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Research paper

Trends in sleep problems and patterns among Japanese adolescents: 2004 to 2017

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ABSTRACT

Background: Sleep problems in adolescence, such as insomnia and short sleep duration, are associated with physical and mental health problems. However, little is known about the recent trends in sleep problems among adolescents. Therefore, this study examined trends in sleep problems among Japanese adolescents.

Methods: Using data from the Lifestyle Survey of Adolescents collected in 2004 (n = 102,451), 2008 (n = 95,680), 2010 (n = 98,867), 2012 (n = 101,134), 2014 (n = 85,931), and 2017 (n = 64,417), we calculated the trends of insomnia, shorter sleep duration, late bedtimes, and poor sleep quality. Multivariable logistic regression analysis models were used to examine the association of each sleep problem and survey years.

Findings: We analyzed data from 545,285 Japanese adolescents. Results indicated that, since 2004, the odds ratio for insomnia have decreased (Adjusted odds ratio [AOR] 0•85, 95% CI 0•82–0•87), as have the odds ratio for poor sleep quality (AOR 0•92, 95% CI 0•88–0•95). However, the odds ratio for shorter sleep duration (AOR 1•13, 95% CI 1•10–1•17) and late bedtimes tended to increase (AOR 1•06, 95% CI 1•03–1•08) during this period.

Interpretation: The prevalence of insomnia symptoms and poor sleep quality among adolescents decreased from 2004 to 2017. However, there were increasing trends toward shorter sleep duration and late bedtimes. These changes are both relieving and concerning. Teachers, parents, and health professionals should consider educating adolescents regarding sleep hygiene, adjusting schedules of extracurricular activities, and enhancing time management to improve their sleep quantity.

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Research in context

Evidence before this study

Adolescent sleep problems are becoming increasingly recognized as a significant public health concern. We searched PubMed with the following search terms: "Sleep Disorders," "Adolescent" (Adolescents, Adolescence, Teens, Teen, Teenagers, Teenager, Youth, Youths), and "trend or change." We reviewed titles and abstracts and excluded articles not published in English, that did not target humans, or were not relevant to adolescent sleep problems. Given the extensive literature on adolescent sleep, we included studies that were specific to changes in adolescent insomnia symptoms and sleep duration. Most previous work and a meta-analysis of international studies reported that adolescent bedtimes tended to become increasingly delayed and sleep duration tended to decrease with increasing age, leading to shorter sleep on school nights. However, sleep deterioration among adolescents has been prominent mainly in Western countries and was limited until the early 2000s. We found very few studies that examined the trends of sleep problems in Asian countries.

Added value of this study

The trends of sleep problems have not been previously investigated among Asian countries, creating a significant knowledge gap. This is the first nationally representative repeated cross-sectional study that examines trends in sleep problems among Japanese adolescents. The trends identified here demonstrate that the prevalence of insomnia symptoms and poor sleep quality decreased among Japanese adolescents from 2004 to 2017. However, there were increasing trends toward shorter sleep duration and late bedtimes. This study provides important evidence for policy makers and school officials to educate adolescents regarding improved time management and to address adolescents' sleep needs.

Implications of all the available evidence

The prevalence of later bedtime among adolescents is increasing in line with technological developments such as the Internet and cellular phones. In many countries, the prevalence of adolescent insomnia-related symptoms has tended to increase while, in a few countries, a downward trend has been observed. These differences could be useful in developing more effective prevention strategies in the future. Interventions tailored to prevent late bedtime may aid in maximizing the effects of health education during adolescence. Finally, the results provide a benchmark for monitoring trends in adolescent sleep in Japan and other East Asian countries in the future.

1. Introduction

Adolescent sleep problems are becoming increasingly recognized as a significant public health issue, with many countries reporting a high prevalence of sleep disturbance in adolescence [1]. Previous studies reported that the prevalence of insomnia among adolescents worldwide ranged from 16•9% to 34•0% [2–4]. Most epidemiological studies define insomnia symptoms as having one or more of the following: difficulty initiating sleep (DIS), difficulty maintaining sleep (DMS), early morning awakening (EMA), or nonrestorative sleep (NRS) [2,3,5]. A meta-analysis of international studies reported that, from 1999 to 2010, adolescent bedtimes tended to become increasingly delayed and sleep duration tended to decrease with increasing age, leading to shorter sleep on school nights [1].

In Japan, a representative epidemiological study of sleep disturbances in adolescence was first conducted in 2000 [6] and reported that 28•7% of boys and 32•6% of girls slept on average for less than six hours per night [6]. In 2004, the prevalence of insomnia, which was defined as DIS, DMS, or EMA, among Japanese adolescents was 23•5% [7].

An important question concerning adolescents' sleep is whether sleep problems are increasing in line with other social changes. There are concerns that emergent technological developments, such as the Internet and cellular phones, and the rise of the "24-hour society," have affected adolescents' sleep in recent years [8]. Few studies, however, have investigated population trends in adolescent sleep issues. In the U.S., a study with a representative sample of 272,077 adolescents aged 12 to 19 years showed a 30% lower prevalence of sleep duration of more than seven hours in 2012 compared to 1991 [9]. A systematic cross-country review of data from 690,747 children from 20 countries identified a decline of 0•75 min per year in children's sleep duration over the last 100 years [10]. Another study demonstrated increases in the prevalence of sleep-onset difficulties in Norwegian adolescents from 1983 to 2005 [11] and among European adolescents from 2002 to 2014 [12]. American adolescents' self-reported sleep time also decreased from 2009 to 2015 [13]. These changes have been attributed to increases in electronic device use, including social media engagement and reading news online [13], as well as limited physical activity [12]. Thus, it is recognized that sleep is deteriorating among adolescents in Western societies. Very few studies have examined the trends of sleep problems in Asian countries. For example, sleep duration increased for children from Shanghai aged 6 to 11 years (2005 to 2014) but decreased for children from Hong Kong (2003 to 2012) [14]. The opposite results in sleep duration between the two regions have been attributed to changes in school start times [14]. This is particularly problematic, given that East Asian people are known to sleep less and have later bedtimes than people from Western countries [1,15]. Thus, studies on the sleep trends of Asian adolescents are urgently needed. Furthermore, previous studies of trends in adolescent sleep patterns have focused mainly on sleep disorders and sleep duration, and no studies have evaluated multiple dimensions of sleep, such as insomnia symptoms, sleep quality, and sleep duration.

In 2014, the Japanese Ministry of Health, Labour and Welfare published the "Sleep Guidelines 2014 for Health Promotion." The document is aimed at the general public and includes 12 basic sleep guidelines designed for use in lifestyle coaching to promote health in the population. Since then, schools and corporations in Japan have begun to provide sleep hygiene education [16,17].

According to media campaigns, many Japanese citizens are motivated to get sufficient sleep [18]. However, there is little information about recent trends in sleep problems, such as insomnia symptoms, short sleep duration, and poor sleep quality among Japanese adolescents.

This study aimed to investigate the trends in self-reported sleep problems among Japanese adolescents using nationally representative cross-sectional surveys of adolescents' lifestyle behavior from 2004 to 2017. Given the findings of previous research, we hypothesized that trends in the prevalence of sleep problems, such as insomnia, short sleep duration, and poor sleep quality, among Japanese adolescents would have increased until 2014, when the campaign was implemented, and then declined by 2017.

2. Method

2.1. Data sources

We used data from the Lifestyle Survey of Adolescents collected in 2004, 2008, 2010, 2012, 2014, and 2017. Since 1996, the working group of the Lifestyle Survey of Adolescents, conducted by the Japanese Ministry of Health, Labour and Welfare, has surveyed a representative sample of Japanese adolescents using a single stratified single-stage standard cluster sampling procedure. The cluster

unit was schools. The method involved dividing Japan into regional blocks and randomly selecting schools from each block.

2.2. Participants

The study population was restricted to students between grades 7 and 12 of junior and senior high schools selected throughout Japan using the National School Directory. The proportion of private schools was approximately 7% for junior high schools and 30% for senior high schools in each survey. These proportions are highly similar to the statistics reported by the Ministry of Education, Culture, Sports, Science and Technology, Japan. All students enrolled in the sampled schools were included as the target population of the study. Due to survey budget limitations, the number of schools and students completing the survey varied in each survey year, resulting in changes in sample size across the years. The distribution of the characteristics of schools (e.g., private vs. public) was selected to be representative of the study population [6,7].

2.3. Survey procedure

A letter was sent to the principal of each selected school requesting their cooperation along with a questionnaire form and an envelope for each enrolled student. In participating schools, class teachers informed the students about the study in detail and reassured them about privacy protection and that the completed questionnaires would not be seen by the teachers. Informed written consent was obtained from all study participants. Due to the new epidemiological research guidelines, informed consent was obtained from each junior high school student's parent or guardian for the 2017 survey. Parents' and guardians' informed consent was not required by the guidelines governing anonymous and non-invasive research entailing students who had finished junior high school in the earlier years. The teachers explained the nature of confidentiality and voluntary participation to all the students, and completed questionnaires were returned to the working group in sealed envelopes. This protocol is in accordance with the Japanese Ethical Guidelines for Epidemiological Research announced by the Ministry of Health, Labour and Welfare and the Ministry of Education, Culture, Sports, Science and Technology of Japan. The working group used anonymized questionnaires to prevent the identification of individual participants and to safeguard their privacy. This study was approved by the ethical review board of the Nihon University School of Medicine.

2.4. Outcome measures

The sleep-related items in the survey included questions about insomnia symptoms, sleep duration, and subjective sleep quality. The following three questions were asked to assess insomnia symptoms experienced 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?; and (3) Did you wake up too early in the morning and have difficulty getting back to sleep? Each question had five possible responses: never, seldom, sometimes, often, and always. We defined those reporting "often" and "always" as displaying "severe" symptoms and those reporting "sometimes" as displaying "moderate" symptoms. The severity of insomnia symptoms was defined based on responses to one or more of the three questions. Sleep duration was assessed by asking, "How many hours on average have you slept at night during the previous month?" with response options of less than five hours, five hours or more but less than six hours, six hours or more but less than seven hours, seven hours or more but less than eight hours, eight hours or more but less than nine hours, and nine hours or more. Subjective sleep quality was assessed by asking, "How was the quality of your sleep during the previous month?" with the following response options: very good, good, bad, very bad. If the response to this question was bad or very bad, the adolescent was rated as having poor sleep quality [19]. Concerning the question, "What time do you go to bed?" those who answered 1 am or later were considered as having a "late bedtime (LBT)" [20].

2.5. Covariates

Participants also provided data on demographic and school characteristics, including gender, grade, and type of school (junior high or senior high school). They responded to lifestyle behavior questions including the frequency of eating breakfast ("every day," "sometimes," or "seldom"); participation in club activities ("participation," or "no participation"); smoking status; and alcohol drinking status. Respondents were rated as having regular breakfast if they responded "every day" to the relevant question. For the smoking question ("How many days did you smoke during the previous month?"), participants were considered to be current smokers if they answered that they smoked one or more days. Similarly, those who responded "one day or more" to the alcohol question ("How many days did you consume alcoholic beverages during the previous month?") were considered to be current drinkers.

To evaluate student life plans, students were asked, "What is your plan for your future life course?" Those who selected "university" or "postgraduate school" were grouped as students who intended to go to university, and those who selected "high school," "vocational school," "junior college," "taking a job after leaving the current school," or "not decided yet" were grouped as students who did not intend to go to university. The participants were also asked if they felt happy at school, with the choice of the following responses: "Yes, I do," "Yes and no," and "No, I don't."

Mental health status was assessed using the 2-item General Health Questionnaire (GHQ-2) instead of the 12-item version (GHQ-12), given the limited space available in the survey questionnaire. Previous research indicates a cut-off score of 1 on GHQ-2 has a sensitivity and specificity of 87•0% and 85•1%, respectively, using GHQ-12 as the gold standard [21]. The GHQ-2 included the following questions: "Have you felt more unhappy and depressed than usual in the past 30 days?" and "Have you been able to enjoy your normal daily activities more than usual?" Each item was rated from 0 to 1, with a total score ranging from 0 to 2. A score of 0 was regarded as indicative of good mental health, whereas scores of 1 or 2 were regarded as indicative of poor mental health.

2.6. Statistical analysis

First, we compared the number of participants in each survey year using chi-squared tests and examined the participants' demographic characteristics by survey year. Second, we calculated the prevalence of insomnia symptoms, shorter sleep duration, late bedtimes, and poor sleep quality by survey year. Third, we examined time trends of sleep problems using bivariate and multivariate binary logistic models. To better describe sleep trends across the entire study period, the survey year was transformed by subtracting 2004 from the year and dividing the results by 13. Thus, the transformed value ranged from 0 for 2004 to 1 for 2017. The odds ratios associated with this transformed variable of survey year represent changes in odds of sleep problems during the study period. This method enabled us to interpret the corresponding regression coefficients as changes in the odds of each sleep problem from 2004 to 2017 [22]. The outcome for these analyses was the dichotomous variable for the presence of sleep problems, and the predictor was each survey year. To evaluate insomnia and sleep duration, we performed ordinal logistic regression. The final covariates

in the ordinal and binary logistic regression analysis included demographic characteristics (gender, birth cohort, and school grade), lifestyle behaviors (having breakfast, participating in clubs, drinking alcohol, smoking status), student life (intention to study at university and having fun at school), and mental health status. These covariates were selected because they have been associated with sleep problems in previous studies [6,7,19,23]. The birth cohort was divided into three categories (1984–1989, 1990–1997, and 1998–2005) based on the revision of the Learning Guidance Guidelines in 1989 and 1998. Sampling weights were constructed based on the participation rate of junior/senior high school students in each survey year. The grade-adjusted estimates were calculated using the direct method with projected students in the year 2004 as the standard. We set the significance level at $p<0•01$ because of the large sample size. We adopted pairwise deletion to handle missing data. All analyses were performed using Stata 15 (Statacorp, College Station, Texas).

2.7. Sensitivity analyses

To assess reproducibility and validity in defining the prevalence of sleep problems across the years, we redefined each sleep problem. Insomnia was redefined as one or more symptoms of DIS, DMS, or EMA experienced "often" and "always" [7]. Short sleep duration was defined as less than seven hours [9]. Subjective poor sleep quality was redefined as a response of "very bad." LBT was redefined as a bedtime of 12 am or later. To examine gender effects, we analyzed trends in sleep problems according to gender.

2.8. Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the paper. The corresponding author had full access to all the data in the study and all authors shared final responsibility for the decision to submit for publication.

3. Results

The number of participants in each survey year was determined by budgetary constraints, and it varied from 102,451 in 2004 to 64,417 in 2017 (Table 1). The respective student response rates declined from 64•7% in 2004 to 54•5% in 2017.

Regarding demographic characteristics over the survey years, approximately twice as many participants were high school students (Grades 10–12) as junior high school students (Grades 7–9; Table 2). The prevalence of smoking and drinking consistently declined over the survey years, whereas the prevalence of mental health problems increased in 2014 and 2017. The prevalence of poor mental health was lowest in 2012.

Table 3 and Fig. 1 present the trends in sleep problems from 2004 to 2017. Significant linear trends were observed for all sleep problems except for LBT. The unadjusted prevalence of severe insomnia decreased from 23•3% in 2004 to 18•3% in 2017. The unadjusted prevalence of sleep duration below seven hours was the lowest in 2004. The unadjusted and adjusted prevalence of LBT was least prevalent in 2008 and highest in 2010. The prevalence of poor sleep quality displayed a declining trend overall but was the highest in 2008. In the final model (adjusted for participants' weight, gender, birth cohort, junior/senior high school, grade, mental health status, breakfast consumption, club activity, having fun at school, drinking alcohol, smoking, and future plans), the adjusted prevalence of severe and moderate insomnia decreased from 22•0% and 40•1% in 2004 to 19•2% and 38•9% in 2017 (adjusted odds ratio [AOR] 0•85, 95% confidence interval [CI] 0•82–0•87). Similarly, the adjusted prevalence of poor sleep quality decreased

Table 1
Response rate statistics from 2004 to 2017.

Year	Junior high school			Senior high school			p-value	Total eligible participants	Total enrolled participants	Total response rate (%)
	Eligible participants	Enrolled participants	Response rate (%)	Eligible participants	Enrolled participants	Response rate (%)				
2004	64,885	39,385	60•7	93,155	63,066	67•7		158,040	102,451	64•8
2008	62,638	40,151	64•1	89,419	55,529	62•1		152,057	95,680	62•9
2010	62,081	38,552	62•1	92,366	60,315	65•3		154,447	98,867	64•0
2012	65,002	38,871	59•8	101,571	62,263	61•3	0.007	166,573	101,134	60•7
2014	65,638	31,769	48•4	99,563	54,162	54•4		165,201	85,931	52•0
2017	48,641	22,275	45•8	69,662	42,142	60•5		118,303	64,417	54•5

p-value was calculated for the chi-squared test (junior versus senior response rate).

Table 2
Demographic characteristics of the participants.

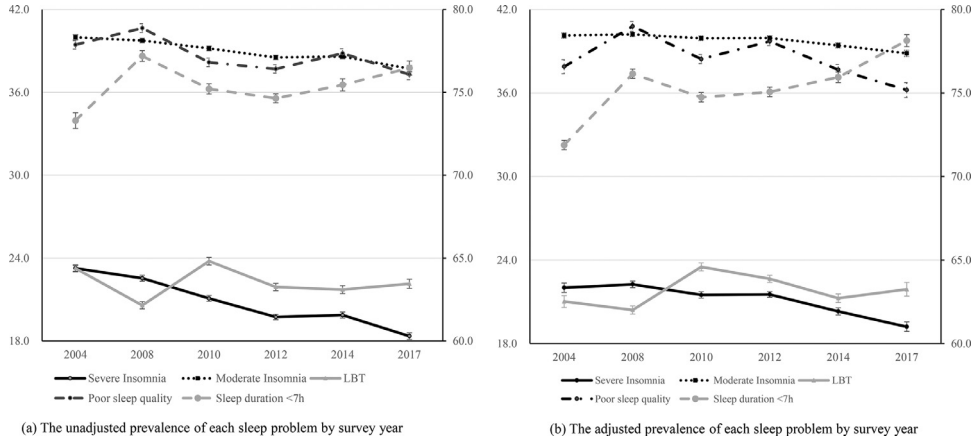
		2004		2008		2010		2012		2014		2017		p-value	Total
		N	%	N	%	N	%	N	%	N	%	N	%		
Grade															
	7	13,146	12•8	13,266	14•0	13,041	13•3	13,405	13•4	10,528	12•4	7384	11•6	<0.001	70,770
	8	13,079	12•8	13,606	14•4	12,816	13•0	12,884	12•9	10,481	12•3	7329	11•5		70,195
	9	13,160	12•9	12,871	13•6	12,476	12•7	12,205	12•2	10,465	12•3	7415	11•6		68,592
	10	21,815	21•3	20,118	21•2	21,444	21•8	21,480	21•5	19,048	22•4	14,201	22•2		118,106
	11	21,530	21•0	18,261	19•3	20,168	20•5	20,026	20•0	17,738	20•9	14,212	22•2		111,935
	12	19,721	19•3	16,655	17•6	18,466	18•8	20,050	20•0	16,728	19•7	13,404	21•0		105,024
	Number missing	0		0		456		0		0		384			840
Gender															
	Boy	55,998	54•7	48,077	50•7	48,794	49•4	51,587	51•6	41,225	48•5	34,582	53•9	<0.001	280,263
	Girl	46,453	45•3	46,700	49•3	50,073	50•7	48,463	48•4	43,763	51•5	29,570	46•1		265,022
	Number missing	0		0		0		0		0		177			177
Mental health															
	Good	56,112	55•2	50,737	54•1	52,384	53•8	59,093	60•3	35,615	42•8	28,045	45•0	<0.001	281,986
	Poor	45,528	44•8	43,038	45•9	44,968	46•2	38,860	39•7	47,649	57•2	34,232	55•0		254,275
	Number missing	811		1002		1515		2097		1724		2052			9201
Eating breakfast															
	Sometimes/seldom	17,561	18•2	14,091	15•4	14,281	14•6	12,618	12•9	11,255	13•7	9169	14•7	<0.001	78,975
	Daily	78,733	81•8	77,461	84•6	83,273	85•4	85,330	87•1	70,688	86•3	53,262	85•3		448,747
	Number missing	6157		3225		1313		2102		3045		1898			17,740
Participating in extracurricular activities															
	No	33,017	33•0	27,812	30•5	28,529	29•4	27,710	28•4	25,470	31•0	17,123	27•5	<0.001	159,661
	Yes	67,157	67•0	63,271	69•5	68,396	70•6	69,894	71•6	56,689	69•0	45,141	72•5		370,548
	Number missing	2277		3694		1942		2446		2829		2065			15,253
Having fun at school															
	Yes	58,752	58•4	58,058	63•5	62,523	64•2	65,208	66•7	54,395	66•2	41,697	67•0	<0.001	340,633
	Neither	32,739	32•5	25,836	28•3	27,121	27•9	25,661	26•3	21,548	26•2	16,249	26•1		149,154
	No	9137	9•1	7568	8•3	7688	7•9	6891	7•1	6172	7•5	4311	6•9		41,767
	Number missing	1823		3315		1535		2290		2873		2072			13,908
Present drinking alcohol															
	No	71,684	70•3	78,312	83•1	84,038	85•6	87,569	87•9	76,605	91•8	60,282	94•4	<0.001	458,490
	Yes	30,233	29•7	15,956	16•9	14,127	14•4	12,034	12•1	6812	8•2	3584	5•6		82,746
	Number missing	534		509		702		447		1571		463			4226
Present smoking															
	No	91,603	90•5	89,640	94•8	94,723	96•0	97,075	97•2	82,568	98•1	63,299	98•8	<0.001	518,908
	Yes	9614	9•5	4903	5•2	3934	4•0	2851	2•9	1570	1•9	769	1•2		23,641
	Number missing	1234		234		210		124		850		261			2913
Intention to study at university															
	No	62,996	62•7	53,441	58•5	57,990	59•6	58,919	60•2	48,708	59•1	34,854	55•9	<0.001	316,908
	Yes	37,467	37•3	37,936	41•5	39,291	40•4	38,893	39•8	33,655	40•9	27,515	44•1		214,757
	Number missing	1988		3400		1586		2238		2625		1960			13,797

p-values were calculated for chi-square-test (survey year) × (each variables).
Participants for whom data were missing were excluded from the analyses.

Table 3
Trends of sleep problems from 2004 to 2017 in Japanese adolescents.

	Insomnia (n = 328,379)				Sleep duration (n = 533,580)				LBT (n = 118,933)				Poor sleep quality (n = 206,446)			
	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value	OR	95% CI		p-value
Trend (2004–2017)																
Adjusted	0.85	0.82	0.87	<0.001	1.13	1.10	1.17	<0.001	1.17	1.12	1.23	<0.001	0.92	0.88	0.95	<0.001
Crude	0.74	0.73	0.75	<0.001	0.93	0.92	0.95	<0.001	0.88	0.86	0.91	<0.001	0.86	0.85	0.88	<0.001

Abbreviations: OR = odds ratio, CI = confidence interval.
Participants for whom data were missing were excluded from the analyses.
Insomnia in those who answered that they experienced one or more symptoms of DIS, DMS, or EMA "often" or "always" was classified as "severe" and in those who answered "sometimes" was classified as "moderate.".
Sleep duration were classified as less than five hours, five hours or more but less than six hours, six hours or more but less than seven hours, seven hours or more but less than eight hours, eight hours or more but less than nine hours, and nine hours or more.
LBT: late bedtime (after 1:00 a.m.).
Poor sleep quality: those who answered that their sleep quality was bad or very bad.
Odds ratios were derived from ordinal and binary logistic regression models and adjusted for participants' weight, birth cohort, gender, junior/senior high school, grade, mental health status, breakfast consumption, club activity, having fun at school, drinking alcohol status, smoking status, and intention to study at university.



(a) The unadjusted prevalence of each sleep problem by survey year

(b) The adjusted prevalence of each sleep problem by survey year

Fig. 1. Trends of the prevalence of each sleep problem by survey year.

Table 4
Sensitivity analyses for trend of sleep problems among Japanese adolescents from 2004 to 2017.

	Insomnia (n = 114,421)				Sleep duration <7 h (n = 404,392)			
	AOR	95% CI		p-value	AOR	95% CI		p-value
Trend (2004–2017)	0.87	0.83	0.91	<0.001	1.37	1.31	1.43	<0.001
	LBT (n = 242,815)				Poor sleep quality (n = 28,379)			
	AOR	95% CI		p-value	AOR	95% CI		p-value
	1.15	1.11	1.20	<0.001	0.84	0.77	0.91	<0.001

Abbreviations: AOR = adjusted odds ratio, CI = confidence interval.
Participants for whom data were missing were excluded from the analyses.
This logistic model was adjusted for participants' weight, birth cohort, gender, junior/senior high school, grade, mental health status, breakfast consumption, club activity, having fun at school, drinking alcohol status, smoking status, and intention to study at university.
Insomnia: Those who experienced one or more of DIS, DMS, or EMA "often" or "always" were considered to have insomnia.
SSD: short sleep duration (< 7 h).
LBT: late bedtime (after 12:00 a.m.).
Poor sleep quality: those who answered that their sleep quality was very bad.

from 37•9% in 2004 to 36•2% in 2017 (AOR 0•92, 95% CI 0•88–0•95). Conversely, the adjusted odds ratio of shorter sleep duration significantly increased (AOR 1•13, 95% CI 1•10–1•17) and the adjusted prevalence of LBT increased from 21•0% in 2004 to 21•9% in 2017 (AOR 1•17, 95% CI 1•12–1•23).

3.1. Sensitivity analyses

The odds ratios of all sleep problems were in the same direction as the original results (Table 4). The statistical tests for all analyses remained highly significant (p<0•001), suggesting that the results are robust to these alternative definitions of sleep problems. The adjusted prevalence of sleep duration below seven hours increased from 71•9% in 2004 to 78•1% in 2017 (AOR 1•37, 95% CI 1•31–1•43) (Table 4 and Fig. 1). There were no gender differences in the trends of sleep problems (Supplemental Table 1).

4. Discussion

This study is the first nationwide, representative study to examine trends of sleep problems among Japanese adolescents and indicates decreased trends of insomnia symptoms and poor sleep quality in this population from 2004 to 2017. However, there were increasing trends toward shorter sleep duration and late bedtimes.

Thus, both welcome and unwelcome developments were observed in adolescent sleep patterns, with important implications for public health.

Surprisingly, the decreasing trend of insomnia observed among Japanese adolescents contrasts with trends in other countries. A large international study including 33 European countries/regions reported that the average prevalence of sleep-onset difficulties in adolescents aged 11, 13, and 15 years increased from 17•5% in 2002 to 20 0•8% in 2014 [12]. Twenty-eight out of the 33 countries showed an increasing trend in the prevalence of difficulty falling asleep during the 12-year period, except for Greece (−4•3%), Spain (−4•1%), Norway (−2•0%), England (−1•7%), and Portugal (−1•3%) [12]. Difficulty in sleep-onset and DIS represent the same symptom, which is the highest among all the insomnia symptoms [7]. In Finland, the prevalence of insomnia symptoms (DIS and DMS) increased approximately two-fold from the mid-1990s to the end of the 2000s, while the increasing trend for insomnia abated after 2008 [24]. Thus, in many countries, the prevalence of insomnia-related symptoms has tended to increase while, in a few countries, a downward trend has been observed.

The trend of shorter sleep duration worsened between 2004 and 2017. Several studies have reported on trends of sleep duration in adolescence. In the U.S., compared to 1995, the probability of regularly getting more than seven hours of sleep significantly decreased from 1996 to 2012 [9]. Additionally, U.S. adolescents in 2015 were 16–17% more likely to report insufficient sleep compared to 2009 [13]. Matricciani et al. noted that 34 of the 51 reports on long-term trends in sleep time among school-aged children cited evidence of declines in sleep duration [25]. 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 [26]. Notably, later night electronic media use is associated with delayed bedtimes and shortened sleep duration [13,26]. These results of increasing trends of shorter sleep duration and delayed bedtimes are consistent with those of the present study.

The National Sleep Foundation recommends that adolescents should sleep nine hours per night [27], but our results demonstrated that almost all Japanese adolescents get significantly less than nine hours of sleep [6]. The consistent declines observed in adolescents' sleep are concerning given that shorter sleep durations have been associated with negative health outcomes such as cardiovascular disease, diabetes mellitus, and depression [28]. One of the key questions for future research is whether sleep deprivation experienced during adolescence has an adverse effect on adult health, independent of sleep duration in adulthood.

Our results revealed that the prevalence of insomnia and poor sleep quality among Japanese adolescents decreased between 2004 and 2017. There are at least two possible explanations for these results. The first explanation is related to sleep education policy in school. The Ministry of Health, Labour and Welfare of Japan introduced the "Sleep Guidelines for Health Promotion" in 2003 and dissemination of information on sleep has been promoted in cooperation with the local governments and mass media. In 2014, the sleep guidelines were changed to 12 messages on how to improve sleep for health and how adequate sleep can reduce the risk of non-communicable diseases as well as accidents. The 12 messages were included in the Japanese school text. These policies may have raised the general population's awareness of sleep by promoting sleep hygiene education activities and campaigns through the mass media [17]. Our data showed lower smoking and drinking alcohol prevalence and higher breakfast intake rates during this period, which suggests that adolescents tend to exhibit healthy lifestyle behaviors. Lifestyle education was also taught in japan schools. In fact, smoking education in Japanese schools contributed to the reduction of smoking rates [29]. For cultural reasons, the magnitude of the effectiveness of lifestyle education in schools may be greater in Japan than in Western countries. Thus, these activities can, directly and indirectly, produce positive changes or prevent negative changes in sleep problems. In reference to these life style behaviors and the prevalence insomnia parallel, consider clearly stating that this relationship is correlational and not causal. Future studies will require a longitudinal approach to examine the relationship between lifestyles and sleep problems.

The second potential explanation is a change in the value placed on sleep among the Japanese with the greater public recognizing that sleep deprivation is associated with reduced academic performance and both physical and mental illness. These changes in understanding the effect of poor sleep may have led to improved sleep hygiene.

Interestingly, the present survey showed a discrepancy between insomnia improvement and the worsening of mental health problems between 2004 and 2017. There are at least two possible explanations for the discrepancy. First, insomnia and short sleep duration are known to be related to mental health problems [7,30]. Our data suggested that short sleep duration may have a greater association with mental health than insomnia. Our hypothesis was supported that short sleep duration was significantly associated with most mental health problems in adolescents without insomnia but not in those with insomnia [31]. Second, this study used GHQ-2 to evaluate mental health. However, this scale is too short and may not represent the actual prevalence of poor mental health. Future research should use more appropriate scales such as GHQ-12 or Depression Self-Rating Scale for Children [32].

Some limitations of this study bear mention. First, the data are subject to a variety of biases. For example, a non-response bias existed, as over 40% of adolescents did not participate in the 2017 survey. This could be due to some schools refusing to participate in the survey at the discretion of the school principals. However, the survey accounts for nonresponse by weighting participants relative to their likelihood of responding. These weights increase the likelihood that the data obtained are adequately representative of the target population. Second, although we adjusted for several potential confounding variables, no data on factors related to participants' socioeconomic status (SES) such as family income or parental educational levels, school start time, pubertal development, or media screen-time were available. Previous research indicates an association between sleep problems and these factors [13,14,27,33–35]. Thus, future research should include SES, school start time, pubertal development, and media screen-time factors. Third, due to limited space on the questionnaire, our insomnia assessment did not include the entire clinical diagnostic criteria listed in the International Classification of Sleep Disorders [36]. Therefore, insomnia as measured in this study may not reflect clinical insomnia. Future studies should use validated questionnaires such as the Insomnia Severity Index (ISI) and Pittsburgh Sleep Quality Index (PSQI) [37,38]. Fourth, the surveys did not distinguish between sleep duration on weekends and weekdays. Objective data indicate that a misalignment in bedtimes and wake-up times on both weekdays and weekends have been observed among East Asian adolescents [15]. Previous research indicated that irregular sleep-wake patterns characterized by variations between school day and non-school day sleep-wake timing may be a factor contributing to sleep problems [39]. Some researchers have recommended a school start time later than 8:30 am in junior and senior high schools to ensure adolescent health and improve academic performance [40]. Future studies should examine not only the total sleep duration but also the regularity of adolescent sleep-onset and wake-up time on weekends and weekdays and school start time. Fifth, this study was based on self-reports, which are prone to bias. Objective measurements such as an actigraph could be employed to evaluate sleep duration. Although desirable, such measurements are not normally included in epidemiological stud-

ies because of the number of participants involved. However, several studies have indicated that self-reported sleep data have moderate agreement with laboratory studies [41].

In conclusion, findings from this study of large-scale repeated cross-sectional surveys of adolescents in Japan over 13 years suggest that insomnia and poor sleep quality are declining; however, many adolescents continue to have late bedtimes and a lack of sufficient sleep duration. Despite the improvement of insomnia and sleep quality, the survey's results suggested that adolescents should show greater interest in their sleep duration; inadequate sleep may cause, and aggravate, physical and mental health problems. These results could be useful in developing more effective prevention strategies in the future. Interventions tailored to prevent late bedtimes may aid in maximizing the effects of health education in adolescence. Finally, the results provide a benchmark for future monitoring of trends in adolescent sleep in Japan and other East Asian countries.

5. Contributors

Dr. Otsuka and Dr. Kaneita conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript.

Dr. Spira and Dr. Mojtabai critically reviewed the manuscript for important intellectual content and edited the manuscript.

Drs. Iatni, Jike, Kuwabara, and Kinjyo designed the data collection instruments and collected data.

Drs. Kanda and Higuchi conceptualized and designed the study.

Dr. Osaki conceptualized and designed the study, and coordinated and supervised data collection.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Declaration of Competing Interest

Yoshitak Kaneita reports grants from Eisai, outside the submitted work; Adam P. Spira received an honorarium from Springer Nature Switzerland AG for Guest Editing a Special Issue of Current Sleep Medicine Reports. The other authors declare no conflicts of interest associated with this manuscript.

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Data Sharing

The datasets generated and/or analyzed during 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.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.lanwpc.2021.100107.

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