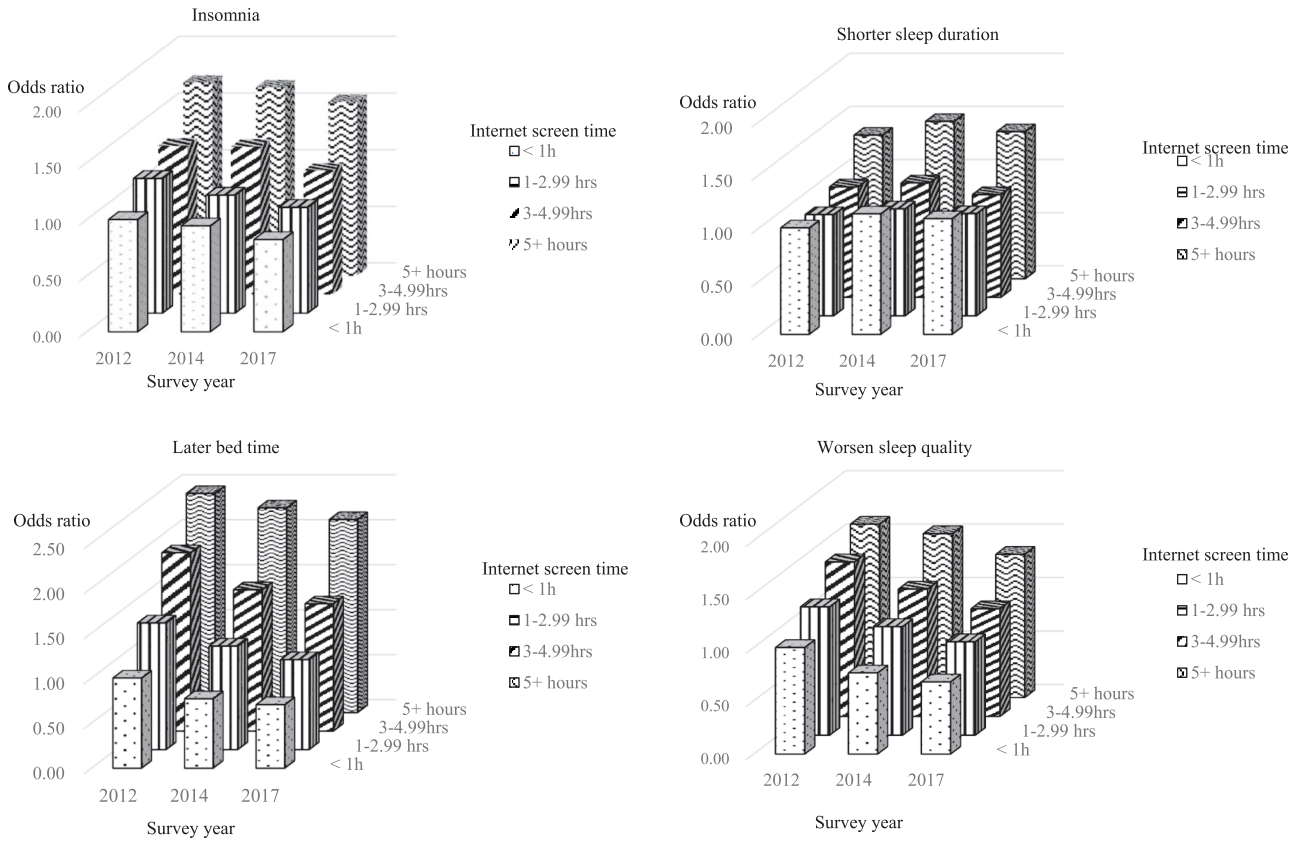

Figure 2. Association between Internet screen time and each sleep problem. Odds ratios came from binary for insomnia and ordinal logistic regression models in shorter sleep duration, longer bedtime, and worsen sleep quality. Adjusted for participants' and statistics population weight, survey year, Internet usage duration, sex, grade, mental health status, breakfast consumption, club activity, having fun at school, drinking alcohol status, smoking status, and future plans.

Table 5. Association between Internet service and sleep problems from merged data 2012, 2014, and 2017 among Japanese adolescents

	Sleep problems															
	Insomnia				Shorter sleep duration				Later bedtime				Worse sleep quality			
	aOR	95% CI		*p*	aOR	95% CI		*p*	aOR	95% CI		*p*	aOR	95% CI		*p*
Internet service																
Internet surfing (yes)	0.96	0.93	0.98	.001	1.16	1.14	1.19	<.001	1.10	1.08	1.13	<.001	1.09	1.06	1.11	<.001
Social media use (yes)	1.09	1.05	1.12	<.001	1.15	1.12	1.17	<.001	1.27	1.24	1.30	<.001	1.17	1.15	1.20	<.001
Streaming (yes)	1.07	1.04	1.10	<.001	1.06	1.03	1.08	<.001	1.12	1.09	1.14	<.001	1.15	1.13	1.17	<.001
Online gaming (yes)	1.06	1.03	1.09	<.001	1.06	1.04	1.08	<.001	1.26	1.23	1.28	<.001	1.26	1.23	1.29	<.001

aOR, adjusted odds ratio; CI, confidence interval. Participants for whom data were missing were excluded from analyses. Insomnia: those who answered one or more of difficulty initiating sleep (DIS), difficulty maintaining sleep (DMS), and early morning awakening (EMA) as experienced "often" or "always." Sleep duration was classified as <6 h, 6–7.99 h, and ≥8 h. Bedtimes were classified as before 11 pm, 11 pm–1 am, and after 1 am. Sleep quality was classified as "very good," "good," "poor," and "very poor." Odds ratios came from binary for insomnia and ordinal logistic regression models in shorter sleep duration, later bedtimes, and worsened sleep quality. Weights adjusted to match national population statistics and for survey year, Internet usage duration, sex, grade, mental health status, breakfast consumption, club activity, having fun at school, drinking alcohol status, smoking status, and future plans.

and online gaming) and sleep problems. We revealed a negative association between Internet surfing and insomnia, while other Internet services had a positive association with insomnia. In addition, social networking was strongly related to later bedtime, and online gaming was strongly related to later bedtime and worse sleep quality. Gender-specific differences were observed in habitual patterns of Internet services. Adolescent males tended to focus more on the entertainment aspects of the Internet, while females seem to be more interested in the relational aspects of social media and in communicating with friends on the Internet [20, 29, 30]. Thus, it is desirable to focus on social networking for females and online games for males to provide sleep hygiene education.

Some previous studies indicated the association between social media use and sleep problems [31, 32]. For example, a large-scale cross-sectional study among Canadian students aged 11–20 years reported that social media use was associated with higher odds of shorter sleep duration, and a dose–response association was observed between social media use and shorter sleep duration [31]. A systematic review showed a

Table 6. Association between Internet screen time, Internet service, and sleep health scores from merged data of 2012, 2014, and 2017 in Japanese adolescents

	Sleep health score							
	0 (*N* = 98 232)	1 (*N* = 64 297)	2 (*N* = 40 871)	3 (*N* = 27 040)	4 (*N* = 9052)	aOR	95% CI	*p*
Internet screen time								
<1 h	26.4	23.1	16.5	13.2	10.0	1.00		
1–3 h	50.1	46.9	46.0	42.1	34.0	1.04	1.01–1.06	0.002
3–5 h	15.7	18.3	21.1	22.6	22.3	1.32	1.28–1.36	<0.001
≥5 h	7.9	11.7	16.4	22.1	33.8	2.03	1.96–2.10	<0.001
Internet services							-	
Internet surfing	69.0	72.7	74.1	75.8	75.6	1.11	1.09–1.14	<0.001
Social media use	51.9	56.8	64.9	69.9	73.6	1.14	1.12–1.16	<0.001
Streaming	28.6	30.9	34.0	36.7	41.4	1.13	1.11–1.16	<0.001
Online games	66.5	68.7	74.1	76.7	78.6	1.11	1.09–1.14	<0.001

CI, confidence interval. Participants for whom data were missing were excluded from the analyses. Weights adjusted to match national population statistics. Sleep health scores were expressed in percentage (%). Odds ratios come from ordinal logistic regression models in sleep health scores. Weights adjusted to match national population statistics and for survey year, Internet usage duration, gender, grade, mental health status, breakfast consumption, club activity, having fun at school, drinking alcohol status, smoking status, and future plan to study at a university.

notably strong association between multiplayer online gaming and poor sleep quality [33]. However, our study showed that all reasons for using Internet services had a weak association with adolescents' sleep. In the future, it will be necessary to investigate further the association between sleep problems and service usage time.

The causal pathways linking sleep problems with Internet usage are still not clear. There are several explanations for these associations. First, longer Internet usage time could reduce sleep duration and delay bedtime directly [34] or indirectly by displacing time spent on other behaviors such as physical activity that promote good sleep [35, 36]. Second, exposure to artificial light from viewing the Internet can affect circadian rhythms, which can contribute to shorter sleep duration, poor sleep quality, and insomnia symptoms [10, 37]. Third, Internet use in the evenings may increase mental, emotional, or physiological arousal [38].

In contrast, several studies have suggested that sleep problems could influence electronic media use [38]. Sleep disturbance partially mediated the relationship between electronic media use and depressive symptoms among adolescents in Switzerland [39]. In fact, lack of sleep could lead to tiredness and fatigue the next day, increasing the likelihood of performing sedentary behaviors, such as Internet use [40, 41]. Adolescents with underlying sleep problems may use the Internet as a stress-coping method or to improve sleep. Given the potential tradeoff between sleep duration and Internet time spent among adolescents, bidirectional relationships may exist between sleep and Internet use [12].

Our results showed that the association between Internet use and sleep problems seems to have weakened in more recent surveys, except for shorter sleep duration. Similarly, concerning our findings about sleep duration, a survey of US adolescents from 2009 to 2015 reported that the use of electronic devices, social media, and reading news online significantly increased the odds of short sleep duration, and time spent on these screen activities increased over the survey period [14]. There are two possible reasons for the weakened association between Internet use, insomnia, and sleep quality. The first is that most Japanese adolescents consider the Internet as a part of their daily lives; thus, the association with their sleep habits was reduced. In fact, Japanese adolescents' use of televisions, radios, and magazines has decreased while their Internet usage time has increased [19]. Thus, their overall screen time was unchanged. The second reason may be that adolescents' sleep hygiene activities, such as avoiding using the Internet before bed, prevented insomnia and promoted sleep quality. Our previous study showed that Japanese adolescents' sleep problems such as insomnia and poor sleep quality decreased between 2004 and 2017 [21]. Although the reason was unclear, we suggested the effect of Japanese sleep countermeasures. The Japanese Ministry of Health, Labour and Welfare introduced the "Sleep Guidelines for Health Promotion" in 2014, which included 12 messages about sleep hygiene. These policies may have raised adolescents' awareness of sleep by educating them at school. In fact, lifestyle education was taught in schools in Japan. Specifically, the smoking education provided in Japanese schools contributed to the reduction of smoking rates [42]. Thus, Japanese adolescents tend to adopt healthy lifestyle behaviors to ensure they get good sleep [21].

Nevertheless, this study showed that 90% of Japanese adolescents had insufficient sleep duration. East Asian adolescents are known to sleep less and have later bedtimes than adolescents from Western countries [17]. In East Asian countries such as China, Korea, and Japan, many children face severe academic pressure emphasizing study time [43, 44], In Japan, "we tried hard without sleeping" is desirable, resulting in the term "Shitougoraku" (sleep 4 hours and pass, sleep 5 hours and fail [when cramming for university entrance exams]). Thus, sleep health in Japan has been neglected by the people and the magnitude of sleep problems is more remarkable than that in Western countries. Shortened sleep duration in adolescence occurs as a result of progressive delays in bedtimes, not as a result of a change in wake-up time [45]. Certainly, later night electronic media use is associated with delayed bedtimes and shortened sleep duration [18, 27]. However, the present study showed that the link of Internet usage time with sleep duration was not strong. Our data also showed lower smoking and drinking alcohol prevalence and higher breakfast intake, which suggests that adolescents tend to exhibit healthy lifestyle behaviors. Thus, other daily activities such as school work, cram school, extracurricular activities, and part-time employment may be associated with later bedtime and shorter sleep duration.

Gender differences emerged regarding sleep problems, except insomnia. Some previous studies showed opposite directions

[46–48]. For example, a cross-sectional study in Norway showed that girls had a higher prevalence of insomnia than boys while boys reported later bedtimes [46]. The mechanisms leading to these gender differences are not yet known [47]. Previous studies showed that the gender differences could be related to pubertal development. This difference between Japan and Western countries may be related to cultural aspects or Internet usage time.

This study has several noteworthy limitations. First, all data were self-reported. Future studies should use more objective measures of both Internet use and sleep. Moreover, researchers should collect more characteristics associated with Internet use that can lead to behavioral changes (e.g. timing, duration, device, and application). However, several studies have indicated that self-reported sleep data had a moderate agreement with laboratory studies [49]. Second, although we adjusted for several potential confounding variables, we did not control for regional aspects (urban vs. rural), economic status, and other screen devices such as TVs and gaming machines. These factors were associated with sleep problems [9, 10, 25, 50, 51]. Thus, future research should include these factors. Third, owing to the cross-sectional study design, causal relationships cannot be examined. To do so, longitudinal studies with better measures of Internet use and sleep are needed. Fourth, our study could not investigate the difference in sleep duration between weekdays and weekends. A study has shown that different bedtime and wake-up habits during school days and weekends are associated with increased screen time [52]. Despite these limitations, this study suggests that assessing the time adolescents spend on the Internet and their sleep habits may be valuable indicators for healthcare providers.

In conclusion, the findings from these large-scale, repeated cross-sectional surveys of Japanese adolescents suggest that longer Internet time, especially at least 5 h/day, is associated with worse sleep problems. The findings also suggest that future interventions should specifically target social media use and online gaming for adolescents. Teachers, parents, and adolescents must be aware of the possible negative impact of Internet use on adolescent sleep. These results would be useful in developing more effective interventions. For example, students should be educated in school about the advantages and disadvantages of the Internet and how to use it safely, and parents need to develop rules for Internet use at home. Teachers and parents should be aware of gender-specific patterns of Internet services and sleep problems. Future studies need to expand upon the present study by examining both weekday and weekend sleep duration, bedtime, and wake-up times and any other screen time such as watching TV, playing video games, and studying on a tablet.

Supplementary material

Supplementary material is available at *SLEEP* online.

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Disclosure Statement

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Data availability

The datasets generated used in the current study are not publicly available because it is necessary to obtain permission from the Ministry of Health, Labour and Welfare in Japan. Related documents will be available from https://mhlw-grants.niph.go.jp/niph/search/NIST00.do.

References

1. Shochat T, *et al*. Functional consequences of inadequate sleep in adolescents: a systematic review. *Sleep Med Rev*. 2014;**18**(1):75–87.
2. Otsuka Y, *et al*. Association between unhealthy dietary behaviors and sleep disturbances among Japanese adolescents: a nationwide representative survey. *Sleep Biolog Rhythms*. 2019;**17**(1):93–102.
3. Saxvig IW, *et al*. Prevalence and correlates of delayed sleep phase in high school students. *Sleep Med*. 2012;**13**(2):193–199.
4. Kaneita Y, *et al*. Insomnia among Japanese adolescents: a nationwide representative survey. *Sleep*. 2006;**29**(12):1543–1550. doi:10.1093/sleep/29.12.1543
5. Calamaro CJ, *et al*. Adolescents living the 24/7 lifestyle: effects of caffeine and technology on sleep duration and daytime functioning. *Pediatrics*. 2009;**123**(6):e1005–e1010.
6. Mednick SC, *et al*. The spread of sleep loss influences drug use in adolescent social networks. *PLoS One*. 2010;**5**(3):e9775.
7. Short MA, *et al*. A cross-cultural comparison of sleep duration between US and Australian adolescents: the effect of school start time, parent-set bedtimes, and extracurricular load. *Health Educ Behav*. 2013;**40**(3):323–330.
8. Kaneita Y, *et al*. Association between mental health status and sleep status among adolescents in Japan: a nationwide cross-sectional survey. *J Clin Psychiatry*. 2007;**68**(9):1426–1435.
9. Van den Bulck J. Television viewing, computer game playing, and Internet use and self-reported time to bed and time out of bed in secondary-school children. *Sleep*. 2004;**27**(1):101–104. doi:10.1093/sleep/27.1.101
10. Munezawa T, *et al*. The association between use of mobile phones after lights out and sleep disturbances among Japanese adolescents: a nationwide cross-sectional survey. *Sleep*. 2011;**34**(8):1013–1020. doi:10.5665/SLEEP.1152
11. Bartel KA, *et al*. Protective and risk factors for adolescent sleep: a meta-analytic review. *Sleep Med Rev*. 2015;**21**:72–85.
12. Chen YL, *et al*. Sleep problems and Internet addiction among children and adolescents: a longitudinal study. *J Sleep Res*. 2016;**25**(4):458–465.
13. Randler C, *et al*. Smartphone addiction proneness in relation to sleep and morningness–eveningness in German adolescents. *J Behav Addict*. 2016;**5**(3):465–473.
14. Twenge JM, *et al*. Decreases in self-reported sleep duration among U.S. adolescents 2009–2015 and association with new media screen time. *Sleep Med*. 2017;**39**:47–53.

15. Matricciani L, *et al*. In search of lost sleep: secular trends in the sleep time of school-aged children and adolescents. *Sleep Med Rev*. 2012;**16**(3):203–211.
16. Ghekiere A, *et al*. Trends in sleeping difficulties among European adolescents: are these associated with physical inactivity and excessive screen time? *Int J Public Health*. 2019;**64**(4):487–498.
17. Gradisar M, *et al*. Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep. *Sleep Med*. 2011;**12**(2):110–118.
18. Alimoradi Z, *et al*. Internet addiction and sleep problems: a systematic review and meta-analysis. *Sleep Med Rev*. 2019;**47**:51–61.
19. Government of Japan Cabinet Office. *Internet Usage Environment Among Youth* (in Japanese). https://www8.cao.go.jp/youth/youth-harm/chousa/r01/jittai-html/2_1_1.html. Accessed June 23, 2020.
20. Mihara S, *et al*. Internet use and problematic Internet use among adolescents in Japan: a nationwide representative survey. *Addict Behav Rep*. 2016;**4**:58–64.
21. Otsuka Y, *et al*. Trends in sleep problems and patterns among Japanese adolescents: 2004 to 2017. *Lancet Reg Health West Pac*. 2021;**9**:100107.
22. Williams R. Generalized ordered logit/partial proportional odds models for ordinal dependent variables. *Stata J*. 2006;**6**(1):58–82.
23. Erkan A, *et al*. Parallel lines assumption in ordinal logistic regression and analysis approaches. *Int Interdiscip J Sci Res*. 2014;**1**(3):8–23.
24. Williams R. Understanding and interpreting generalized ordered logit models. *J Math Sociol*. 2016;**40**(1):7–20.
25. Hale L, *et al*. Screen time and sleep among school-aged children and adolescents: a systematic literature review. *Sleep Med Rev*. 2015;**21**:50–58.
26. Lange K, *et al*. Electronic media use and insomnia complaints in German adolescents: gender differences in use patterns and sleep problems. *J Neural Transm (Vienna)*. 2017;**124**(Suppl 1):79–87.
27. Hysing M, *et al*. Sleep and use of electronic devices in adolescence: results from a large population-based study. *BMJ Open*. 2015;**5**(1):e006748.
28. Kim J, *et al*. The role of Internet user characteristics and motives in explaining three dimensions of Internet addiction. *J Comput Mediat Commun*. 2009;**14**(4):988–1015.
29. Weiser EB. Gender differences in Internet use patterns and Internet application preferences: a two-sample comparison. *Cyberpsychol Behav*. 2000;**3**(2):167–178.
30. Pujazon-Zazik M, *et al*. To tweet, or not to tweet: gender differences and potential positive and negative health outcomes of adolescents' social Internet use. *Am J Mens Health*. 2010;**4**(1):77–85.
31. Sampasa-Kanyinga H, *et al*. Use of social media is associated with short sleep duration in a dose–response manner in students aged 11 to 20 years. *Acta Paediatrica*. 2018;**107**(4):694–700.
32. Woods HC, *et al*. #Sleepyteens: social media use in adolescence is associated with poor sleep quality, anxiety, depression and low self-esteem. *J Adolesc*. 2016;**51**:41–49.
33. Lam LT. Internet gaming addiction, problematic use of the Internet, and sleep problems: a systematic review. *Curr Psychiatry Rep*. 2014;**16**(4):444.
34. Eggermont S, *et al*. Nodding off or switching off? The use of popular media as a sleep aid in secondary-school children. *J Paediatr Child Health*. 2006;**42**(7–8):428–433.
35. Driver HS, *et al*. Exercise and sleep. *Sleep Med Rev*. 2000;**4**(4):387–402.
36. Gregory AM, *et al*. Annual research review: sleep problems in childhood psychiatric disorders—a review of the latest science. *J Child Psychol Psychiatry*. 2016;**57**(3):296–317.
37. Chang AM, *et al*. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proc Natl Acad Sci USA*. 2015;**112**(4):1232–1237.
38. Cain N, *et al*. Electronic media use and sleep in school-aged children and adolescents: a review. *Sleep Med*. 2010;**11**(8):735–742.
39. Lemola S, *et al*. Adolescents' electronic media use at night, sleep disturbance, and depressive symptoms in the smartphone age. *J Youth Adolesc*. 2015;**44**(2):405–418.
40. Ortega FB, *et al*. Sleep duration and activity levels in Estonian and Swedish children and adolescents. *Eur J Appl Physiol*. 2011;**111**(10):2615–2623.
41. Taheri S. The link between short sleep duration and obesity: we should recommend more sleep to prevent obesity. *Arch Dis Child*. 2006;**91**(11):881–884.
42. Osaki Y, *et al*. Decrease in the prevalence of smoking among Japanese adolescents and its possible causes: periodic nationwide cross-sectional surveys. *Environ Health Prev Med*. 2008;**13**(4):219–226.
43. Steger B, *et al*. *Night-Time and Sleep in Asia and the West. Exploring the Dark Side of Life*. London, United Kingdom/New York, NY: Routledge Curzon; 2003.
44. Jenni OG, *et al*. Children's sleep: an interplay between culture and biology. *Pediatrics*. 2005;**115**(1 Suppl):204–216.
45. Dollman J, *et al*. Trends in the duration of school-day sleep among 10- to 15-year-old South Australians between 1985 and 2004. *Acta Paediatr*. 2007;**96**(7):1011–1014.
46. Hysing M, *et al*. Sleep patterns and insomnia among adolescents: a population-based study. *J Sleep Res*. 2013;**22**(5):549–556.
47. Johnson EO, *et al*. Epidemiology of DSM-IV insomnia in adolescence: lifetime prevalence, chronicity, and an emergent gender difference. *Pediatrics*. 2006;**117**(2):e247–e256.
48. Keyes KM, *et al*. The great sleep recession: changes in sleep duration among US adolescents, 1991-2012. *Pediatrics*. 2015;**135**(3):460–468.
49. Short MA, *et al*. The discrepancy between actigraphic and sleep diary measures of sleep in adolescents. *Sleep Med*. 2012;**13**(4):378–384.
50. Marco CA, *et al*. Family socioeconomic status and sleep patterns of young adolescents. *Behav Sleep Med*. 2011;**10**(1):70–80.
51. Hense S, *et al*. Factors that influence weekday sleep duration in European children. *Sleep*. 2011;**34**(5):633–639. doi:10.1093/sleep/34.5.633
52. Hena M, *et al*. Social Jetlag and its association with screen time and nighttime texting among adolescents in Sweden: a cross-sectional study. *Front Neurosci*. 2020;**14**:122.