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Heat-not-burn tobacco, electronic cigarettes, and combustible cigarette use among Japanese adolescents: a nationwide population survey 2017

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Abstract

Background: From among the global public health concerns, smoking remains one of the most crucial challenges. Especially for adolescents, the increase in the use of electronic cigarettes is controversial, as its use may lead to established smoking. In Japan, where a unique tobacco regulation system exists, the heat-not-burn tobacco market has been growing. However, the prevalence and association of combustible cigarettes and new tobacco-related products have not yet been closely investigated among Japanese adolescents. This study aimed to clarify the prevalence of smoking among adolescents, including new types of tobacco-related products, and to compare the characteristics of their users.

Methods: The 2017 Lifestyle Survey of Adolescents is a nationally-representative survey collected in Japan. From the national school directory, 98 junior high schools and 86 high schools were randomly sampled throughout Japan. The students completed an anonymous questionnaire at school. We calculated the prevalence of use for each type of tobacco product. Then, the use of a combination of products and the characteristics of different types of products were examined.

Results: In total, 64,152 students from 48 junior high schools and 55 high schools were included the analysis (school response rate = 56%, M_{age} = 15.7 years, 53.9% boys). The age-adjusted rate of ever (current) use of electronic cigarettes was 2.1% (0.7%) in junior high school and 3.5% (1.0%) in high school; that of combustible cigarettes was 2.6% (0.6%) in junior high school and 5.1% (1.5%) in high school. The rate of heat-not-burn tobacco use was lower relative to other products: 1.1% (0.5%) in junior high school and 2.2% (0.9%) in high school. An examination of the combined use of the three products identified a high number of dual users. Comparisons between different types of users indicated different backgrounds for combustible cigarette users and new product users.

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Conclusions: The prevalence of new tobacco-alternative products is growing in popularity among Japanese adolescents. Dual use is common, and many adolescents use new products only. Moreover, e-cigarettes might attract a broader range of groups to smoking. Continuous monitoring and research are needed to investigate their influence as a possible gateway to tobacco smoking.

Keywords: Cigarette smoking, E-cigarettes, Tobacco use, Adolescents, Smoking, Heat-not-burn tobacco, Prevalence

Background

Smoking is a preventable health risk factor that results in numerous diseases and deaths [1, 2]. Smoking control is particularly critical among adolescents, as individuals who use tobacco at a young age are at a considerably higher risk of becoming subsequent smokers [3]. Moreover, tobacco can be a gateway to other types of drug dependence [4]. Therefore, smoking control during adolescence is a crucial public health issue. The National Health Promotion Act has focused on tobacco control, and the prevalence of adolescents who report having smoked combustible cigarettes within last 30 days has continued to decline from 2000 to 2014; 9.4/5.6% (boys/girls) to 1.3/0.6% in junior high school students and 29.9/13.1% to 3.5/1.5% in high school students [5]. However, in recent years, tobacco industries have begun selling new tobacco-related products such as electronic cigarettes (e-cigarettes) and heat-not-burn (HNB) tobacco as alternatives to combustible cigarettes [6].

E-cigarettes use a battery to heat a cartridge containing a liquid, generating steam (i.e. smoke from burning is not generated) [7, 8]. E-cigarettes were first launched in China in 2003, and their consumption has shown a global growth through intense promotion via media geared towards young people, such as YouTube [9, 10]. In smoking surveys worldwide, a rapid rise in the use of e-cigarettes has been seen among adults and adolescents [11–13]. Some of the purported benefits of e-cigarettes are that fewer harmful substances are generated compared to combustible cigarettes [14, 15] and that they can lead to the reduction or cessation of combustible cigarette use. However, there is a concern, particularly for adolescents, that the use of e-cigarettes may cause an increase in established smokers in the future [16]. Moreover, the longitudinal health impact of e-cigarettes has not yet been sufficiently clarified [17]; thus, its use involves potential harm. In Japan, the emergence of e-cigarettes was evaluated by the authorities, and the sale of e-cigarettes containing nicotine is prohibited by the Pharmaceutical Affairs Law of 2010. However, e-cigarettes without nicotine are accessible to adolescents and youth because they are not covered by this law.

HNB tobacco, also known as the 'I-quit-ordinary-smoking' (IQOS) system, involves an electronic device that heats tobacco leaves in a stick, and the user inhales the generated aerosol instead of smoke [18]. Tobacco companies in Japan are promoting HNB tobacco as a cigarette that causes less harm to users and bystanders. Philip Morris International (PMI) petitioned the US Food and Drug Administration for approval of HNB tobacco products as a smoking cessation tool, but the application was declined. In 2014, PMI introduced IQOS only in Japan and Italy and was available in 37 countries by August 2018. Japan is the unique country in which HNB tobacco was legally sold nationwide under the Tobacco Industries Act, making it an important market for companies that produce HNB products [19]. The popularity and use of HNB tobacco have increased [20]; in October 2016, Japan comprised 98% of the worldwide IQOS sales [21]. Other HNB products include Japan Tobacco's Ploom TECH (2016) and British American Tobacco's Glo product line (2016). Thus, tobacco companies are looking to expand their market offerings [22].

In Japan, where there is a unique market for tobacco-related products, reports on the prevalence of e-cigarette and HNB tobacco use are limited to Internet surveys targeting individuals aged over 18 [23]. As the rapid increase in the popularity of e-cigarettes among adolescents in other countries and of HNB tobacco use in Japan, investigating the prevalence of new products among adolescents is important. Thus, from the 2017 Lifestyle Survey of Adolescents, we obtained data on junior high and high school students' smoking habits and their use of the new types of tobacco-related products in Japan. Our study aimed to clarify the prevalence of smoking of combustible cigarettes and new tobacco products, as well as the combined use of these products and to compare the background of adolescent users of different types of products.

Methods

Study population

This study aimed to evaluate the nationwide prevalence of use of cigarettes and alternative tobacco products. Considering sampling bias, this study involved a cross-sectional random sample survey with single-stage cluster sampling [24], wherein the school was set as the cluster unit. Using the national school directory, junior high schools attended by students aged 12 to 15 and high schools, attended by students aged 15 to 18, throughout Japan were randomly selected, and the survey was

distributed to all students in these schools in 2017. A total of 98 of Japan's 10,325 junior high schools and 86 of the 4907 high schools were sampled. The proportion of private schools was 8.2% of junior high schools and 19.8% of high schools. The survey period was from December 2017 to February 2018.

Data collection

We asked the school principals for cooperation and sent the survey forms to them for distribution to students through class teachers, who explained to the students that participation was voluntary and that they should answer honestly. The students were given anonymous questionnaires and envelopes, which were completed and sealed by the students, collected by their teachers, and then returned to our research office with the seals intact. This survey was approved by the Ethics Review Committee of Tottori University Faculty of Medicine.

Measures

The questionnaire survey focused on adolescents' lifestyle, such as smoking behaviour, alcohol use, and school life (Additional File 1). Referring to the questionnaires used by Centers of Disease Control and Prevention and WHO [25, 26], the questions about smoking included experience with and frequency of combustible cigarette smoking: 'Have you ever smoked a combustible cigarette including even a single puff?' and 'How many days have you smoked combustible cigarettes in the previous 30 days?'. Similar questions were used for new tobacco-alternative products. *Ever users*, *current users*, and *daily users* were defined as those who had smoked even once in the past, had smoked at least once in the past 30 days, and had smoked every day for the past 30 days, respectively. These definitions of frequency were also used for users of e-cigarettes and HNB tobacco.

Tobacco products

Since we needed to discriminate between combustible cigarettes and new tobacco-alternative products, in the questionnaire, we described a combustible cigarette as 'a cigarette made from rolled paper and tobacco and smoked with fire'. Due to the number of e-cigarette brands currently for sale, we used the names of the most popular brands in the questionnaire, stating 'electronic cigarettes include brands such as フレヴォ (FLEVO), エミリ (EMILI), ビタフル (VITAFUL), and ビタシグ (VITASIG)'. The question for HNB tobacco also included product names to avoid any confusion: 'heat-not-burn tobacco is any product such as アイコス (IQOS), プルームテック (Plume Tech), or グロー (glo)'.

Data analysis

The age-adjusted prevalence rates were calculated using the number of junior high and high school students nationwide from the School Basic Survey of the Ministry of Education, Science and Technology (2017) as a standard population. Proportions with a 95% confidence interval (95% CI), as presented in the tables, were calculated using a weighting method based on one-stage cluster random sampling [24]. Two proportion *Z*-tests were conducted to compare the prevalence of each product between boys and girls. To observe the associations between the use of the three different types of products, we calculated the prevalence of combined use. Then, the proportions of combined use of products were calculated, which made the comparison of combined use easier. Moreover, the background of ever users of different products was compared in terms of gender, school grade, municipality size, having breakfast, and participating in club activities. IBM SPSS 25.0 was used for all data analyses.

Results

A total of 56% of 184 schools, including 48 of 98 junior high schools (response rate: 49%) and 55 of 86 high schools (response rate: 64%) took part in the survey. In total, 64,417 questionnaires were returned to the research office. After excluding the questionnaires that were blank, or had invalid/missing gender information or inconsistent responses, 64,152 questionnaires were analysed. The characteristics of the study participants are shown in Table 1. The mean age (standard deviation) of students in junior high school was 13.7 (1.0) years, and 16.7 (0.9) years for high school students. For the gender-ratio, 50.3% of junior high school students and 55.8% of high school students were boys.

Rates of cigarette and new tobacco-alternative product use

Broken down by product type and student gender, the age-adjusted rate of students who were ever/current/every day users of cigarettes, e-cigarettes, or HNB tobacco are shown in Table 2.

The rate of ever users of cigarettes (male/female/both) was 3.1% (95% CI: 3.0, 3.2)/2.1% (95% CI: 2.0, 2.2)/2.6% (95% CI: 2.5, 2.7) for junior high school students, and 6.9% (95% CI: 6.6, 7.2)/3.3% (95% CI: 2.0, 2.2)/5.1% (95% CI: 2.3, 2.9) for high school students. E-cigarette use was slightly lower than cigarette use, at 2.4% (95% CI: 2.3, 2.5)/1.7% (95% CI: 1.6, 1.8)/2.1% (95% CI: 2.0, 2.2) among junior high school students, and 4.9% (95% CI: 4.7, 5.1)/2.1% (95% CI: 2.1, 2.1)/3.5% (95% CI: 3.3, 3.7) among high school students. The rate of HNB tobacco users was relatively lower relative to other products, at 1.3% (95% CI: 1.3, 1.3)/0.9% (95% CI: 0.9, 0.9)/1.1% (95%

Table 1 Baseline characteristics of the study participants

	Male		Female		Total	
	n = 34,582		*n* = 29,570		*n* = 64,152	
	n	%	n	%	n	%
School grade						
Junior high school (12–15 y/o)						
Grade 7	3740	10.8	3644	12.3	7384	11.5
Grade 8	3687	10.7	3642	12.3	7329	11.4
Grade 9	3702	10.7	3713	12.6	7415	11.6
High school (15–18 y/o)						
Grade 10	7963	23.0	6238	21.1	14,201	22.1
Grade 11	7903	22.9	6309	21.3	14,212	22.2
Grade 12	7470	21.6	5934	20.1	13,404	20.9
Unknown	117	0.3	90	0.3	207	0.3
Municipality size groups						
Large cities	5551	16.1	5968	20.2	11,519	18.0
Cities with populations ≥300,000	10,203	29.5	7288	24.6	17,491	27.3
Cities with populations ≥100,000	11,049	32.0	9339	31.6	20,388	31.8
Cities with populations < 100,000	5995	17.3	5168	17.5	11,163	17.4
Smaller towns and villages	1784	5.2	1807	6.1	3591	5.6
Having breakfast						
Every day	28,070	81.2	25,192	85.2	53,262	83.0
Sometimes	3079	8.9	2600	8.8	5679	8.9
Seldom	2169	6.3	1321	4.5	3490	5.4
Unknown	1264	3.7	457	1.5	1721	2.7
Participating in club activities						
Active	20,106	58.1	16,136	54.6	36,242	56.5
Passive	4667	13.5	4232	14.3	8899	13.9
Not engaging	8477	24.5	8646	29.2	17,123	26.7
Unknown	1332	3.9	556	1.9	1888	2.9

CI: 1.0, 1.2) among junior high school students, and 2.9% (95% CI: 2.8, 3.0)/1.4% (95% CI: 1.4, 1.4)/2.2% (95% CI: 2.0, 2.4) among high school students. Experience with of all products was significantly higher among adolescent boys than girls.

The rate of current use of the three products (male/female/both) was rare. For cigarettes, the rate was 0.7% (95% CI: 0.7, 0.7)/0.5% (95% CI: 0.5, 0.5)/0.6% (95% CI: 0.5, 0.7) among junior high school students, and 2.0% (95% CI: 1.9, 2.1)/0.9% (95% CI: 0.9, 0.9)/1.5% (95% CI: 1.4, 1.6) among high school students. For e-cigarettes, it was 0.8% (95% CI: 0.8, 0.8)/0.5% (95% CI: 0.5, 0.5)/0.7% (95% CI: 0.6, 0.8) for junior high school students, and 1.5% (95% CI: 1.4, 1.6)/0.5% (95% CI: 0.5, 0.5)/1.0% (95% CI: 0.9, 1.1) for high school students. For HNB tobacco, it was 0.6% (95% CI: 0.6, 0.6)/0.4% (95% CI: 0.3, 0.5)/0.5% (95% CI: 0.5, 0.5) for junior high school students, and 1.2% (95% CI: 1.1, 1.3)/0.6% (95% CI: 0.6, 0.6)/0.9% (95% CI: 0.8, 1.0) for high school students. Among high school students, current use of three products were significantly higher among boys than girls. Significant difference was observed only in e-cigarette use among junior high school students.

The proportion of students who used the products every day was quite low, with the highest prevalence being that of cigarette use among high school students (male/female/both): 0.7% (95% CI: 0.6, 0.8)/0.2% (95% CI: 0.2, 0.2)/0.5% (95% CI: 0.4, 0.6). The age-adjusted rates for the new products were 0.1% or less.

As shown in Fig. 1, the use of combustible cigarettes was the most prevalent regardless of grade level. Ever use of e-cigarettes followed slightly below that of cigarettes, especially among the younger generation. A divergence was evident between ever use of HNB tobacco and that of the two other types. As for current use, the graphs of the three products overlapped each other in

Table 2 Junior high (grades 7–9) and high school (grades 10–12) students' age-adjusted smoking prevalence rates by gender

	Ever C use		Ever EC use		Ever HNB use	
	%	95% CI	%	95% CI	%	95% CI
Grades 7–9						
Male	3.1	3.0, 3.2	2.4	2.3, 2.5	1.3	1.3, 1.3
Female	2.1**	2.0, 2.2	1.7**	1.6, 1.8	0.9*	0.9, 0.9
Both	2.6	2.5, 2.7	2.1	2.0, 2.2	1.1	1.0, 1.2
Grades 10–12						
Male	6.9	6.6, 7.2	4.9	4.7, 5.1	2.9	2.8, 3.0
Female	3.3**	3.2, 3.4	2.1**	2.1, 2.1	1.4**	1.4, 1.4
Both	5.1	4.8, 5.4	3.5	3.3, 3.7	2.2	2.0, 2.4
	Current C use		Current EC use		Current HNB use	
	%	95% CI	%	95% CI	%	95% CI
Grades 7–9						
Male	0.7	0.7, 0.7	0.8	0.8, 0.8	0.6	0.6, 0.6
Female	0.5	0.5, 0.5	0.5**	0.5, 0.5	0.4	0.4, 0.4
Both	0.6	0.5, 0.7	0.7	0.6, 0.8	0.5	0.5, 0.5
Grades 10–12						
Male	2.0	1.9, 2.1	1.5	1.4, 1.6	1.2	1.1, 1.3
Female	0.9**	0.9, 0.9	0.5**	0.5, 0.5	0.6**	0.6, 0.6
Both	1.5	1.4, 1.6	1.0	0.9, 1.1	0.9	0.8, 1.0
	Daily C use		Daily EC use		Daily HNB use	
	%	95% CI	%	95% CI	%	95% CI
Grades 7–9						
Male	0.2	0.2, 0.2	0.1	0.1, 0.1	0.1	0.1, 0.1
Female	0.1	0.1, 0.1	0.1	0.1, 0.1	0.1	0.1, 0.1
Both	0.1	0.1, 0.1	0.1	0.1, 0.1	0.1	0.0, 0.2
Grades 10–12						
Male	0.7	0.6, 0.8	0.1	0.1, 0.1	0.1	0.1, 0.1
Female	0.2**	0.2, 0.2	0.1	0.1, 0.1	0.0**	0.0, 0.0
Both	0.5	0.4, 0.6	0.1	0.1, 0.1	0.1	0.1, 0.1

C combustible cigarette, *EC* electronic cigarette, *HNB* heat-not-burn tobacco, *CI* confidence interval
Two proportion Z-tests were conducted to compare male and female.
**$P < 0.01$, *$P < 0.05$

the younger generation, but in grades 11 and 12, combustible cigarette use was significantly higher than the use of the other two products.

Combined use of any tobacco product

The age-adjusted rates of combined use of tobacco-related products were calculated (Additional File 2), including all possible combinations of combustible cigarettes, e-cigarettes, and HNB tobacco. Across the various patterns, the exclusive users of cigarettes and exclusive users of e-cigarettes were the largest groups.

Moreover, to make comparisons more understandable, the proportions of ever and current users of any product are shown in Table 3. In terms of ever use, the proportion of exclusive users of combustible cigarettes was about 40% of users of any product in both junior high schools and high schools. Meanwhile, around 36% of users of any product used only e-cigarettes and/or HNB tobacco in junior high schools. Among high school users, around 25% of males and 32% of females ever used either one or both new alternative products. Furthermore, among junior high school students who currently used any product, exclusive e-cigarette users were the largest group among all patterns of use. In high school, exclusive combustible cigarette use, 30%, was dominant across the patterns; however, more than 30% of users currently used only new alternative products. It is worth mentioning that dual users who currently used both cigarettes and another type of products exceeded 30% in junior high school as well as in high school.

Additional File 3 shows the comparison of ever users of different products according to gender, school grade, municipality size, custom of having breakfast, and participation in club activities. Across the different users, the proportions of males were higher than those of females. However, gender differences were smaller when comparing e-cigarette users and HNB users with cigarette users. There were upward trends from lower to higher school grades in exclusive cigarette use and cigarette use combined with other products, but the trends were not clear among new alternative products users. Regarding lifestyle, adolescents who ever used new types of products showed acceptable habits. The percentage of individuals who had breakfast every day and participated in club activities was higher among new products users than among cigarette users.

Discussion

This study is the first in Japan to examine the prevalence of use of combustible cigarettes and new tobacco-alternative products among adolescents. At present, the rate of combustible cigarette use was the highest, followed by e-cigarettes and HNB tobacco use. The rates of use for all three products rose in tandem with increasing school grade. The prevalence of combustible cigarette use was much higher relative to alternative products among high school students, as these alternative products had been introduced into the market more recently. However, ever use of e-cigarettes became close to that of combustible cigarettes among the younger generations. Moreover, the current use of the three products was quite similar, suggesting that new tobacco-alternative products are becoming popular among young users.

Japan is included in the countries with the lowest smoking prevalence according to a World Health Organization report on the global tobacco epidemic

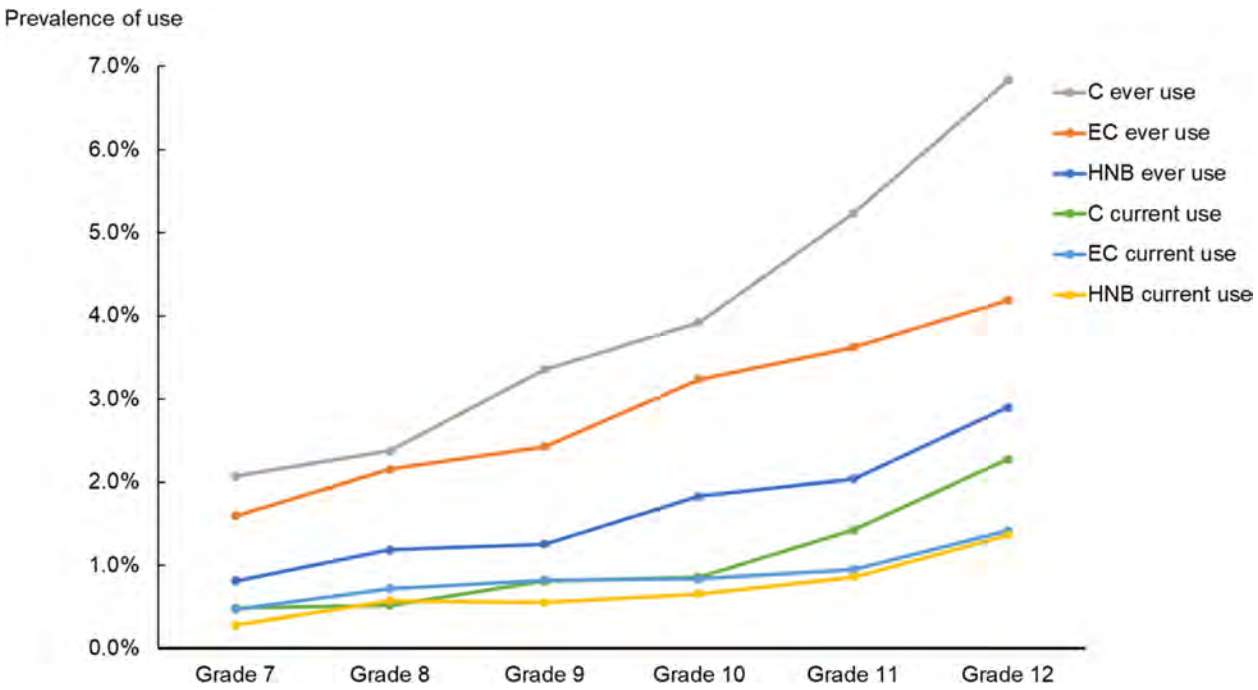

Fig. 1 Prevalence of the three tobacco-related products in each grade (both genders). C: combustible cigarette, EC: electronic cigarette, HNB: heat-not-burn tobacco

Table 3 Junior high (grades 7–9) and high school (grades 10–12) students' age-adjusted prevalence of combined smoking by gender

Proportions of students who ever used either

			Grades 7–9, ever use (%)			Grades 10–12, ever use (%)		
C	EC	HNB	Male	Female	Both	Male	Female	Both
+	–	–	41.1	40.3	40.8	38.4	43.2	39.8
+	+	–	7.8	6.5	7.3	11.6	6.0	10.0
+	–	+	5.6	4.4	5.1	8.1	7.9	8.0
+	+	+	9.6	12.3	10.7	16.7	10.2	14.8
–	+	–	26.3	27.5	26.8	20.0	23.6	21.1
–	–	+	5.0	4.4	4.7	2.7	5.5	3.5
–	+	+	4.6	4.6	4.6	2.4	3.5	2.7

Proportions of students who currently used either

			Grades 7–9, current use (%)			Grades 10–12, current use (%)		
C	EC	HNB	Male	Female	Both	Male	Female	Both
+	–	–	23.3	20.9	22.4	30.7	29.9	30.5
+	+	–	4.6	3.2	4.1	6.8	6.6	6.8
+	–	+	4.7	9.9	6.6	13.7	17.4	14.6
+	+	+	18.7	28.5	22.4	16.0	14.6	15.7
–	+	–	31.3	28.6	30.3	21.3	16.0	20.0
–	–	+	10.0	7.7	9.1	6.5	9.5	7.3
–	+	+	7.3	1.1	5.0	4.9	6.0	5.1

Proportions excluding those who did not smoke any products
C combustible cigarette, *EC* electronic cigarette, *HNB* heat-not-burn tobacco

[27]. The present study focused on the use of new tobacco-alternative products among Japanese adolescents. However, even considering the increasing prevalence of these new products, the smoking rate has shown a downward trend compared with the respective proportions in time-series data. The current use of e-cigarettes of 0.7% in junior high schools and 1.0% in high schools in Japan is lower than that reported by the 2017 National Youth Tobacco Survey in the US (3.3% in middle school and 11.7% in high school) [28]. The law that regulates the sale of e-cigarettes containing nicotine in Japan might contribute to the lower use of these products. Another explanation may be that HNB tobacco exists as a substitute for e-cigarettes. Even though the current use of new products was low in our study, the use of e-cigarettes has been increasing in several countries. Continuous monitoring of e-cigarette use is thus indispensable.

Moreover, given the large population of e-cigarettes among any products users, it is of significance in assessing whether e-cigarettes used by Japanese adolescents contain nicotine or not. A previous study among Canadian high school students by Hamilton et al. showed that approximately 72% of those adolescents who were ever e-cigarettes users used non-nicotine e-cigarettes, while about 28% used nicotine e-cigarettes [29]. Similarly, a previous study indicated that in Japan, about 30% of ever users of new tobacco products used e-cigarettes containing nicotine [19]. The regulation of e-cigarettes in

Canada is quite similar to that in Japan, suggesting that the figures among the Japanese adolescents might be comparable to Hamilton's results. To note, Tabuchi et al. indicated that about 15% of those who were ever users had used e-cigarettes with unknown nicotine. Misinformation about nicotine content is concerning because nicotine might impact the developing brain of adolescents [29]. Future research should investigate these issues.

The prevalence of HNB tobacco use was lower than that of e-cigarette use; however, HNB tobacco use was still observed among adolescents. To our knowledge, there are no comparable reports about HNB tobacco use in other countries. Tabuchi et al. reported the current use as 3.6% in a 2017 internet survey targeting adults in Japan [23], which is comparable to our results. The prevalence of HNB tobacco use is more similar between adolescents and adults relative to the prevalence of combustible cigarette use. Awareness of and advertisements for HNB tobacco have increased in recent years [22]; a domestic Japanese newspaper reported in 2018 that the sales units of HNB tobacco exceeded 2 million for Glo, 5 million for IQOS, and 4 million for Ploom Tech, and indicated that the tobacco market was accelerating the shift to HNB tobacco [30]. The association between smoking rates and tobacco advertisements has been previously studied, and the increase in the use of e-cigarettes in Western countries has been attributed to media promotion [31]. The current momentum of HNB tobacco in Japan is expected to affect its future use rates. Its prevalence should be monitored, as there is substantial uncertainty regarding the health consequences of HNB tobacco [32, 33].

Gender differences in the prevalence rates were examined in the current study. Boys were more likely to use the tobacco-related products, which is consistent with the results previously reported by the WHO [27] and another study conducted in Japan [19, 23]. Previous research has indicated the importance of investigating gender difference in e-cigarette marketing strategies including innovations in product features (e.g., packaging and device design, appealing flavours), as they can influence gender difference in consumption. The authors also highlighted the necessity of examining gender differences in nicotine use by quantifying the amount of nicotine in the e-cigarettes being used by youth [34]. To our knowledge, no research to date has investigated gender difference in HNB consumption. Future research should examine the context in which gender differences in nicotine use might occur.

This study also examined the various patterns of use of the three products. As for adolescents' ever use and current use, exclusive cigarette use was dominant in all cases except for the exclusive use of e-cigarettes in junior high school. A considerable proportion of any-product users were ever or current users of new alternative products only. Therefore, it is an important concern whether e-cigarette or HNB tobacco use can lead to established cigarette use in the future. A previous systematic review indicated that the use of e-cigarettes among adolescents was likely to cause subsequent cigarette smoking [16]. Although it is unclear, it is plausible that the use of HNB tobacco use has the same consequences. Future research is required to clarify this issue.

Another concern is 'dual use' which refers to the use of both combustible cigarette and at least one new tobacco products. Our results suggest that the proportion of dual users exceeded 30% in junior high school as well as in high school. Although the latest expert consensus indicated that e-cigarette use is much less harmful than smoking combustible cigarettes [17], dual use potentially denotes the addition of unknown harm from e-cigarettes or HNB tobacco to that of smoke from combustible cigarettes [17]. There is controversy over whether dual use of e-cigarettes can assist with smoking cessation or not. A recent systematic review has indicated that e-cigarettes are not likely to lead to smoking cessation [16]. Furthermore, to date, there has been no empirical evidence that has indicated that HNB tobacco products play a role in cessation. Future research should investigate these issues in order to clarify their implications for the overall health impact of e-cigarettes and HNB tobacco in Japan.

Moreover, our results indicated different characteristics in the healthy behaviours between those who were cigarette users and new products users. Previous studies have suggested that smoking is associated with an unhealthy lifestyle [35, 36]. Similarly, an association between health risk behaviour and e-cigarettes use has been reported [37]. However, to our knowledge, the relationship between new products and healthy behaviour among adolescents has not been sufficiently investigated. Dunbar et al. concluded that e-cigarettes use among adolescents is not necessarily associated with greater engagement in health behaviours compared to cigarette use [37]. With regard to HNB tobacco, Lee et al. indicated that physically active adolescents were more likely to use cigarettes as well as new products [38] and theorised that these findings were owing to peer influences from participating social activities. However, our results suggest that new products may be an entrance to smoking for a broad variety of adolescents, who are less likely to begin smoking if using combustible cigarettes alone. Previous studies indicated that new products might entice new groups of consumers with characteristics distinct from those of combustible cigarette smokers [39, 40]. Although the mechanism has not been

sufficiently clarified, it could be that new adolescent users may believe that the new products are 'safe' [41]. Future studies are needed to examine the association between health behaviours and the type of products used by adolescents. It is also significant to clarify whether young people who are at low-risk of becoming smokers are more attracted by new products.

A strength of the present study is that our large student sample represents the nationwide adolescent population of Japan. In addition, considering our specific tobacco regulation, Japan is a fertile market for tobacco industries. Our study is unique in that it reports on a novel product, HNB tobacco, which is not available in all countries. However, in this survey, the number of schools selected was relatively smaller than in past studies. Additionally, the response rates in junior high schools were low, leading to the use of age-adjusted rates in the tables. This study required strict ethical considerations due to the age groups taking part, which may have contributed to the low response rate. Although we devised questions about e-cigarettes and HNB tobacco, including the trade names of popular products, students still may not have recognised these products correctly and could have confused e-cigarettes and HNB tobacco. It is also difficult to confirm the validity of self-report answers. Continuous monitoring using the same standards and methods may be the only feasible option. Furthermore, this study entailed a cross-sectional analysis; therefore, the temporal relationship of how the smokers' practices changed as a consequence of the emergence of new tobacco products could not be clarified. Future research should address these limitations.

Conclusions

According to this nationwide population survey, the prevalence of new tobacco-related products is just below the use of combustible tobacco among Japanese adolescents. Dual use is common, and e-cigarettes or HNB tobacco use represent a considerable proportion of the tobacco-related products used by youth. Findings from background comparison suggest that new tobacco-related products might lure a broader population into smoking. The longitudinal impact of these new products remains unclear; thus, continuous monitoring and further research are necessary to provide guidance for the implementation of enhanced public measures against smoking and the use of new tobacco-related products.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12889-020-08916-x.

Additional file 1. The list of questions from the survey questionnaire

Additional file 2. Junior high (grades 7–9) and high school (grades 10–12) students' age-adjusted combined smoking prevalence rates by gender.

Additional file 3. Patterns of ever use of tobacco-related products by demographics, lifestyle, and future education intention.

Abbreviations

E-cigarette: Electronic cigarette; HNB: Heat-not-burn; CI: Confidence interval; WHO: World Health Organization

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Authors' contributions

YO, SH, and YoK designed the study and devised the study protocols. OI, YuO, MJ, and HY did the literature review and helped summarise previous research studies. HK, AK, MF, and AI carried out the statistical analyses. YK wrote the first draft of the manuscript. All authors have read and approved the manuscript.

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Availability of data and materials

The datasets used in the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The participants were older than 12 years of age. Before the survey, the school principals provided participants' parents with the details of the survey. The parents were advised that they were allowed to refuse participation if they were reluctant to allow their children to take part in the survey. In other words, the parents were given the opportunity to opt their children out of the survey if they were not comfortable with them participating in the survey. The students whose parents refused permission for the survey were not included. This survey and opt out parental consent procedure were approved by the Ethics Review Committee of Tottori University Faculty of Medicine (reference no. 17A078).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Comparing Factors Related to Any Conventional Cigarette Smokers, Exclusive New Alternative Product Users, and Non-Users among Japanese Youth: A Nationwide Survey

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Abstract: The impact of heated-tobacco-products (HTPs) and electronic cigarettes (e-cigarettes) on youth is a controversial public health issue, as it is unknown whether alternative products result in more youth using such products or smoking. In Japan, e-cigarettes with nicotine are prohibited, but e-cigarettes without nicotine are available. HTPs are marketed as tobacco products. Within this unique context, we aimed to compare any conventional cigarette smokers (including those who also used alternative products) with exclusive users of alternative products and examine factors relating to their use in Japan. In 2017, 22,275 students in grades 7–9 (age 12–15) and 42,142 in grades 10–12 (age 15–18) nationwide were surveyed. Overall, 1.8% were current users of any of the three products over the last month. Multivariable analysis revealed that risk factors for alternative product use were the same as those for cigarette use. Among all users, exclusive new product users were more likely to participate in club activities and intend to continue to higher education; any conventional cigarette users (including those who also used alternative products) were more likely to be exposed to secondhand smoke at home and to drink alcohol. Reducing adult smoking and disseminating health education remain relevant as strategies for preventing adolescents' future tobacco use.

Keywords: cigarette smoking; e-cigarettes; tobacco use; adolescents; smoking; heat-not-burn tobacco; heated tobacco product; Japan; tobacco control policies; WHO Framework Convention on Tobacco Control (FCTC); noncombustible tobacco/nicotine products; harm reduction

1. Introduction

Tobacco control presents a crucial public health challenge worldwide. A wide range of health problems are attributable to tobacco use, including not only non-communicable diseases, but also perinatal problems and impaired physical and mental development [1]. In fact, premature death due to tobacco use is more preventable than deaths caused by any other drugs [2]. Moreover, the younger people are when they start smoking, the more likely they are to continue smoking [3], making them susceptible to well established smoking-related diseases including cancer, cardiovascular disease and respiratory diseases. The World Health Organization (WHO) has taken the initiative in promoting

global tobacco control. Since 2008, the WHO Framework Convention on Tobacco Control (FCTC) has been endorsing practical and cost-effective ways to reduce tobacco demand worldwide using the acronym MPOWER, standing for Monitor (use and prevention), Protect (people from smoke), Offer (help in quitting), Warn (about dangers), Enforce (bans on advertising, promotions and sponsorship) and Raise (taxes on tobacco products).

Smoking cigarettes comprises one of the biggest risk factors for death and disease in Japan, as indicated by a study that estimated the contribution of several risk factors to disability-adjusted life years (DALYs) in Japan from the findings of the Global Burden of Disease (GBD) 2010 project [4]. The Institute for Health Metrics and Evaluation (IHME), a research center dedicating to measuring health problems affecting populations worldwide, reported that cigarette smoking was the dominant risk for death and disability combined in Japan for all years from 2007 through 2017 [5]. Due to the seriousness of the problems associated with smoking, the Ministry of Health, Labor, and Welfare (MHLW) has been tackling issues of tobacco control. In 2000, the national health promotion campaign 'Healthy Japan 21' was launched, which included dissemination of knowledge about the health effects of smoking, encouraging youth to stop smoking, calling for the separation of smoking areas and launching a smoking cessation program. In 2003, the Health Promotion Law mandated the management of public facilities to prevent public exposure to secondhand smoke. The law promoted the creation of smoke-free spaces and smoke-free regulation by local authorities. Since 2013, Healthy Japan 21 (second term) has been in effect. The tobacco control measure included four main objectives: (1) decrease the smoking rate for adults from 19.5% in 2010 to 12% in 11 years; (2) eliminate smoking among adolescents and young adults; (3) stop women from smoking during pregnancy; and (4) decrease the occurrence of secondhand smoke and eliminate smoke exposure in all administrative and medical institutions. These political measures added to the already-existing nationwide tobacco controls and smoking prevalence has been decreasing for both adults and adolescents over several decades [6], yet tobacco regulation in Japan still has not met all the FCTC's recommendations [7].

Meanwhile, new types of alternative nicotine delivery products such as e-cigarettes and various heated tobacco products (HTPs, also called heat-not-burn tobacco products) have emerged in the tobacco market. The e-cigarettes market has rapidly expanded according to a report from the WHO [8]. This matches the findings of a separate study that reported on the prevalence of these new products in several parts of the world [9]. Additionally, the U.S. Center for Disease Control recently reported the trial of e-cigarettes (people 'trying' the product) exceeds that of conventional cigarettes in the US [10]. A study from Japan also indicated an increase in the trial of new alternative products [11].

Recently, the U.S. Food and Drug Administration (FDA) permitted the sale of IQOS—an HTP that generates a nicotine aerosol compound—with restrictions on how it can be marketed [12]. While tobacco industries advertise that the tobacco used in HTPs is cleaner, public health experts are discussing the challenges and opportunities created by these new products.

Some of the challenges involve how to categorize and regulate the products, and regulation varies across different countries. Notably, Japan is unique in that national law prohibits selling e-cigarettes containing nicotine, but HTPs are sold as legal tobacco products. In terms of regulation, e-cigarettes without nicotine are available to everyone in Japan, but the purchase and use of HTPs are prohibited among people aged under twenty years old. The age requirement for cigarettes is also twenty years old.

There is a significant and controversial public health concern as to whether the novel products attract susceptible young non-users to initiate use of e-cigarettes or HTPs and then go on to smoking [13]. Previous studies have shown that some youth who are otherwise at low risk for smoking cigarettes, and therefore at low risk for using nicotine, are attracted to using e-cigarettes [14] and later begin to smoke conventional cigarettes [15]. Moreover, to consider the overall population impact of HTPs, more evidence is necessary to inform discussion of the likelihood of adolescents who are not tobacco users or who are former tobacco users adopting the use of nicotine with the new products [16]. On the other hand, if the novel products are confined to youth who are already likely to become smokers,

or who use them to stop smoking, they may represent an opportunity to reduce the number of adolescents who are harmed by the effects of combustible cigarettes [17].

The purpose of this study was to compare the background of conventional cigarette smokers with exclusive users of alternative products among young people aged 12 to 18 to highlight the difference between the groups.

2. Materials and Methods

2.1. Study Population

In 2017, Japan had 10,325 registered junior high schools and 4907 registered senior high schools in a total of 47 prefectures. For our study, schools were chosen for students to participate in a lifestyle survey of adolescents. The participating schools were selected using a cross-sectional random sample method with single-stage cluster sampling [18], wherein a school was considered a cluster unit. The sampling method included dividing Japan into regional blocks and randomly selecting schools from each block. The advantage of this methodology is the minimization of sampling bias [18]. Using the national school directory, junior high schools and senior high schools throughout Japan were randomly extracted, and the survey was administered to all students in these schools. Thereby, 98 of Japan's junior high schools from 44 prefectures and 86 of the senior high schools from 42 prefectures were sampled; therefore, the selection rates were 0.95% and 1.75% of all schools, respectively. Private schools comprised 8.2% of the junior high schools and 19.8% of the senior high schools in the study. The surveys were administered from December 2017 through February 2018.

2.2. Data Collection

We approached the principal of each school for cooperation and sent the survey forms to the schools. The principals arranged for class teachers to distribute the forms to the students. The teachers explained to the students that participation was voluntary and that they should answer honestly. The students were given anonymous questionnaires and envelopes, which were completed and sealed by the students, collected by their teachers, and then returned to the research office with the seals intact.

2.3. Measures

The questionnaire included information about basic demographic data (sex, school grade, type of school); use of cigarettes, e-cigarettes and HTPs; exposure to secondhand smoke and understanding of the harmful effects of smoking; lifestyle behaviors and intentions regarding future education; and alcohol use. The list of the questions was provided in Supplementary file 1.

2.4. Use of Cigarettes, e-Cigarettes and Heated Tobacco Products

2.4.1. Discrimination of the Three Products

The three products were described in detail to ensure students were able to distinguish between them. Since we focused on investigating alternative products, we explained that a conventional cigarette is considered, 'a cigarette made from rolled paper and tobacco and smoked with fire'. Due to the number of e-cigarettes currently for sale, we used the names of the most popular brands in the survey; for example, e-cigarettes included フレヴォ(FLEVO), エミリ (EMILI), ビタフル (VITAFUL) and ビタシグ (VITASIG). HTPs were also explained using product names to avoid any confusion; for example, heat-not-burn tobacco included アイコス (IQOS), プルームテック (Ploom Tech) and グロー (glo).

2.4.2. Frequency of Use

To assess the frequency of conventional cigarette use, with the explanation of products above, we used two questions: 'Have you ever smoked a conventional cigarette, including even a single puff?'

and 'How many days have you smoked conventional cigarettes in the previous 30 days?' Similar questions were used to determine the frequency of use of alternative products. For the experience question, 'No, I have not' or 'Yes, I have' were response options. To assess frequency of use, seven options were given: '0 days,' '1–2 days,' '3–5 days,' '6–9 days,' '10–19 days,' '20–29 days,' or 'every day'.

'Experience' of cigarette/e-cigarette/HTP use was defined as smoking/using even once in the past; 'current' use of cigarettes/e-cigarettes/HTPs was defined as smoking/using at least once in the past 30 days. 'Current use' is more relevant to actual smoking behavior and is commonly used as an indicator of adolescent smoking. Furthermore, previous studies suggest that even minimal use of cigarettes leads to a significantly higher risk of becoming a chronic smoker [19,20]. Therefore, we determined 'current use' as a feasible outcome to use for analysis.

Additionally, in our analyses, we used 'exclusive-use' categories, meaning the exclusive use of a particular type of product. For instance, if we described 'exclusive alternative product use', the group included participants who currently used either e-cigarettes or HTPs but did not use conventional cigarettes. 'Non-current user' was defined as those who currently used neither cigarettes, e-cigarettes, nor HTPs. 'Any conventional cigarette smokers' were defined as those who currently smoke conventional tobacco cigarettes, including those who currently smoke conventional tobacco cigarettes exclusively and those who currently use conventional tobacco products plus HTP and/or e-cigarettes.

2.5. Lifestyle Behaviors and Intentions towards Future Education

In Japan, many students participate in after-school clubs. Some students engage in sports clubs at school, such as baseball, tennis or basketball; others choose cultural clubs, such as brass band, tea ceremony and flower arrangement. The questions asked about how often students participated in such 'after school club' activities as well as how often they had breakfast and their plans for the future. For analysis, answers indicating they eat breakfast 'every day' were categorized into 'Yes'; answers of 'sometimes' or 'seldom' were categorized as 'No.' Regarding their plans for the future, students selected one out of seven options: 'vocational school,' 'junior college,' 'college,' 'postgraduate school,' 'taking a job after graduating the current school,' and 'not decided yet'. We categorized those who selected 'college' or 'postgraduate school' into the 'college or more' group.

2.6. Exposure to Secondhand Smoke and Understanding the Harmful Effects of Smoking

For the survey questions about smoking exposure, we did not discriminate between the three products and described smoke as from 'tobacco.' In addition, 'to smoke' was the same as 'to use tobacco.' Students were asked about if and how often they were exposed to secondhand smoke at home. Participants who indicated they had been exposed at least once in the preceding seven days were categorized as 'exposed.' Survey questions were also used to determine how much students understood about the health risks of smoking. We categorized those who selected 'I think that smoking is harmful' into 'Yes' for understanding the harmful effects of smoking; all other responses were categorized as 'No.' Likewise, understanding the harm associated with secondhand smoking was evaluated; participants who selected 'I think it is harmful' were categorized into the 'Yes' group for understanding and all other responses were considered 'No.'

2.7. Alcohol Use

We assessed how many days participants had engaged in drinking alcohol in the previous 30 days and the frequency of binge drinking. We consider drinking 'a lot' to be 'five or more' drinks of an ordinary can (350 mL) for beer and sweet cider. We defined a 'current drinker' as a student who had used alcohol on more than one or two days in the previous month and 'binge drinkers' as those who used alcohol including more than five cans of beer or sour at least once in a month. Specifically, having multiple drinks 'once or twice in a month', 'once or twice in a week', or 'more than three times in a week' were categorized as 'yes' for 'binge drinking' for the purpose of analysis.

2.8. Data Analysis

First, a descriptive analysis of the baseline characteristics of the study participants was performed including their grade levels (junior or senior high school), the overall prevalence of use of any products, and factors known to be associated with smoking. Second, Chi-squared tests were used to examine differences in each factor between any conventional cigarette smokers and non-current users. The Mantel–Haenszel test was used to compare the trends of the proportion of use in each school grade. Similarly, exclusive users of alternative products were compared with non-current users and then with any conventional cigarette smokers (including dual users and multiple users). For the latter comparison, we were interested in whether those youth who currently used only alternative products differed from those who currently smoked conventional cigarettes. Furthermore, in the comparison, we conducted the statistical tests for each of the 11 variables; hence, the Bonferroni correction was used to adjust the cut-off of p-values for significance due to multiplicity. Third, a multivariable logistic regression analysis was used to investigate the relationship between the use of cigarettes and several factors from the questionnaire. The adjusted odds ratio (OR) was calculated for each factor and its 95% confidence interval (95% CI) for cigarette use. Likewise, another logistic regression analysis was done with alternative product use. Finally, among any product users, the risk of alternative product use was compared with any conventional cigarette users in a third logistic regression model. Before the logistic regression analysis, the researchers discussed the relevance of all of the variables in this study and selected, by consensus, those most appropriate for inclusion in the models. Descriptive analysis and univariate analysis were performed using SPSS 25.0 (IBM Corp, New York, NY, USA). R i386 3.5.2 (R Foundation for Statistical Computing, Vienna, Austria) was used to conduct multivariable logistic regression analyses. Missing data were excluded from the analysis. We also conduct a supplementary analysis to compare exclusive cigarette users and exclusive alternative products (APs) users.

2.9. Ethical Statement

According to the Ethical Guidelines for Epidemiological Studies jointly announced by the Ministry of Health, Labor and Welfare and the Ministry of Education, Culture, Sports, Science and Technology of Japan, personal information is defined as follows: information of a living individual and the name, birthday and other descriptions included in that information that can be used to identify a specific individual. The questionnaire in our survey did not include any such information in consideration of identity protection and safeguarding privacy. This survey was reviewed and approved by the Ethics Review Committee of Tottori University School of Medicine when we conducted the survey (reference no. 17A078).

3. Results

The flow and results of the data collection are described in Figure 1. A total of 184 schools (98 junior high, 86 high school) were invited and 56.0% (103), including 49.0% of junior highs (48) and 64.0% of high schools (55), agreed to participate. The response rate of all students in the participating schools was 90.5% (64,152 of 70,927) for fully completed surveys, including 84.0% (22,215 of 26,604) from the junior highs and 94.6% (41,937 of 44,323) from the high schools.

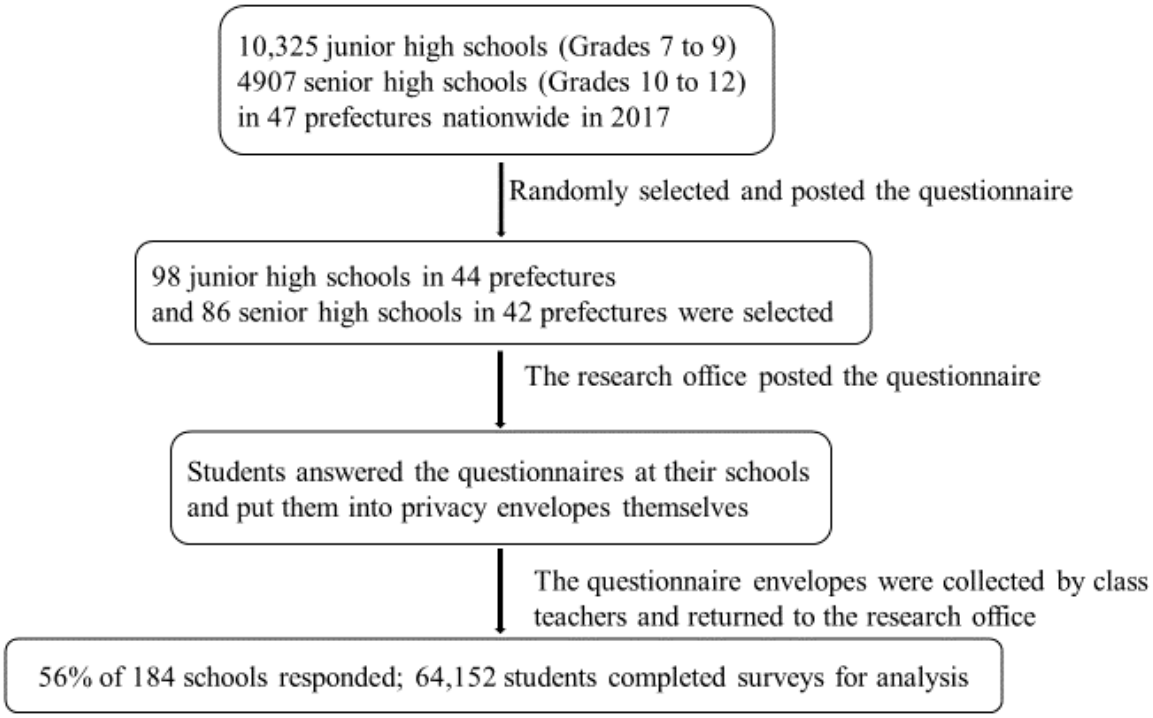

Figure 1. Flowchart of data collection.

Figure 1. Flowchart of data collection.

3.1. Participant Characteristics

Table 1 shows the baseline characteristics of the study participants. In terms of lifestyles, the proportion of participants who indicated mostly healthy lifestyle habits was higher in junior high school students than senior high school students; however, more senior high students than junior high students intended to go to college or university. Regarding students who had used any products (tobacco or alternative); 4.1% in junior high and 7.3% in senior high school had at some time in their lives; 1.1% in junior high and 2.2% in senior high had at least once within the 30 days preceding the survey. The percentage of students who reported drinking alcohol at least once in the past month was 2.9% in junior high and 7.0% in senior high school. While binge drinking was quite rare in junior high school (0.6%), 1.9% of senior high school students responded that they had five or more cans of alcoholic beverages in one bout of drinking at least once in the preceding month.

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To clarify the relationships between the use of the three different products, we created a Venn diagram (Figure 2) to show the total number of respondents who were 'currently' using each product. Overall, 1.8% (n = 1183) students reported using any product at least once in the prior month. Just over 40% were currently using more than one product; 200 students (17% of all current users) were 'currently' using all three products. Thirty percent of those using any product were exclusive e-cigarette or exclusive HTPs users, although compared to cigarettes and e-cigarettes, the number of respondents who only used HTPs was small. Thus, HTPs were most commonly used along with other products.

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Table 1. Baseline characteristics of the study participants.

		Junior High School (Grades 7 to 9) N = 22,215		Senior High School (Grades 10 to 12) N = 41,937	
		n	(%)	n	(%)
Sex (Female)		11,036	(49.7)	18,534	(44.2)
School grade					
	First grade	7384	(33.2)	14,201	(33.9)
	Second grade	7329	(33.0)	14,212	(33.9)
	Third grade	7415	(33.4)	13,404	(32.0)
Having breakfast every day		19,079	(85.9)	34,183	(81.5)
Engaging in club activities		17,605	(79.3)	27,536	(65.6)
Future education intention (College or more)		4253	(19.1)	23,262	(55.5)
Experience of any tobacco or alternative products (Once in life)		911	(4.1)	3063	(7.3)
Current use of any tobacco or alternative products (Once in last 30 days)		244	(1.1)	939	(2.2)
Currently drinking alcohol (Once in last 30 days)		634	(2.9)	2950	(7.0)
Binge drinking [a]		134	(0.6)	809	(1.9)

[a] People who drink more than five cans of beer or sour at least once in a month.

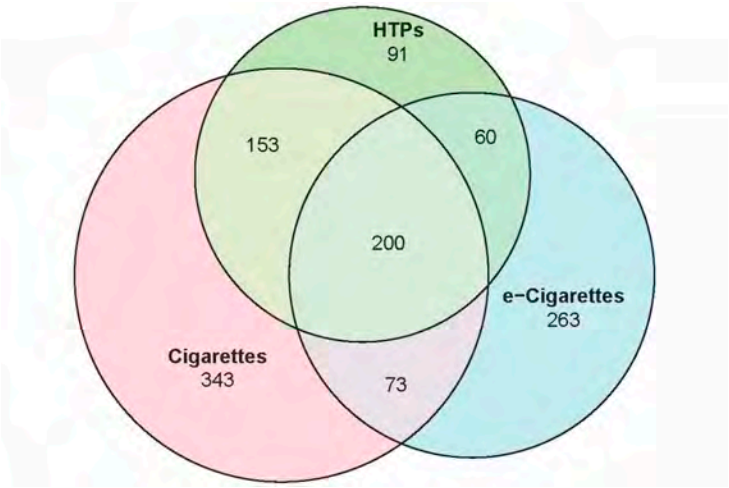

Figure 2. The number of current users of any products, Grade 7–12, male and female. In total, n = 1183 (1.8%; N = 64,152). The overlap areas represent those who used both or all; the non-overlap area indicates the total number of students who used each product exclusively. Abbreviations: HTPs = heated-tobacco products.

3.2. Comparison among Any Conventional Cigarette Users, Exclusive Alternative Products Users and Non-Users

Table 2 compares the proportion of respondents according to sociodemographic, lifestyle and other variables among three groups: people who do not currently use any products, any conventional cigarette users and exclusive AP users (the numbers vary slightly from table to table due to missing data). By Bonferroni correction, we adjusted the cut-off for significance as $p < 0.0045$. Overall, more males than females were users of any type of product; however, there was no significant difference between genders among users in terms of which type of product they used (cigarettes or APs). Regarding school grade, the trend in the proportions of the three groups were significantly different. For other variables—having breakfast every day, engaging in club activities, understanding the health effects of smoking, exposure to secondhand smoke and alcohol use—the proportions of students

were significantly different between non-users and the other two groups. Moreover, the statistical tests showed that there were significant differences in those variables between AP users and any conventional cigarette users, except for that of having breakfast every day, future education intention and understanding of harmful effects of smoking.

Table 2. Cross-comparison of three group: non-users with any conventional cigarette smokers and exclusive alternative-product use in youth, including demographics, lifestyles, school life and drinking habits.

	1. People Who Say They Do Not Use Any Products		2. Any Conventional Cigarette Users		3. Exclusive AP Users		1 vs. 2	1 vs. 3	2 vs. 3
	N = 62,969		*N* = 769		*N* = 414				
Variables	***n***	**(%)**	***n***	**(%)**	***n***	**(%)**	***p*-Value**	***p*-Value**	***p*-Value**
Female gender	29,243	(46.4)	218	(28.3)	109	(26.3)	<0.001	<0.001	0.459
School grade [a]							<0.001 [b]	<0.001 [b]	<0.001 [b]
Grade 7	7327	(99.2)	36	(0.5)	21	(0.3)			
Grade 8	7246	(98.9)	38	(0.5)	45	(0.6)			
Grade 9	7314	(98.6)	60	(0.8)	41	(0.6)			
Grade 10	13,981	(98.5)	122	(0.9)	98	(0.7)			
Grade 11	13,914	(97.9)	203	(1.4)	95	(0.7)			
Grade 12	12,989	(96.9)	305	(2.3)	110	(0.8)			
Having breakfast every day	52,605	(83.5)	406	(52.8)	251	(60.6)	<0.001	<0.001	0.010
Engaging in club activities	44,558	(70.8)	330	(42.9)	253	(61.1)	<0.001	<0.001	<0.001
Future education intention (College or more)	27,251	(43.3)	155	(20.2)	109	(26.3)	<0.001	<0.001	0.015
Understanding that smoking is harmful	57,188	(90.8)	514	(66.8)	296	(71.5)	<0.001	<0.001	<0.100
Understanding that secondhand smoking is harmful	55,239	(87.7)	574	(74.6)	298	(72.0)	<0.001	<0.001	<0.321
Secondhand smoking at home	16,526	(26.2)	530	(68.9)	224	(54.1)	<0.001	<0.001	<0.001
Secondhand smoking out of home	18,576	(29.5)	621	(80.8)	225	(54.3)	<0.001	<0.001	<0.001
Currently drinking alcohol (Once in 30 days)	2884	(4.6)	546	(71.4)	154	(37.6)	<0.001	<0.001	<0.001
Binge drinking [b]	583	(0.9)	316	(41.1)	44	(10.6)	<0.001	<0.001	<0.001

Abbreviations: APs = alternative products. Missing data were excluded in each analysis. *p*-Values are based on Chi-squared test. [a.] Mantel–Haenszel test for trend is used in the variable. [b] People who drink more than five cans of beer or cider at least once in a month.

3.3. The Association between Selected Factors and Any Conventional Cigarette Smoking or Exclusive Alternative Products Use

The results of a logistic regression analysis examining the risk factors for any conventional cigarette smokers compared with non-users are shown in Table 3. All factors—sex, school grade, understanding that smoking is harmful, having breakfast every day, participating in club activities, intending to go to college or a higher education course and present alcohol drinking—were significantly associated with any conventional cigarette smoking after mutual adjustment. Similarly, an analysis comparing lifestyle variables of exclusive AP users with those of non-users revealed that seven out of eight variables were significantly associated with AP use (Table 4). Although the students engaging in club activities were less likely to smoke cigarettes (OR 0.64, 95% CI 0.54, 0.76), the variable was not a significant preventive factor for exclusive AP use (OR 1.17, 95% CI 0.94, 1.48).

Table 3. Results of logistic regression: association between selected factors and any conventional cigarette smokers (n = 63,738).

Variables	OR	95% CI			p-Value
Sex					
Female	0.50	0.42	to	0.59	<0.01
Male (reference)	1.00				
School grade *	1.06	1.04	to	1.08	<0.01
Understand that smoking is harmful					
Yes	0.45	0.38	to	0.55	<0.01
No (reference)	1.00				
Having breakfast every day					
Everyday	0.69	0.58	to	0.83	<0.01
Sometimes, seldom (reference)	1.00				
Participating in club activities					
Yes	0.64	0.54	to	0.76	<0.01
No (reference)	1.00				
Intending to pursue higher education					
College or postgraduate school	0.49	0.40	to	0.59	<0.01
Others (reference)	1.00				
Secondhand smoking at home					
At least once in the preceding 7 days	3.18	2.68	to	3.78	<0.01
None in the preceding 7 days (reference)	1.00				
Currently drinking alcohol					
At least once in the previous month	34.66	29.31	to	41.12	<0.01
None in the previous month (reference)	1.00				

* This variable was modeled as a continuous variable. Abbreviations: OR = Odds ratio, 95% CI = 95% confidence interval.

Table 4. Results of logistic regression: association between selected lifestyle variable factors and exclusive alternative products use (n = 63,383).

Variables	OR	95% CI			p-Value
Sex					
Female	0.48	0.38	to	0.60	<0.01
Male (reference)	1.00				
School grade *	1.03	1.01	to	1.06	<0.01
Understand that smoking is harmful					
Yes	0.47	0.37	to	0.60	0.01
No (reference)	1.00				
Having breakfast every day					
Everyday	0.59	0.47	to	0.75	<0.01
Sometimes, seldom (reference)	1.00				
Participating in club activities					
Yes	1.17	0.94	to	1.48	0.17
No (reference)	1.00				
Intending to pursue higher education					
College or postgraduate school	0.61	0.48	to	0.77	<0.01
Others (reference)	1.00				
Secondhand smoking at home					
At least once in the preceding 7 days	2.24	1.82	to	2.76	<0.01
None in the preceding 7 days (reference)	1.00				
Currently drinking alcohol					
At least once in the previous month	9.29	7.51	to	11.46	<0.01
None in the previous month (reference)	1.00				

* This variable was modeled as a continuous variable. Abbreviations: OR = odds ratio, 95% CI = 95% confidence interval.

3.4. The Risk of Exclusive Alternative Product Use Compared with Any Conventional Cigarette Smoking among Any Product Users

Table 5 shows the result of logistic regression analysis which examined risk-associated lifestyle variables for exclusive AP users compared with those for any conventional cigarette smokers among users of any products. The results show that AP users were less likely to be higher school grade, more likely to participate in club activities (OR 1.61, 95% CI 1.22, 2.12), less likely to be exposed to secondhand smoking at home (OR 0.68, 95% CI 0.52, 0.90) and less likely to be current alcohol drinkers (OR 0.27, 95% CI 0.21, 0.35). In addition, there was a borderline significant association of exclusive AP users with 'intention to pursue higher education' (OR 1.35, 95% CI 0.99, 1.83).

Table 5. The risk of exclusive alternative product use compared with any conventional cigarette use among any product users (n = 1183).

Variables	OR	95% CI			p-Value
Sex					
Female	1.02	0.75	to	1.37	0.91
Male (reference)	1.00				
School grade *	0.96	0.93	to	0.99	0.02
Understand that smoking is harmful					
Yes	1.18	0.89	to	1.57	0.26
No (reference)	1.00				
Having breakfast everyday					
Everyday	1.03	0.78	to	1.35	0.84
Sometimes, seldom (reference)	1.00				
Participating in club activities					
Yes	1.61	1.22	to	2.12	<0.01
No (reference)	1.00				
Intending to pursue higher education					
College or postgraduate school	1.35	0.99	to	1.83	0.06
Others (reference)	1.00				
Secondhand smoking at home					
At least once in the preceding 7 days	0.68	0.52	to	0.90	0.01
None in the preceding 7 days (reference)	1.00				
Currently drinking alcohol					
At least once in the previous month	0.27	0.21	to	0.35	<0.01
None in the previous month (reference)	1.00				

* This variable was modeled as a continuous variable. Abbreviations: OR = Odds ratio, 95% CI = 95% confidence interval. An odds ratio of greater than one indicates that exclusive alternative product users had higher odds of the factor than any conventional cigarette users.

The results of an additional logistic regression analysis were the same as for the groups compared above regarding club activities and alcohol use when comparing exclusive combustible cigarette smoking (conventional cigarettes only) to exclusive AP use, (Supplementary file 2).

4. Discussion

The prevalence of any current product use in this Japanese sample, (1.1% of junior high school and 2.2% of senior high school) in 2017, was much lower than has been shown for students in the U.S. (7.2% of middle school and 27.1% of high school [10]) and UK (5% of 11–15 years old who smoke cigarettes at least once in a week and 6% of young people estimated as current e-cigarette users [21]). The prevalence of current cigarette smoking has continued to decline from 2000 to 2014; 9.4/5.6% (boys/girls) to 1.3/0.6% in junior high school students and 29.9/13.1% to 3.5/1.5% in high school students [6]. Our data indicates the continuous downward trends. The relationship between the three products illustrates a significant minority (30%) of those who used any products were exclusive AP users. The prevalence of smoking was much lower than alcohol use among Japanese adolescents.

We were interested in whether the factors related to exclusive use of APs are different from those of any conventional cigarette smokers. To examine this question, we compared three groups: people who do not currently use any products, current AP-exclusive users and any current conventional cigarette smokers. There were significant differences between non-users and exclusive APs users or any cigarette smokers (in all variables studied. In addition, comparing exclusive APs users and any cigarette smokers), four of the eight factors were statistically significant. These results suggest that participant characteristics may be different between non-users and any product users and some of these differed also between AP users and cigarette smokers. Across each variable, the results for AP users fell between the variable results for non-users and those for cigarette users.

The results of logistic regression analysis showed that known factors were significantly associated with any conventional cigarette smoking and APs use even after mutual adjustment. When exploring the difference between exclusive APs users and any conventional cigarette smokers—including those who also use HTPs or e-cigarettes, the conventional cigarette users were more likely to be exposed to secondhand smoke and drinking at home than AP-only users. Moreover, we found that there were differences in participating in club activities between the two groups; intention to pursue higher education also showed borderline significance. These results may suggest different factors—including social circumstances such as parental support, family income, or personal characteristics—may exist between exclusive AP users and those smoking cigarettes with or without the use of other products. Broadly consistent results were found when comparing exclusive cigarette smokes with exclusive AP users. The implications of this are unclear as those exclusively using APs may have previously smoked conventional cigarettes and stopped or may go on to smoke conventional cigarettes or remain exclusive AP users. This requires further research.

Our analytical strategy followed that of a previous study by Hanewinkel et al. that investigated risk factors associated with the use of e-cigarettes in a cohort study among German adolescents [22]. They compared the effect of each risk factor across e-cigarette, conventional cigarette and dual product use. The study implied the possibility that e-cigarettes attract a broader range of adolescents compared to conventional cigarettes. Several results of the present cross-sectional study were consistent with the Hanewinkel's study. Gender and parent smoking showed significant effects on the use of both e-cigarettes and cigarettes. In addition, in their study, the relationship with a future academic career varied between e-cigarettes users and conventional cigarette users. Regarding HTPs, the findings of Wu et al.'s study indicate that relatively well-educated people tend to use HTPs [23]. These findings support our borderline significance in the association between education and exclusive APs use. Moreover, the previous cross-sectional study by Wills et al. [24] tried to determine whether established risk factors for smoking discriminate user categories by testing how e-cigarette users differed on a range of variables including social-cognitive factors, problem behavior risk factors and collateral substance use. Their findings showed parental factors, academic achievement, behavioral self-control, smoking expectancies, alcohol use, and heavy drinking significantly varied across non-users, e-cigarette exclusive users and dual users. Thus, their results also support our findings.

On the other hand, East et al. explained the former issue in a more nuanced way [25]. In their longitudinal study, they indicated that e-cigarette use was associated with cigarette use and vice versa. Certain psychological processes ('common liabilities') are used to explain the relationship of two. Specifically, curiosity, rebelliousness, and sensation-seeking were indicated as the psychological factors affecting product use. These psychological mechanisms also influence alcohol use. Hence, the strong association between any conventional cigarette smokers and alcohol use may be explained by these factors. In addition, the authors discussed several important differences to consider. In the UK, e-cigarettes are more accessible and convenient for young people compared to combustible cigarettes. Novel devices, the variety of flavors and the reduced risks of the new products have been demonstrated to be attractive to youth. Hair et al. also indicated that HTPs attract youth by the novelty [26]. Thus, several reports clarify that APs often appeal to those who are not smokers, but it remains unclear whether people in this group would have gone on to smoking if APs had not been on the market.

Furthermore, it is necessary to further investigate the exclusive conventional cigarette use and the use of conventional cigarettes plus APs and their association with secondhand smoke at home, as there may be an implication that APs users intentionally avoid being exposed to and exposing others to secondhand smoke. On the other hand, it is possible that exclusive conventional cigarette users and those that use them along with APs may be high-risk groups who do not care about the negative consequences of exposure to multiple substances.

Our findings suggest several implications for future tobacco control. From the consistent results related to secondhand smoking at home, the smoking status of any family members significantly affects any type of product use among younger populations, suggesting that public health measures are needed to decrease adult smoking in order to prevent smoking among younger people and vice versa. Although the systematic reviews showed inconsistent results about the effect of e-cigarettes on smoking cessation, the latest PHE reports deduced that a considerable number of smokers quit after e-cigarettes were introduced in the UK [27]. Similarly, Lee et al. estimated that introducing a reduced-risk product into Japan substantially reduced smoking-related deaths [28]; further independent research would be useful in this area [29]. It is also worth mentioning that there is a gap in the implementation of MPOWER between Japan and the UK. As mentioned above, the regulation of tobacco, including APs, in Japan is unique and is behind global standards.

Furthermore, understanding of the harmful effects of smoking showed a protective effect against any type of product use. This finding implies that health education about smoking is an indispensable tobacco control measure. Adolescent trends in tobacco use have been decreasing and are at their lowest level seen in many years. We must maintain this trend of fewer adolescents using tobacco and keep up the use of this essential strategy—health education—with younger generations. It is also important to continue to monitor the trend of tobacco use including the novel alternative products in order to evaluate our current public health measures for tobacco control.

Our study includes several strengths. The data were collected from a nationwide large sample survey. This methodology enabled us to minimize sampling bias [18]. Hence, the result of this study can potentially be generalizable nationwide for Japanese adolescents. Although the proportion of current users of any of the three products was relatively small, the large sample size enabled us to select 'current use of the products' as the outcome for analysis, in contrast to previous studies that selected 'having ever used' as an outcome. However, it should be noted that our definition of 'current use' (in line with other research) is 'any use within the last 30 days' so it picks up a range of users including some who may only be using intermittently. In addition, Japan has a unique regulatory environment. E-cigarettes without nicotine are available, but HTP products have also been widely promoted since 2014. This means that the situation around cigarettes and APs differ from other countries. Given Japan's unique situation, this study aimed to clarify the prevalence and risk factors of AP use among adolescents in Japan.

However, there are several limitations to the present study. First, the schools' response rates were not as high as we expected, though the student-response rate was preserved, as it was high among those schools that did participate. Despite the efforts of the research team, ethical concerns and inconvenience due to the need for strict explanations may have caused the lower rate of cooperation among schools. However, the higher ethical concern was required to meet the criteria for recent ethical approval. Second, the fact that class teachers distributed the forms may have impacted the results. As stated above, to address students' concerns about privacy, student questionnaires were anonymous, and the students put them into private envelopes themselves. In addition, the explanatory document given to the class teachers explained that they must ensure students' privacy. Third, the consequences of multiple testing must be considered. As shown in Table 2, many hypotheses tests were performed, increasing the possibility of spuriously significant results. However, most of the significant results were lower than the adjusted p values—less than 0.004—and we factored this into our interpretation of the results. Fourth, the survey questions for the smoking environment only about asked about 'tobacco'. This may have caused confusion for students answering questions as to if their parents used

APs or about their exposure to aerosol from APs. Finally, as stated above, we should be cautious in interpreting the presented relationships identified in this cross-sectional analysis as causal. In addition, it is possible that confounding causes spurious associations, either through residual confounding of recorded variables, or variables that were not recorded at all. Therefore, present results are limited with regard to investigating what causes the relationship and accurate effect size. However, by using available variables, we tried to explore the factors which were associated with cigarettes and APs and compare them to clarify the relationships. As mentioned above, similar results from previous literature can support our findings.

5. Conclusions

In conclusion, the study results show that currently there is a very low prevalence of smoking and/or alternative products among youth in Japan aged 12 to 18 years. We found that the characteristics of alternative product users and any conventional cigarette smokers, differ from non-users, and there were some differences between exclusive AP users and any conventional cigarette smokers. Conventional factors consistently related to alternative products' use indicate that reducing adult smoking and disseminating health education among adolescents remain important strategies for future tobacco control among adolescents. The priority must be to reduce tobacco use and nicotine addiction even further. To achieve the obvious goal, further research is necessary into the use of alternative products. Policymakers need to consider the updated measures on restrictions on labeling, advertising, sales to minors, pricing and taxation so that the Japanese national public health agenda goals can be achieved.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/17/9/3128/s1, Supplementary file 1: The list of questions from the survey questionnaire; Supplementary file 2: The risk of exclusive alternative product use compared with exclusive cigarette use among any product users.

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Heated Tobacco Product Smokers in Japan Identified by a Population-Based Survey

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ABSTRACT

Background: In this study, we aim to estimate the prevalence of heated tobacco product (HTP) smokers 3 years after the launch of HTPs in Japan.

Methods: Our study, performed in February 2018 in Japan, had a cross-sectional population-based design. A total of 4,628 adult participants (2,121 men and 2,507 women) were randomly sampled from all regions of Japan. The response rate was 57.9%. Interviews were conducted by trained investigators who visited participants' homes. A survey on current (past 30 days) and lifetime tobacco use (including e-cigarettes and HTPs), as well as numerous sociodemographic factors, was conducted.

Results: The age-adjusted rates and estimated number of lifetime-HTP smokers were 14.1% (95% confidence interval [CI], 12.5–15.6%; 7.11 million men) and 3.7% (95% CI, 2.9–4.4%; 1.99 million women). The age-adjusted rates for current HTP smokers were 8.3% (95% CI, 7.1–9.6%; 4.21 million men) and 1.9% (95% CI, 1.3–2.4%; 1.02 million women). Multiple variables were found to be associated with a higher prevalence of current HTP use, including being male, aged 20–39 years, a current Internet user, a risky drinker, or a heavy episodic drinker. HTP use was also higher among men with 10 years or more of education, women with 15 years or less of education, and men with middle- or high-level household incomes.

Conclusion: We concluded that HTP use has increased substantially in Japan. However, regulations for HTPs are weaker than those for combustible cigarettes in Japan. Thus, HTPs should be subjected to the same regulations as combustible tobacco products.

Key words: heated tobacco products; heat-not-burn tobacco; tobacco; population-based study; Japan

INTRODUCTION

Heated tobacco products (HTPs) are relatively new, sold by several tobacco companies, and are used with electronic devices that, without combustion, allow smokers to inhale aerosols produced by heated tobacco leaves.[1–3] Tobacco companies advertise HTPs as being relatively less harmful than other forms of tobacco, yet HTP aerosols contain nicotine and other chemicals,[4–6] and the potential harm of secondhand exposure to HTPs has been reported.[7,8] In 2014, the first HTP, IQOS, was created in Japan. By 2018, the IQOS market share of tobacco sales in Japan reached 15.5%.[9] Thus, it is necessary to understand the present increase in HTP use from a public health perspective by conducting an empirical investigation into potential harmful effects of HTPs. Given their efficient implementation, Internet-based surveys have predominantly been used to provide current estimates of the prevalence of HTP use in three countries.[8,10,11] However, to the best of our knowledge, no population-based studies on HTP prevalence have yet been reported. The participants sampled in web-based surveys may be potentially biased in terms of age and high familiarity with information technology, as participants are typically recruited from a voluntary registered pool. Therefore, the current study was conducted to provide a more accurate estimate of HTP users in Japan by utilizing a nationwide population-based survey.

METHODS

Design

In this cross-sectional study, adults were randomly sampled from all regions of Japan. The respondents were visited at home and interviewed by trained investigators.

Participants

Participants were recruited using a stratified, two-stage random sampling approach. The strata were determined by first dividing the survey districts into eleven areas (Hokkaido, Tohoku, Kanto, Hokuriku, Tosan [Yamanashi, Nagano, and Gifu], Tokai, Kinki, Chugoku, Shikoku, Northern Kyushu, and Southern Kyushu) and then into five groups classified by municipality size (large cities,

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$n = 14$; cities with populations ≥300,000, ≥100,000, <100,000, and smaller towns and villages). The survey districts were selected from each stratum in proportion to the adult (≥20 years old) population. Survey data were collected from participants during the years of 2003 ($n = 3,500$), 2008 ($n = 7,500$), 2013 ($n = 7,500$), and 2018 ($n = 8,000$). This study utilized the 2018 survey dataset, as it included questions on HTPs. The datasets from 2003, 2008, and 2013 were utilized to calculate percentages of tobacco users.

Survey procedures and response rates

The 2018 survey was conducted in February and March of that year. A survey request document was sent to the municipal office after the surveying district was randomly selected. Participants were then randomly selected by the investigator from the resident register at the municipal office. To ensure that participants provided informed consent, they were asked whether or not they would participate in the survey and, if they voluntarily agreed, the investigator visited their residence and conducted the interview. The number of participants and response rate were 4,628 and 57.9%, respectively. The details of previous surveys have been reported.[12]

Indicators of tobacco use

The question on general tobacco use was, "Have you smoked any tobacco often or daily within the past 30 days? (Yes/No)". The following question on HTPs was answered by any current (ie, past 30 days) tobacco user: "Have you ever used heated tobacco products such as iQOS, glo, or Ploom TECH?". The question regarding e-cigarettes asked: "Have you ever used e-cigarettes such as FLEVO, EMILI, VITAFUL, or VITACIG?". The answer choices for those two questions were: "never used", "have used before, but not within the past 30 days", and "currently use". These items identified "any tobacco smoker, past 30 days", "HTP smoker, lifetime", "HTP smoker past 30 days", "e-cigarette smoker, lifetime", and "e-cigarette smoker, past 30 days". In addition, participants were categorized into four groups: "non-smoker", "only smokes combustible tobacco", "HTP smoker or dual smoker", and "other".

Socio-demographic, Internet use, and alcohol use indicators

Participants were classified into the following age groups: 20–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years, and 80 years and older. Educational attainment was classified into four categories: ≤9 years of education (junior high school level), 10–12 years of education (senior high school level), 13–15 years of education (technical school level or current university students), and ≥16 years of education (university and graduate school level). Marital status was classified into three categories: married or living with a partner, bereaved or divorced, and unmarried. Household size was classified into three categories: living alone, two persons, and three persons or more. Working status was classified according to six categories: regular employee, self-employed, non-regular employee, student, housework, and unemployed. There was no housework status classification for men. Household income was classified into three categories: <4,000,000 yen per year, 4,000,000–8,000,000 yen per year, and ≥8,000,000 yen per year (100 yen = 0.92 dollars as of February 1, 2018). In 2016, the median and average household incomes in Japan were approximately 4,420,000 and 5,602,000 yen, respectively.[13] Individuals who used the Internet within the past 30 days were defined as current Internet users. Risky drinkers were defined by daily alcohol consumption (≥40 g for men or ≥20 g for women), which were the levels adopted in the second term of the National Health Promotion Movement of the 21st century (Health Japan 21).[14] Heavy episodic drinking was defined as drinking ≥60 g of alcohol on a single occasion within the past 30 days.[15]

Statistical analyses

The age-adjusted rates and estimated numbers of HTP users were weighted based on the population of Japan in October 1, 2017. To calculate lower and upper 95% confidence intervals (CIs) regarding any tobacco, HTP, and e-cigarette smokers, the following formula was used: age-adjusted point estimate ± 1.96 × standard error of age-adjusted rate. Regarding the proportion of any tobacco, HTP, and e-cigarette users by sociodemographic background, crude rates were used, and 95% CIs were calculated, without adjusting for age. Individuals who did not respond to questions were included in the analysis as non-respondents. Statistical analyses were performed using Microsoft Excel 2016 software for Windows (Microsoft Corp., Redmond, WA, USA).

Ethical considerations

The study protocol was approved by the ethics committee at the Kurihama Medical and Addiction Centre. During the visit for the interview, the investigator obtained informed consent from participants after providing a comprehensive explanation of the purpose of the investigation, its content, and how personal information would be protected. Researchers did not collect any personally identifiable information from the respondents, as it was excluded from the survey data.

RESULTS

A total of 2,121 men and 2,507 women participated in the 2018 nationwide survey. Participant characteristics are shown in Table 1. Almost 70% of participants were current Internet users. The prevalence of any current tobacco use had steadily decreased between 2003 and 2013, but plateaued between 2013 and 2018.

Table 2 shows the estimates of various tobacco product smokers. The age-adjusted rate and estimated number of current HTP smokers in the Japanese population was 5.23 million, with 4.21 million men (8.3%; 95% CI, 7.1–9.6%) and 1.02 million women (1.9%; 95% CI, 1.3–2.4%). The age-adjusted rate of current users of any type of tobacco was 30.8% (95% CI, 28.8–32.8%) among men and 9.4% (95% CI, 8.3–10.5%) among women. Almost one-third of men and one-fifth of women were HTP smokers in the tobacco-user population. The age-adjusted rate of current e-cigarette smokers was 1.6% (95% CI, 1.0–2.2%) among men and 0.5% (95% CI, 0.2–0.7%) among women, and the number of HTP smokers was higher than e-cigarette smokers. The age adjusted rate estimates were calculated for "non-smoker" (men = 69.2%; women = 90.6%), "only smoke combustible tobacco" (men = 22.0%; women = 7.5%), "HTP smoker or dual smoker" (men = 7.2%; women = 1.4%), and "other" (men = 1.7%; women = 0.5%) groups (see Figure 1).

Table 3 shows the crude rate of various types of tobacco smokers among men by sociodemographic factors. The prevalence of HTP smokers was highest among the following groups:

Table 1. Participant characteristics

	Men		Women		Total	
	n	(%)	*N*	(%)	*n*	(%)
Total	2,121	45.8	2,507	54.2	4,628	100.0
Age groups, years						
20–29	167	7.9	197	7.9	364	7.9
30–39	262	12.4	316	12.6	578	12.5
40–49	362	17.1	476	19.0	838	18.1
50–59	310	14.6	398	15.9	708	15.3
60–69	426	20.1	490	19.5	916	19.8
70–79	422	19.9	411	16.4	833	18.0
80 years and older	172	8.1	219	8.7	391	8.4
Areas						
Hokkaido	103	4.9	109	4.3	212	4.6
Tohoku	182	8.6	193	7.7	375	8.1
Kanto	623	29.4	751	30.0	1,374	29.7
Hokuriku	103	4.9	130	5.2	233	5.0
Tosan	107	5.0	109	4.3	216	4.7
Tokai	242	11.4	257	10.3	499	10.8
Kinki	326	15.4	388	15.5	714	15.4
Chugoku	124	5.8	179	7.1	303	6.5
Shikoku	67	3.2	77	3.1	144	3.1
Northern Kyushu	135	6.4	169	6.7	304	6.6
Southern Kyushu	109	5.1	145	5.8	254	5.5
Municipality size						
Large cities	512	24.1	609	24.3	1,121	24.2
Cities with populations ≥300,000	349	16.5	416	16.6	765	16.5
Cities with populations ≥100,000	544	25.6	679	27.1	1,223	26.4
Cities with populations <100,000	507	23.9	564	22.5	1,071	23.1
Smaller towns and villages	209	9.9	239	9.5	448	9.7
Educational attainment						
1–9 years	232	10.9	297	11.8	529	11.4
10–12 years	797	37.6	1,092	43.6	1,889	40.8
13–15 years	289	13.6	681	27.2	970	21
16 years	798	37.6	435	17.4	1,233	26.6
No response	5	0.2	2	0.1	7	0.2
Marital status						
Married	1,573	74.2	1,730	69.0	3,303	71.4
Bereaved or divorced	139	6.6	433	17.3	572	12.4
Unmarried	404	19.0	339	13.5	743	16.1
No response	5	0.2	5	0.2	10	0.2
Number of cohabitants						
Alone	202	9.5	246	9.8	448	9.7
2 persons	695	32.8	703	28.0	1,398	30.2
3 or more persons	1,221	57.6	1,558	62.2	2,779	60.0
No response	3	0.1	0	0.0	3	0.1
Working status						
Employee (regular)	939	44.3	477	19.0	1,416	30.6
Employee (non-regular)	218	10.3	670	26.7	888	19.2
Self-employed	296	14.0	195	7.8	491	10.6
Student	40	1.9	37	1.5	77	1.7
Housework	0	0.0	865	34.5	865	18.7
Unemployed	624	29.4	256	10.2	880	19.0
Others	4	0.2	7	0.3	11	0.2
Annual household income						
<4,000,000 yen	732	34.5	819	32.7	1,551	33.5
4,000,000–8,000,000 yen	652	30.7	593	23.7	1,245	26.9
≥8,000,000 yen	368	17.4	389	15.5	757	16.4
No response	369	17.4	706	28.2	1,075	23.2

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	Men		Women		Total	
	n	(%)	*N*	(%)	*n*	(%)
Internet user, past 30 days	1,499	70.7	1,632	65.1	3,131	67.7
Risky drinker (male 40 g/day, female 20 g/day or more)	316	14.9	169	6.7	485	10.5
Heavy episodic drinker, past 30 days	649	30.6	205	8.2	854	18.5
Any tobacco use, past 30 days						
Year 2003	555	46.9	198	14.5	753	29.6
Year 2008	761	40.5	258	11.5	1,019	24.7
Year 2013	570	30.5	206	9.0	776	18.7
Year 2018	637	30.0	242	9.4	879	19.0
Use of new tobacco products						
HTP[a] smoker, lifetime (Year 2018)	264	12.4	90	3.6	354	7.6
HTP[a] smoker, past 30 days (Year 2018)	131	7.3	55	1.8	186	4.3
E-cigarette smoker, lifetime (Year 2018)	155	6.2	45	2.2	200	4.0
E-cigarette smoker, past 30 days (Year 2018)	31	1.5	11	0.4	42	0.9
Smoking patterns						
Non-smoker	1,484	70.0	2,265	90.3	3,749	81.0
Only smoke combustible tobacco	473	22.3	197	7.9	670	14.5
HTP[a] smoker or dual smoker	133	6.3	34	1.4	167	3.6
Other	31	1.4	11	0.4	42	0.9

[a]HTP, heated tobacco products.

Table 2. Frequency and estimates of tobacco product use

		Men	Women	Total
Any tobacco use, past 30 days	Crude rate (%)	30.0	9.7	19.0
	Age-adjusted rate[a] (%)	30.8	9.4	19.7
	95% CI of the proportion (%)	28.8–32.8	8.3–10.5	18.6–20.8
	Estimated number (in millions)	15.57	5.13	20.70
	95% CI of the estimated number (in millions)	14.56–16.58	4.51–5.75	19.52–21.89
HTP smoker, lifetime	Crude rate (%)	12.4	3.6	7.6
	Age-adjusted rate[a] (%)	14.1	3.7	8.7
	95% CI of the proportion (%)	12.5–15.6	2.9–4.4	7.8–9.5
	Estimated number (in millions)	7.11	1.99	9.10
	95% CI of the estimated number (in millions)	6.32–7.90	1.59–2.40	8.21–9.99
HTP smoker, past 30 days	Crude rate (%)	7.3	1.8	4.3
	Age-adjusted rate[a] (%)	8.3	1.9	5.0
	95% CI of the proportion (%)	7.1–9.6	1.3–2.4	4.3–5.6
	Estimated number (in millions)	4.21	1.02	5.23
	95% CI of the estimated number (in millions)	3.58–4.84	0.73–1.32	4.54–5.93
E-cigarette smoker, lifetime	Crude rate (%)	6.2	2.2	4.0
	Age-adjusted rate[a] (%)	6.8	2.3	4.4
	95% CI of the proportion (%)	5.6–7.9	1.7–2.9	3.8–5.1
	Estimated number (in millions)	3.42	1.23	4.65
	95% CI of the estimated number (in millions)	2.84–4.00	0.91–1.56	3.99–5.32
E-cigarette smoker, past 30 days	Crude rate (%)	1.5	0.4	0.9
	Age-adjusted rate[a] (%)	1.6	0.5	1.0
	95% CI of the proportion (%)	1.0–2.2	0.2–0.7	0.7–1.3
	Estimated number (in millions)	0.82	0.25	1.07
	95% CI of the estimated number (in millions)	0.53–1.11	0.10–0.40	0.74–1.40

CI, confidence interval. HTP, heated tobacco products.
[a]The 2017 population data vital statistics were used to adjust for age.

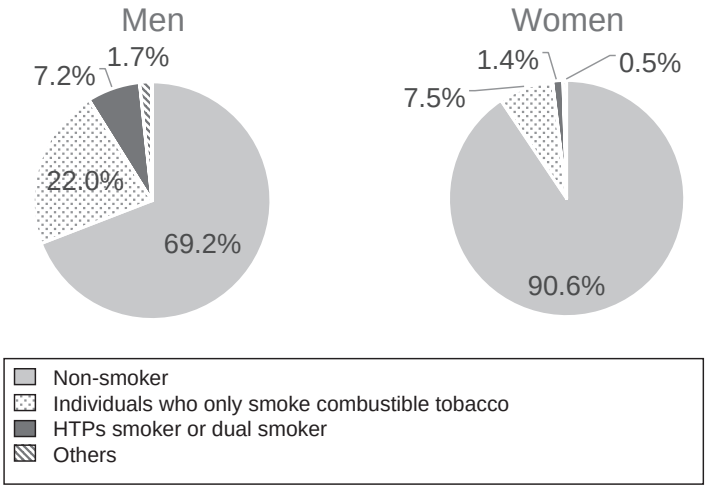

Figure 1. Proportions of tobacco smoking habits in Japan

Table 3. Male tobacco smoker types by sociodemographic characteristics

	Any tobacco use, past 30 days		HTP smoker, lifetime		HTP smoker, past 30 days		E-cigarette smoker, lifetime		E-cigarette smoker, past 30 days	
	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)
Total	30.0	(28.0–32.0)	12.4	(11.0–13.8)	7.3	(6.2–8.4)	6.2	(5.2–7.2)	1.5	(1.0–2.0)
Age groups, years										
20–29	26.3	(24.4–28.2)	22.2	(20.4–24.0)	12.6	(11.2–14.0)	10.8	(9.5–12.1)	2.4	(1.7–3.1)
30–39	31.7	(29.7–33.7)	20.6	(18.9–22.3)	13.4	(12.0–14.8)	9.9	(8.6–11.2)	3.1	(2.4–3.8)
40–49	41.7	(39.6–43.8)	21.0	(19.3–22.7)	13.3	(11.9–14.7)	7.2	(6.1–8.3)	1.7	(1.1–2.3)
50–59	37.4	(35.3–39.5)	14.2	(12.7–15.7)	7.7	(6.6–8.8)	7.1	(6.0–8.2)	1.3	(0.8–1.8)
60–69	32.6	(30.6–34.6)	8.9	(7.7–10.1)	5.6	(4.6–6.6)	5.2	(4.3–6.1)	1.9	(1.3–2.5)
70–79	20.6	(18.9–22.3)	3.1	(2.4–3.8)	0.7	(0.3–1.1)	3.3	(2.5–4.1)	0.2	(0.0–0.4)
80 years and elder	9.9	(8.6–11.2)	1.2	(0.7–1.7)	0.0	(0.0–0.0)	1.7	(1.1–2.3)	0.0	(0.0–0.0)
Area										
Hokkaido	32.0	(30.0–34.0)	10.7	(9.4–12.0)	5.8	(4.8–6.8)	10.7	(9.4–12.0)	4.9	(4.0–5.8)
Tohoku	31.9	(29.9–33.9)	10.4	(9.1–11.7)	8.2	(7.0–9.4)	3.8	(3.0–4.6)	1.1	(0.7–1.5)
Kanto	28.4	(26.5–30.3)	12.4	(11.0–13.8)	6.7	(5.6–7.8)	6.3	(5.3–7.3)	1.3	(0.8–1.8)
Hokuriku	36.9	(34.8–39.0)	16.5	(14.9–18.1)	9.7	(8.4–11.0)	11.7	(10.3–13.1)	2.9	(2.2–3.6)
Tosan	38.3	(36.2–40.4)	20.6	(18.9–22.3)	15.9	(14.3–17.5)	9.3	(8.1–10.5)	3.7	(2.9–4.5)
Tokai	31.8	(29.8–33.8)	13.6	(12.1–15.1)	8.3	(7.1–9.5)	5.0	(4.1–5.9)	0.4	(0.1–0.7)
Kinki	26.4	(24.5–28.3)	12.3	(10.9–13.7)	8.3	(7.1–9.5)	4.3	(3.4–5.2)	1.5	(1.0–2.0)
Chugoku	25.8	(23.9–27.7)	8.9	(7.7–10.1)	3.2	(2.5–3.9)	4.0	(3.2–4.8)	0.8	(0.4–1.2)
Shikoku	20.9	(19.2–22.6)	7.5	(6.4–8.6)	3.0	(2.3–3.7)	4.5	(3.6–5.4)	0.0	(0.0–0.0)
Northern Kyushu	32.6	(30.6–34.6)	12.6	(11.2–14.0)	5.2	(4.3–6.1)	5.9	(4.9–6.9)	0.0	(0.0–0.0)
Southern Kyushu	33.9	(31.9–35.9)	11.0	(9.7–12.3)	4.6	(3.7–5.5)	9.2	(8.0–10.4)	1.8	(1.2–2.4)
Municipality size										
Large cities	25.4	(23.5–27.3)	11.1	(9.8–12.4)	7.0	(5.9–8.1)	6.1	(5.1–7.1)	1.6	(1.1–2.1)
Cities with populations ≥300,000	28.1	(26.2–30.0)	12.0	(10.6–13.4)	6.3	(5.3–7.3)	6.0	(5.0–7.0)	1.4	(0.9–1.9)
Cities with populations ≥100,000	32.2	(30.2–34.2)	12.9	(11.5–14.3)	7.2	(6.1–8.3)	5.7	(4.7–6.7)	1.3	(0.8–1.8)
Cities with populations <100,000	33.1	(31.1–35.1)	14.0	(12.5–15.5)	8.7	(7.5–9.9)	6.5	(5.5–7.5)	1.4	(0.9–1.9)
Smaller towns and villages	31.6	(29.6–33.6)	11.5	(10.1–12.9)	6.7	(5.6–7.8)	7.2	(6.1–8.3)	1.9	(1.3–2.5)
Educational attainment										
1–9 years	29.3	(27.4–31.2)	6.9	(5.8–8.0)	3.9	(3.1–4.7)	3.9	(3.1–4.7)	0.4	(0.1–0.7)
10–12 years	35.0	(33.0–37.0)	13.6	(12.1–15.1)	7.9	(6.8–9.0)	8.0	(6.8–9.2)	1.8	(1.2–2.4)
13–15 years	31.5	(29.5–33.5)	15.6	(14.1–17.1)	9.3	(8.1–10.5)	7.6	(6.5–8.7)	1.7	(1.1–2.3)
≥16 years	24.7	(22.9–26.5)	11.9	(10.5–13.3)	7.0	(5.9–8.1)	4.5	(3.6–5.4)	1.4	(0.9–1.9)
No response	40.0	(37.9–42.1)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Marital status										
Married	28.8	(26.9–30.7)	12.0	(10.6–13.4)	7.2	(6.1–8.3)	5.5	(4.5–6.5)	1.4	(0.9–1.9)
Bereaved or divorced	39.6	(37.5–41.7)	9.4	(8.2–10.6)	5.0	(4.1–5.9)	7.2	(6.1–8.3)	2.2	(1.6–2.8)

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	Any tobacco use, past 30 days		HTP smoker, lifetime		HTP smoker, past 30 days		E-cigarette smoker, lifetime		E-cigarette smoker, past 30 days	
	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)
Unmarried	31.7	(29.7–33.7)	15.6	(14.1–17.1)	8.7	(7.5–9.9)	8.7	(7.5–9.9)	1.5	(1.0–2.0)
No response	20.0	(18.3–21.7)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Number of cohabitants										
Alone	35.1	(33.1–37.1)	12.4	(11.0–13.8)	5.9	(4.9–6.9)	8.9	(7.7–10.1)	1.5	(1.0–2.0)
2 persons	25.2	(23.4–27.0)	7.9	(6.8–9.0)	5.5	(4.5–6.5)	4.3	(3.4–5.2)	1.4	(0.9–1.9)
3 or more persons	31.9	(29.9–33.9)	15.1	(13.6–16.6)	8.6	(7.4–9.8)	6.8	(5.7–7.9)	1.5	(1.0–2.0)
No response	66.7	(64.7–68.7)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Working status										
Employee (regular)	35.6	(33.6–37.6)	18.3	(16.7–19.9)	11.4	(10.0–12.8)	8.3	(7.1–9.5)	2.3	(1.7–2.9)
Employee (non-regular)	33.5	(31.5–35.5)	11.5	(10.1–12.9)	6.9	(5.8–8.0)	6.4	(5.4–7.4)	0.5	(0.2–0.8)
Self-employed	31.4	(29.4–33.4)	13.9	(12.4–15.4)	6.1	(5.1–7.1)	7.1	(6.0–8.2)	1.0	(0.6–1.4)
Student	17.5	(15.9–19.1)	15.0	(13.5–16.5)	12.5	(11.1–13.9)	7.5	(6.4–8.6)	5.0	(4.1–5.9)
Housework										
Unemployed	20.8	(19.1–22.5)	3.2	(2.5–3.9)	1.6	(1.1–2.1)	2.4	(1.7–3.1)	0.5	(0.2–0.8)
Other	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Annual household income										
<4,000,000 yen	29.8	(27.9–31.7)	9.0	(7.8–10.2)	4.4	(3.5–5.3)	5.2	(4.3–6.1)	1.1	(0.7–1.5)
4,000,000–8,000,000 yen	36.3	(34.3–38.3)	17.0	(15.4–18.6)	11.3	(10.0–12.6)	7.7	(6.6–8.8)	2.0	(1.4–2.6)
≥8,000,000 yen	25.5	(23.6–27.4)	14.4	(12.9–15.9)	8.4	(7.2–9.6)	6.8	(5.7–7.9)	1.1	(0.7–1.5)
No response	23.8	(22.0–25.6)	9.2	(8.0–10.4)	4.9	(4.0–5.8)	4.9	(4.0–5.8)	1.6	(1.1–2.1)
Internet use, past 30 days										
Non-Internet user, past 30 days	27.3	(25.4–29.2)	3.7	(2.9–4.5)	1.1	(0.7–1.5)	3.4	(2.6–4.2)	0.5	(0.2–0.8)
Internet user, past 30 days	31.2	(29.2–33.2)	16.1	(14.5–17.7)	9.9	(8.6–11.2)	7.3	(6.2–8.4)	1.9	(1.3–2.5)
Risky drinking										
Drink alcohol less than 40 g/day	28.1	(26.2–30.0)	11.6	(10.2–13.0)	6.8	(5.7–7.9)	5.9	(4.9–6.9)	1.4	(0.9–1.9)
Drink alcohol more than 40 g/day	40.8	(38.7–42.9)	17.4	(15.8–19.0)	10.1	(8.8–11.4)	7.9	(6.8–9.0)	1.6	(1.1–2.1)
Heavy Episodic drinking										
Non-heavy episodic drinker, past 30 days	27.6	(25.7–29.5)	9.6	(8.3–10.9)	5.5	(4.5–6.5)	5.0	(4.1–5.9)	1.0	(0.6–1.4)
Heavy episodic drinker, past 30 days	35.6	(33.6–37.6)	19.0	(17.3–20.7)	11.4	(10.0–12.8)	8.9	(7.7–10.1)	2.5	(1.8–3.2)

20–49-year-olds, residents of Tosan, individuals with 10 years or more of education, individuals who were not bereaved or divorced, individuals with 4,000,000 yen or more annual household income, current Internet users, risky drinkers, and heavy episodic drinkers.

Table 4 shows the crude rate of various tobacco smoker types among women by sociodemographic factors. The prevalence of HTP smokers was highest in the following groups: 20–39-year-olds, individuals with 15 years or less of education, individuals with a household size of three or more persons, individuals who were employed or self-employed, current Internet users, risky drinkers, and heavy episodic drinkers.

DISCUSSION

This is one of the first reports to estimate the prevalence HTP smokers using a national population-based survey. The current survey indicated that the estimated number of current HTP smokers in Japan was 4.21 million (8.3%) men and 1.02 million (1.9%) women, as of February 2018. The proportion of HTP smokers is more than one-fourth of the total tobacco-user population.

Several web-based studies have reported HTP prevalence. One study from Japan observed that the prevalence of IQOS use increased from 0.4% in 2015 to 10.6% in 2018 among men and from 0.2% in 2015 to 3.1% in 2018 among women.[8,16] The 2018 follow-up survey was conducted at the same time as the current study. Considering the 2018 web-based survey was limited to IQOS, the current prevalence estimation is lower than that of the previous study. The difference could be explained by the differences in the age range of participants, the characteristics of participants between web-based surveys and face-to-face interviews, and the research design between cohort studies and cross-sectional studies.

The trend of a decline in tobacco use ceased between 2013 and 2018. While it is unclear whether the current plateau is associated with the launch of HTPs, tobacco industry marketing tactics that suggest HTPs are less harmful than traditional tobacco products may attract conscientious individuals concerned with their health.[17] Additionally, HTPs are presented as sophisticated and clean, which may appeal to young individuals with no prior interest in tobacco.[17,18] Thus, it is quite possible that the prevalence of tobacco use could have declined further if HTPs had not been introduced.

Table 4. Female tobacco smoker types by sociodemographic characteristics

	Any tobacco use, past 30 days		HTP smoker, lifetime		HTP smoker, past 30 days		E-cigarette smoker, lifetime		E-cigarette smoker, past 30 days	
	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)
Total	9.7	(8.5–10.9)	3.6	(2.9–4.3)	1.8	(1.3–2.3)	2.2	(1.6–2.8)	0.4	(0.2–0.6)
Age groups, years										
20–29	8.6	(7.5–9.7)	6.1	(5.2–7.0)	4.1	(3.3–4.9)	4.1	(3.3–4.9)	0.5	(0.2–0.8)
30–39	13.6	(12.3–14.9)	7.9	(6.8–9.0)	4.7	(3.9–5.5)	5.4	(4.5–6.3)	1.9	(1.4–2.4)
40–49	12.4	(11.1–13.7)	5.0	(4.1–5.9)	2.5	(1.9–3.1)	2.3	(1.7–2.9)	0.8	(0.5–1.1)
50–59	13.8	(12.4–15.2)	4.3	(3.5–5.1)	2.3	(1.7–2.9)	2.5	(1.9–3.1)	0.0	(0.0–0.0)
60–69	9.6	(8.4–10.8)	2.0	(1.5–2.5)	0.2	(0.0–0.4)	1.6	(1.1–2.1)	0.0	(0.0–0.0)
70–79	3.9	(3.1–4.7)	0.2	(0.0–0.4)	0.0	(0.0–0.0)	0.2	(0.0–0.4)	0.0	(0.0–0.0)
80 years and elder	2.3	(1.7–2.9)	0.5	(0.2–0.8)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Area										
Hokkaido	13.8	(12.4–15.2)	1.8	(1.3–2.3)	0.9	(0.5–1.3)	0.9	(0.5–1.3)	0.0	(0.0–0.0)
Tohoku	10.9	(9.7–12.1)	5.2	(4.3–6.1)	2.1	(1.5–2.7)	3.1	(2.4–3.8)	0.5	(0.2–0.8)
Kanto	9.9	(8.7–11.1)	4.3	(3.5–5.1)	2.5	(1.9–3.1)	2.7	(2.1–3.3)	0.5	(0.2–0.8)
Hokuriku	6.2	(5.3–7.1)	3.1	(2.4–3.8)	2.3	(1.7–2.9)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Tosan	11.0	(9.8–12.2)	2.8	(2.2–3.4)	0.9	(0.5–1.3)	2.8	(2.2–3.4)	0.9	(0.5–1.3)
Tokai	8.2	(7.1–9.3)	3.5	(2.8–4.2)	3.1	(2.4–3.8)	2.3	(1.7–2.9)	0.8	(0.5–1.1)
Kinki	10.1	(8.9–11.3)	3.6	(2.9–4.3)	1.0	(0.6–1.4)	2.1	(1.5–2.7)	0.3	(0.1–0.5)
Chugoku	10.6	(9.4–11.8)	3.4	(2.7–4.1)	0.6	(0.3–0.9)	2.8	(2.2–3.4)	0.0	(0.0–0.0)
Shikoku	11.7	(10.4–13)	3.9	(3.1–4.7)	2.6	(2.0–3.2)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Northern Kyushu	11.2	(10.0–12.4)	1.8	(1.3–2.3)	0.6	(0.3–0.9)	1.8	(1.3–2.3)	0.6	(0.3–0.9)
Southern Kyushu	3.4	(2.7–4.1)	2.8	(2.2–3.4)	0.7	(0.4–1.0)	2.1	(1.5–2.7)	0.7	(0.4–1.0)
Municipality size										
Large cities	10.5	(9.3–11.7)	3.8	(3.1–4.5)	1.8	(1.3–2.3)	2.5	(1.9–3.1)	0.8	(0.5–1.1)
Cities with populations ≥300,000	6.0	(5.1–6.9)	1.7	(1.2–2.2)	1.0	(0.6–1.4)	1.4	(0.9–1.9)	0.5	(0.2–0.8)
Cities with populations ≥100,000	10.6	(9.4–11.8)	4.1	(3.3–4.9)	1.8	(1.3–2.3)	2.8	(2.2–3.4)	0.0	(0.0–0.0)
Cities with populations <100,000	10.6	(9.4–11.8)	4.4	(3.6–5.2)	2.5	(1.9–3.1)	2.3	(1.7–2.9)	0.5	(0.2–0.8)
Smaller towns and villages	8.8	(7.7–9.9)	2.9	(2.2–3.6)	1.7	(1.2–2.2)	0.8	(0.5–1.1)	0.4	(0.2–0.6)
Educational attainment										
1–9 years	10.4	(9.2–11.6)	2.7	(2.1–3.3)	1.7	(1.2–2.2)	2.0	(1.5–2.5)	0.7	(0.4–1.0)
10–12 years	11.6	(10.3–12.9)	4.0	(3.2–4.8)	1.8	(1.3–2.3)	2.4	(1.8–3.0)	0.5	(0.2–0.8)
13–15 years	10.0	(8.8–11.2)	5.1	(4.2–6.0)	2.6	(2.0–3.2)	3.4	(2.7–4.1)	0.6	(0.3–0.9)
≥16 years	3.7	(3.0–4.4)	0.7	(0.4–1.0)	0.5	(0.2–0.8)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
No response	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Marital status										
Married	8.4	(7.3–9.5)	3.5	(2.8–4.2)	2.0	(1.5–2.5)	2.0	(1.5–2.5)	0.5	(0.2–0.8)
Bereaved or divorced	13.6	(12.3–14.9)	3.5	(2.8–4.2)	0.5	(0.2–0.8)	2.8	(2.2–3.4)	0.0	(0.0–0.0)
Unmarried	10.9	(9.7–12.1)	4.4	(3.6–5.2)	2.7	(2.1–3.3)	2.7	(2.1–3.3)	0.9	(0.5–1.3)
No response	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Number of cohabitants										
Alone	11.4	(10.2–12.6)	1.2	(0.8–1.6)	0.4	(0.2–0.6)	0.8	(0.5–1.1)	0.4	(0.2–0.6)
2 persons	10.4	(9.2–11.6)	2.8	(2.2–3.4)	1.1	(0.7–1.5)	1.7	(1.2–2.2)	0.0	(0.0–0.0)
3 or more persons	9.1	(8.0–10.2)	4.3	(3.5–5.1)	2.3	(1.7–2.9)	2.6	(2.0–3.2)	0.6	(0.3–0.9)
No response										
Working status										
Employee (regular)	12.4	(11.1–13.7)	5.5	(4.6–6.4)	2.5	(1.9–3.1)	2.7	(2.1–3.3)	0.4	(0.2–0.6)
Employee (non-regular)	13.3	(12.0–14.6)	5.1	(4.2–6.0)	2.2	(1.6–2.8)	3.6	(2.9–4.3)	0.7	(0.4–1.0)
Self-employed	12.3	(11.0–13.6)	5.1	(4.2–6.0)	3.1	(2.4–3.8)	3.1	(2.4–3.8)	1.0	(0.6–1.4)
Student	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)
Housework	5.9	(5.0–6.8)	1.6	(1.1–2.1)	1.0	(0.6–1.4)	1.3	(0.9–1.7)	0.2	(0.0–0.4)
Unemployed	7.4	(6.4–8.4)	2.3	(1.7–2.9)	1.2	(0.8–1.6)	0.4	(0.2–0.6)	0.0	(0.0–0.0)
Other	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)	0.0	(0.0–0.0)

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	Any tobacco use, past 30 days		HTP smoker, lifetime		HTP smoker, past 30 days		E-cigarette smoker, lifetime		E-cigarette smoker, past 30 days	
	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)	%	95% CI (%)
Annual household income										
<4,000,000 yen	12.5	(11.2–13.8)	3.5	(2.8–4.2)	1.6	(1.1–2.1)	2.1	(1.5–2.7)	0.2	(0.0–0.4)
4,000,000–8,000,000 yen	9.8	(8.6–11.0)	4.7	(3.9–5.5)	2.5	(1.9–3.1)	2.2	(1.6–2.8)	0.8	(0.5–1.1)
≥8,000,000 yen	7.5	(6.5–8.5)	3.1	(2.4–3.8)	1.5	(1.0–2.0)	2.8	(2.2–3.4)	0.5	(0.2–0.8)
No response	7.5	(6.5–8.5)	3.0	(2.3–3.7)	1.6	(1.1–2.1)	2.0	(1.5–2.5)	0.3	(0.1–0.5)
Internet use, past 30 days										
Non-Internet user, past 30 days	7.2	(6.1–8.3)	0.9	(0.5–1.3)	0.1	(0.0–0.2)	1.0	(0.6–1.4)	0.1	(0.0–0.2)
Internet user, past 30 days	11.0	(9.7–12.3)	5.0	(4.1–5.9)	2.7	(2.0–3.4)	2.8	(2.1–3.5)	0.6	(0.3–0.9)
Risky drinking										
Drink alcohol less than 20 g/day	8.4	(7.3–9.5)	3.0	(2.3–3.7)	1.5	(1.0–2.0)	1.9	(1.4–2.4)	0.3	(0.1–0.5)
Drink alcohol more than 20 g/day	27.2	(25.5–28.9)	12.4	(11.1–13.7)	6.5	(5.5–7.5)	6.5	(5.5–7.5)	1.8	(1.3–2.3)
Heavy Episodic drinking										
Non-heavy episodic drinker, past 30 days	8.3	(7.2–9.4)	2.5	(1.9–3.1)	1.2	(0.8–1.6)	1.5	(1.0–2.0)	0.2	(0.0–0.4)
Heavy episodic drinker, past 30 days	25.4	(23.7–27.1)	15.6	(14.2–17.0)	8.8	(7.7–9.9)	10.2	(9.0–11.4)	2.9	(2.2–3.6)

The present findings show that individuals living with three or more persons were more likely to be HTP smokers. This result may also be related to marketing campaigns from tobacco companies, as the harmful effects of tobacco smoke are well known in Japan, and smokers generally smoke outside their homes. As such, individuals concerned with second-hand smoke impacting family members might shift from cigarettes to HTPs. However, the harm incurred by HTPs cannot be ignored, and such forms of advertising by the tobacco industry arguably pose a health risk to users.[7] The percentage of HTP users is higher among individuals with risky and/or heavy episodic drinking habits. Smoking habits and drinking habits are highly related, which is likely why HTPs are positively correlated with alcohol consumption.[19] We also observed that the percentage of male HTP users was particularly high in Tosan, an area where the rate of combustible tobacco is also particularly high. However, the findings indicated that the highest percentage of female HTP users was in Tokai, the area where HTPs were first launched in Japan.

The current study has several limitations. The primary limitation is the likely bias associated with self-report measures. Biological samples were not provided by participants, and thus it is possible that participants provided inaccurate answers. To reduce response errors as much as possible, concise and easy questions were used. Additionally, the current survey was carried out in person, which may have reduced incorrect answers. The second limitation is that the sample size of each age group was too small to analyze age differences in HTP prevalence. The effect of age was strong among HTP smokers, and an age-stratified analysis should be conducted to examine related background factors. The fourth limitation is the cross-sectional study design, which does not allow for the verification of causal effects of sociodemographic and risk factors. However, the primary purpose of the current study to estimate the total percentage was not affected by this limitation. The methodology in the current study was suitable in terms of collecting highly representative samples.

In conclusion, the current survey indicated that the estimated number of current Japanese HTP smokers was 4.21 million (8.3%) men and 1.02 million (1.9%) women, as of February 2018. However, the regulations for HTPs in Japan is weaker than those for combustible cigarettes. As such, equivalent regulations should be extended to HTPs.

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ORIGINAL ARTICLE

Association between unhealthy dietary behaviors and sleep disturbances among Japanese adolescents: a nationwide representative survey

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Abstract

Purpose Dietary behaviors and sleep are important lifestyle factors to protect adolescent health. However, little is known about how dietary behaviors are related to sleep disturbances. The purpose of this study was to conduct a large-scale survey among Japanese adolescents to verify the association between unhealthy dietary behaviors and sleep disturbances.

Methods This study included 65,688 and 99,581 students enrolled in 140 and 120 randomly selected junior and senior high schools, respectively. A total of 85,931 self-administered questionnaires were collected from 79 junior and 77 senior high schools from 2014 to 2015. The survey included questions on sleep patterns, dietary behaviors, alcohol consumption, and smoking, as well as questions on mental health. For dietary behaviors, we adopted the items on meal habits in the National Health and Nutrition Survey including, the frequency of eating breakfast, the frequency of family meals, and subjective diet quality. We performed a multivariate analysis on the relationship between the dietary behaviors and sleep disturbance.

Results Data from 84,988 questionnaires were analyzed. Boys and girls with less healthy dietary behaviors had a significantly higher prevalence for each sleep disturbance. Subjective sleep quality and insomnia were significantly associated with breakfast frequency, family meal frequency, and diet quality. Short sleep duration was significantly associated with breakfast frequency and family meal frequency, but not with subjective diet quality.

Conclusions Our study suggested that sleep and dietary behaviors affect one another. Those involved in public health education should encourage adolescents to establish healthy sleep patterns as well as healthy dietary behaviors.

Keywords Sleep quality · Sleep disturbance · Dietary behaviors · Insomnia · Diet quality · Adolescent health

Introduction

Dietary and sleep habits during adolescence are important factors to consider in relation to adolescent health. Disordered dietary behaviors in adolescence lead to nutritional deficiency and delayed development, and they have even been related to poor academic performance [1]. According to the National Health and Nutrition Survey (NHANES), from 1999 to 2000, 20.5% of children aged 9–13 and 36.1% of young people aged 14–18 have skipped breakfast [2]. Adolescents' dietary behaviors tend to persist throughout their lives [3]. Regular family meals could serve as role models for healthy eating behaviors [4]. Diet quality also may be a predictive factor of child growth [5]. Accordingly, adolescents with unhealthy dietary behaviors may have an increased risk of obesity [6], poor mental health [7], and metabolic syndrome such as heart disease and type

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2 diabetes [8]. Thus, adolescents' dietary behaviors are recognized as an important social issue among developed countries [9].

Adolescent sleep disturbances are also recognized internationally as a major health concern. Studies report that 11–30% of adolescents suffer sleep disturbance [10, 11]. A study of sleep disturbances among Japanese adolescents found that 28.7% of boys and 32.6% of girls in junior and senior high school slept for less than 6 h at night [12]. On a related note, insomnia is common among Japanese adolescents, with a prevalence rate of 23.5% [13]. Further, a longitudinal study of Japanese adolescents concluded that sleep disturbance and poor mental health are closely related [14]. A prospective study in the US examined the long-term effects of young men's sleep habits and reported that the relative risk of developing clinical depression was shown to be greater in those young men who reported insomnia while in college [15]. Short sleep duration may increase obesity risk by changing dietary behaviors that cumulatively alter energy balance [16]. Furthermore, sleep disturbance in adolescence has been associated with obesity, insulin resistance, and cardiovascular risk factor abnormalities [17, 18]. Thus, as with their dietary behaviors, adolescents' sleep patterns constitute a major public health concern.

Given the importance of dietary behaviors and sleep in adolescents, ascertaining the relationship between them is an essential step for providing lifestyle habits guidance efficiently and effectively at schools. Short-duration sleepers tended to skip main meals and take snacks over meals [19, 20]. In addition, persons with long daily sleep duration (≥ 10 h) had unconventional eating habits, similar to short sleepers [21]. Short sleepers had elevated ghrelin and reduced leptin, causing sustained feelings of hunger and increased appetite, which explains the increased BMI among those with short sleep duration [19, 20, 22, 23]. Children with shorter sleep duration had less healthy eating habits and consumed more energy-rich foods [22, 23]. Children who ate alone had shorter sleep and were more likely to have poor quality sleep [24]. Diet quality has been studied in relation with sleep [25]. Sufficient sleep and high-quality diet may prevent future obesity [26].

The field has seen a gradual emergence of epidemiological research on the link between sleep disturbances and dietary behavior in adolescents, but the findings of are not yet sufficient. Japanese adolescents with insomnia were more likely to skip breakfast [13]; however, the study did not examine the effects of insomnia on overall dietary behaviors. Other studies in Japan have had many limitations, including small sample size and regional bias. The epidemiological literature also lacks studies that, in addition to examining the effects of sleep disorders on dietary behaviors, assess a broad range of dietary behaviors, including skipping meals and lack of family meals.

To address the limitations of the existing research, we conducted a large-scale survey on sleep and dietary behaviors in Japanese adolescents. This study aimed to verify whether unhealthy dietary behaviors are associated with sleep disturbances. Epidemiological evidence demonstrating the close link between diet and sleep would offer much value; it would provide scientific grounding for public health professionals and support efforts to develop public health policies for adolescents.

Methods and materials

Participants

We sampled in 10,547 junior and 4807 senior high schools registered in Japan in May 2013, 140 junior high schools (selection rate 1.3%) and 124 senior high schools (selection rate 2.6%) with a stratified, single-stage cluster-sampling method. Using this method, we divided Japan into regional blocks and randomly selected schools from each block. To avoid sampling bias toward any regional blocks, stratified sampling was performed with regional blocks as the strata. All students enrolled in the sampled schools were participants in this study. The sample size was determined by referring to the response rate and confidence intervals based on the variance of the results obtained from the previous study [27].

In the Japanese education system, children enter primary school at the age of 6 years and leave after 6 years of education. They then enter junior high school for 3 years of education, followed by 3 years in senior high school. In this report, the first to third years of junior high school are referred to as the 7th to 9th grades, and the first to third years of senior high school are called the 10th to 12th grades.

Survey procedure

We sent a letter to the principal of each of the selected schools asking for cooperation in the survey, along with the same number of questionnaires and envelopes as the number of students enrolled at the school. At each school that agreed to participate in the survey, all teachers were instructed to protect the privacy of the respondents and to explain to the students that the teachers would not see the completed questionnaires and that it was not necessary for the students to participate if they were not willing to do so. Students' willingness to participate was confirmed in writing. After the questionnaires were completed, they were placed in the provided envelopes, which were sealed with an adhesive flap. Delivery and collection of the questionnaires were entrusted to the teachers, who were instructed to follow the guidelines for conducting the survey. The teachers

collected and sent the sealed envelopes back to Nihon University School of Medicine without opening them. The survey period was from October 2014 to the end of January 2015. This survey was approved by the Ethics Committee of Nihon University School of Medicine. Financial support for this study was provided by a health science Research Grant from the Ministry of Health Labor and Welfare of the Japanese Government.

Measures

The primary areas that were included in the questionnaire were: (1) demographic variables, (2) dietary behaviors, (3) sleep status, (4) lifestyle, and (5) mental health status. The demographic variables included gender, school grade, and type of school (junior/senior high school).

We prepared questions and response options for three aspects of dietary behaviors: breakfast, family meals, and diet quality. These questions and response options referred to the Ministry of Health, Labour and Welfare's National Health and Nutrition Examination Survey [28].

1. "Have you eaten breakfast in the previous month?" (1 = *Almost every day*, 2 = *Sometimes*, 3 = *Seldom*).
2. "Have you eaten meals with your family in the previous month?" (1 = *All family*, 2 = *Some family*, 3 = *Alone*, 4 = *Other*).
3. "How was the quality of meals at your house in the previous month?" (1 = *Very good*, 2 = *Good*, 3 = *Bad*, 4 = *Very bad*).

Sleep status was assessed in terms of sleep duration, subjective sleep quality, and insomnia symptoms. Subjective sleep quality (SIS) was assessed with the question "How would you assess the quality of your sleep?" ("Very good", "Good", "Bad", or "Very bad"); participants who responded with "Bad" or "Very bad" were considered to have poor subjective sleep quality. This question is a part of the Pittsburgh Sleep Quality Index (PSQI). The question about sleep duration was "How many hours on average have you slept at night during the previous month?" (answer options were: less than 5 h; 5 h or more, but less than 6 h; 6 h or more, but less than 7 h; 7 h or more but less than 8 h; 8 h or more but less than 9 h; or 9 h or more). Short sleep duration (SSD) was defined as an average sleep duration of less than 6 h. Insomnia symptoms experienced during the previous month were assessed with three questions: (1) "Do you have difficulty initiating sleep (DIS)?" (2) "Do you have difficulty maintaining sleep (DMS)?" (3) "Do you have early morning awakening (EMA)?" Each item had five response options: "Never", "Seldom", "Sometimes", "Often", and "Always". "Often" or "Always" were considered to be affirmative answers to this question and an affirmative answer for any of these questions indicated the presence of insomnia symptoms. These definitions have also been used in other reports [13, 29].

Questions related to lifestyle were added, such as current smoking, current alcohol use, participation in extracurricular activities, exercise habits, more than 5 h of internet usage on weekdays, and their concern for a healthy life.

To evaluate mental health status, two independent factors (depression/anxiety and decrease in positive feelings) included in the 12-item General Health Questionnaire (GHQ-12) were used [23, 24, 30, 31]. Previous studies set the cut-off value for the GHQ-12 to 4 and considered a subject having 4 points or higher as having poor mental health [31]. Using the results of previous studies, a study reported that when one question was extracted from each of the two items and the sum of their scores was calculated, their sensitivity and specificity was high (87.0% and 85.1%, respectively) when a cut-off point of 1 was regarded as indicative of poor mental health [32]. We used one of the items from the depression/anxiety factor that asks whether the respondent has felt an unusual amount of unhappiness and depression in the previous 30 days. Response options were "not at all", "no more than usual", "more than usual", and "much more than usual". The one other item was from the decrease in positive feelings factor that asked whether the respondent was able to enjoy normal activities in the previous month. Response options were "more so than usual", "same as usual", "less than usual", and "much less than usual".

Statistical analyses

First, the basic characteristics of the participants were analyzed according to gender. Second, the prevalence of SIS, SSD, and insomnia symptoms, including DIS, DMS, and EMA, were calculated based on gender and each dietary behavior. Third, we calculated the prevalence of each sleep disturbance by each dietary behavior. Fourth, logistic regression was conducted to examine separately the factors associated with subjective sleep quality, short sleep duration, and insomnia. The predictors were breakfast frequency, family meals, and subjective diet quality. The adjusting factors were: basic demographic attributes (gender and grade in school) and school life (club activities, concern for a healthy life, exercise habits). These items are known to have significant associations with sleep disturbances [12, 13, 33, 34]. We set the level of significance at $P < 0.01$. All analyses were performed using SPSS version 17.0 for Windows.

Results

Response rate

This study included 65,688 and 99,581 students enrolled in 140 and 120 randomly selected junior and senior high

schools, respectively. Replies were obtained from 79 junior high schools (response rate 56.4%) and 77 senior high schools (response rate 64.2%); the combined junior and senior high school response rate was 60.0%. The total number of junior and senior high school students who responded were 31,769 and 54,162, respectively (85,931 in total). The student response rate as a proportion of enrolled students in the sampled schools was 48.4% in the junior high schools, 54.4% in the senior high schools, and 52.0% as a whole. From the collected questionnaires, 943 were excluded because gender was not specified or the responses were inconsistent. Data from the remaining 84,988 questionnaires (31,474 and 53,514 from junior and senior high schools) were analyzed. The effective response rates were 47.9% for junior high and 53.7% for senior high schools (overall rate 51.4%).

Descriptive statistics

Table 1 shows demographic characteristics of the participants. The table shows that 14.2% of boys and 12.4% of girls reported that they never or only sometimes have breakfast. Regarding family meals, 15.4% of boys and 13.6% of girls said they eat alone. As for diet quality, 12.3% of boys and 15.8% of girls answered that their diet quality is "Bad" or "Very bad".

Prevalence of each sleep disturbance

Table 2 shows the prevalence of each sleep disturbance. The prevalence of poor sleep quality was 38.8% (boys 37.4, girls 40.1), SSD was 31.0% (boys 27.9, girls 33.9), insomnia was 21.1% (boys 21.3, girls 21.0), DIS was 13.8% (boys 13.4, girls 14.1), DMS was 9.1% (boys 9.0, girls 9.2), and EMA was 4.9% (boys 5.2, girls 4.6).

Association between sleep disturbances and dietary behaviors

Figure 1 shows the linear relationships observed between the sleep disturbances and dietary behaviors. Prevalence of poor sleep quality was inversely correlated with the frequency of eating breakfast; only 36.3% of those with poor sleep quality were eating breakfast almost every day, whereas 59.6% regularly skipped breakfast. SSD and insomnia prevalence were also inversely correlated with breakfast frequency; only 29.3% of those with SSD and 19.1% of those with insomnia were eating breakfast almost every day, whereas as many as 46.6% and 36.6% regularly skipped breakfast. (Fig. 1a).

Figure 1b shows the relationship between each sleep disturbance and family meal frequency. The prevalence of each sleep disturbance was inversely correlated with family meal frequency; only 32.2% of those with poor sleep quality, 27.4% of those with SSD, and 18.0% of those with insomnia ate meals with the whole family, whereas respectively 54.1%, 42.6%, and 30.7% ate alone.

Figure 1c shows the relationship between each sleep disturbance and diet quality. SIS, SSD, and insomnia were all inversely correlated with diet quality; only 33.1% of those with poor sleep quality, 28.9% of those with SSD, and 18.2% of those with insomnia believed that the quality of their diet was very good, whereas as many as 63.5%, 45.3%, and 43.3%, respectively, reported having a very bad quality diet.

Multiple logistic regression analysis with regard to the association between each dietary behavior and sleep disturbance

Table 3 shows the results of multiple logistic regression analysis with regard to the association between each dietary habit and sleep disturbance. Focusing on SIS, when controlling for regular breakfast-eating, the odds ratio for students with SIS symptoms eating breakfast sometimes was 1.47 (95% CI 1.40–1.55) and for constantly skipping breakfast was 1.74 (95% CI 1.62–1.87). When controlling for eating with the entire family, the odds ratio for students with SIS symptoms eating with some of the family was 1.27 (95% CI 1.23–1.32) and for eating alone was 1.72 (95% CI 1.64–1.81). When controlling for "Very good" diet quality, the odds ratio for "Good" diet quality in students with SIS symptom was 1.28 (95% CI 1.24–1.33), for "Bad" diet quality was 1.44 (95%; CI: 1.37–1.51), and for "Very bad" diet quality was 1.78 (95% CI 1.59–2.00).

Turning next to SSD, when controlling for regular breakfast-eating, the odds ratio for students with SSD symptoms eating breakfast sometimes was 1.24 (95% CI 1.17–1.31) and for constantly skipping breakfast was 1.55 (95% CI 1.44–1.66). When controlling for eating with the entire family, the odds of students with SSD symptoms eating with some of the family were 1.10 (95% CI 1.23–1.32) and for eating alone was 1.54 (95% CI 1.46–1.62). As for diet quality, however, the SSD odds ratio was not correlated with an unhealthy diet.

Focusing on insomnia, when controlling for regular breakfast-eating, the odds ratio for students with insomnia eating breakfast sometimes was 1.52 (95% CI 1.44–1.61) and for constantly skipping breakfast was 1.63 (95% CI 1.51–1.76). When controlling for eating with the entire family, the odds of students with insomnia eating with some of the family was 1.11 (95% CI 1.06–1.15) and for eating alone was 1.45 (95% CI 1.37–1.53). When controlling for "Very good" diet quality, the odds for "Good" quality diet in students with insomnia were 1.12 (95% CI 1.07–1.17), for "Bad" diet quality was 1.33 (95% CI 1.26–1.41), and for "Very bad" diet quality was 1.77 (95% CI 1.58–1.98).

Table 1 Demographic characteristics of analyzed participants (%)

	Boys $N=41,225$	%	Girls $N=43,763$	%
Grade				
Grade 7	5467	13.3	5061	11.6
Grade 8	5426	13.2	5055	11.6
Grade 9	5320	12.9	5145	11.8
Grade 10	9058	22.0	9990	22.8
Grade 11	8348	20.2	9390	21.5
Grade 12	7606	18.4	9122	20.8
Breakfast habit				
Sometimes/no	5840	14.2	5415	12.4
Almost every day	33,401	81.0	37,287	85.2
Unknown	1984	4.8	1061	2.4
Family meals				
Alone	6342	15.4	5956	13.6
All family/some of family	33,227	80.6	36,918	84.4
Other/unknown	1656	4.0	889	2.0
Diet quality				
Bad/very bad	5081	12.3	6897	15.8
Very good/good	34,453	83.6	35,926	82.1
Unknown	1691	4.1	940	97.9
Drinking alcohol				
No	40,124	97.3	43,294	98.9
Yes	1101	2.7	469	1.1
Smoking				
No	37,709	91.5	40,465	92.5
Yes	3516	8.5	3298	7.5
Club activity				
No	11,232	27.2	14,238	32.5
Yes	28,220	68.5	28,469	65.1
Unknown	1773	4.3	1056	2.4
Excise habit				
No	18,838	45.7	29,486	67.4
Yes	20,745	50.3	13,365	30.5
Unknown	1642	4.0	912	2.1
Mental health				
Good	35,994	87.3	36,101	82.5
Bad	5002	12.1	7500	17.1
Unknown	229	0.6	162	0.4
Concern for health				
No	18,055	43.8	17,073	39.0
Yes	22,897	55.5	26,477	60.5
Unknown	273	0.7	213	0.5
Using internet hour 5 h > in weekday				
No	35,515	86.1	37,513	85.7
Yes	5022	12.2	5651	12.9
Unknown	688	1.7	599	1.4

Discussion

This study was a representative survey on the association between sleep disturbances and dietary behaviors in Japanese adolescents. The survey revealed that unhealthy dietary behaviors were associated with a higher prevalence of sleep disturbances. Previous studies have associated insufficient sleep in adults with unhealthy dietary behaviors

Table 2 Prevalence of each sleep disturbance

	SIS	SSD	Insomnia	DIS	DMS	EMA
Total						
N	82,143	82,339	82,129	80,717	82,615	82,694
%	38.8	31.0	21.1	13.8	9.1	4.9
95% CI	38.5–39.2	30.7–31.3	20.8–21.4	13.6–14.0	8.9–9.3	4.7–5.1
Boys						
N	39,433	39,505	39,398	39,507	39,545	39,608
%	37.4	27.9	21.3	13.4	9.0	5.2
95% CI	36.9–37.9	27.4–28.3	20.8–21.7	13.1–13.8	8.7–9.3	5.0–5.5
Girls						
N	42,710	42,828	42,731	42,805	42,835	42,889
%	40.1	33.9	21.0	14.1	9.2	4.6
95% CI	39.6–40.6	33.4–34.4	20.6–21.4	13.8–14.5	8.9–9.5	4.4–4.8
P value	< 0.001	< 0.001	0.415	0.003	0.398	< 0.001

P value was calculated by X2-test(sex; boys or girls) × 2(each sleep disturbance; yes or no)

Participants with missing data were excluded from the analysis

SIS subjectively insufficient sleep, *SSD* short sleep duration (< 6 h), *Insomnia* participants who had one or more symptoms of insomnia (DIS or DMS or EMA) were diagnosed as having insomnia, *DIS* difficulty initiating sleep, *DMS* difficulty maintaining sleep, *EMA* early morning awakening

[35]. Some studies reported a link between breakfast intake and sleep duration in adolescents [36, 37]. However, few have explored the association between unhealthy dietary behaviors and sleep factors comprehensively (e.g., sleep quality, insomnia, sleep duration), or attempted to find a dose–response association between degree of sleep disturbance and unhealthy dietary behaviors. Thus, our findings provide valuable information for developing sleep hygiene guidance for adolescents.

Previous surveys have reported that skipping breakfast is associated with sleep disturbances in adolescents [12, 13]. Our study demonstrated that adolescents who eat breakfast less frequently were significantly more likely to have poor subjective sleep quality, short sleep duration, and insomnia. A significant association between breakfast intake frequency and sleep duration has also been reported [36, 37]. However, to the best of our knowledge, there are no studies that associated dietary behaviors with subjective sleep quality and insomnia. Skipping breakfast is common among those who are nocturnally active, and such people tend to eat energy-rich foods during the night and consume snacks instead of breakfast. In a study of children's dietary behaviors and sleep, 5th grade children who snacked between meals and after supper were more likely to have less sleep time and less likely to have good quality sleep [24]. Another study reported that gastroesophageal reflux was associated with sleep disturbance [38]; eating energy-rich food at night can result in food remaining in the stomach during sleep, creating bile reflux, which in turn can lead to sleep disturbances.

Our study showed that eating alone was associated with each type of sleep disturbance, suggesting that family relations play an important role in sleep hygiene. Previous studies revealed similar associations between family meals and dimensions of mental health [7, 39]. A systematic review found that frequent family meals are inversely associated with disordered eating, alcohol and substance use, violent behavior, and feelings of depression or thoughts of suicide in adolescents [40]. As these findings illustrate, those who eat with the family have a better-quality diet and improved mental health. Thus, this study may demonstrate that eating with the family in and of itself could improve sleep quality.

We showed that poor diet quality was positively associated with insomnia and poor sleep quality, which is consistent with a previous study that showed poor diet quality was associated with poor sleep quality among middle-aged Japanese workers [41]. On the other hand, our results did not find an association between short sleep duration and diet quality. A previous study suggested that short sleep duration and poor sleep quality are associated with increased food intake, poor diet quality, and increased body weight [42]; the different results in our study may be related to the influence of confounding factors and to ethnic and age-based differences. Additionally, short sleep duration was not subjectively assessed, and this may explain the lack of correlation with diet quality which was a subjectively assessed item.

As in our study, previous studies have cited dietary behaviors as sleep-related factors [40, 43], and some studies have examined the sleep factors that influence dietary behaviors [21, 44]. On the assumption that sleep does influence dietary behaviors, some studies have examined the mechanism thereof. Meerlo et al. suggested that

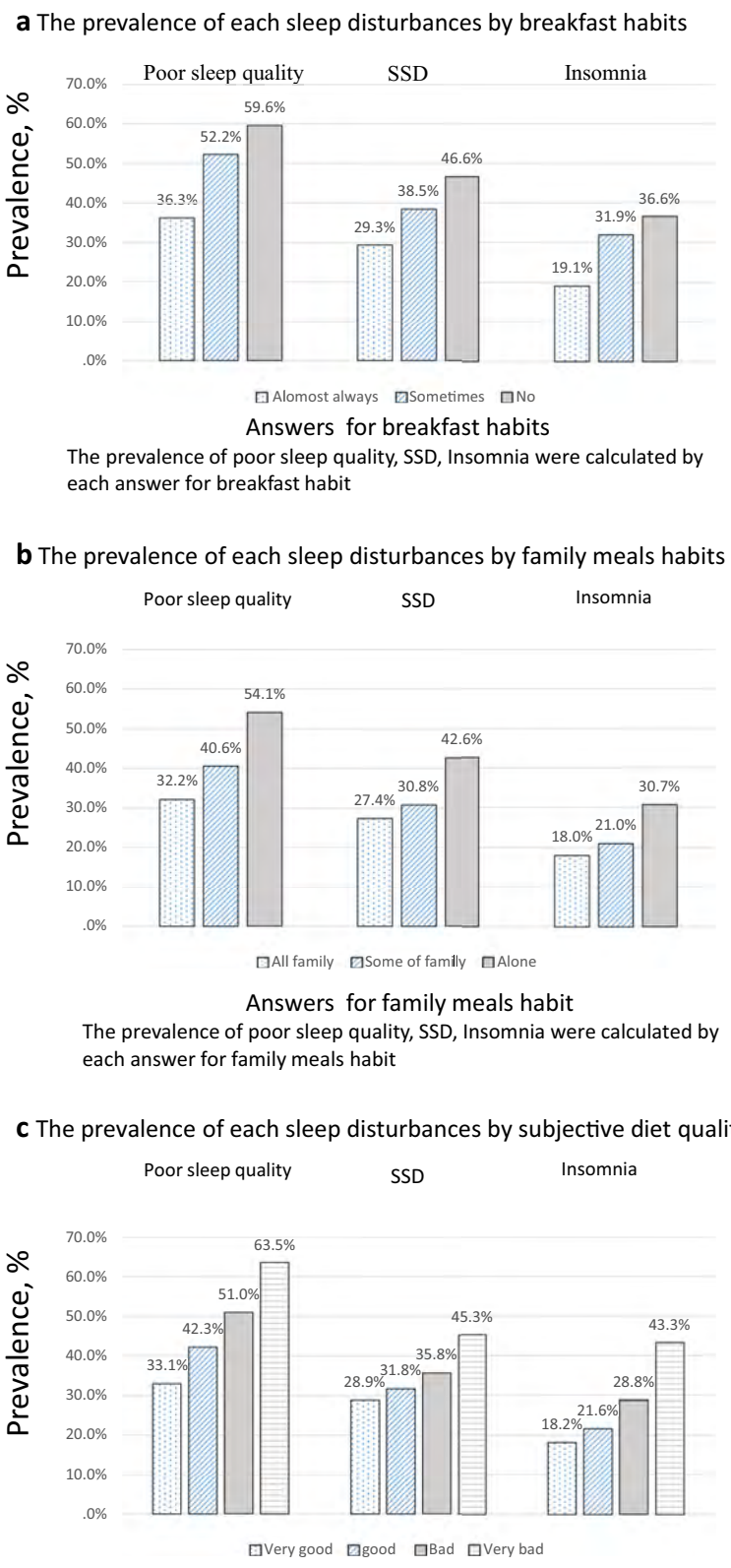

Fig. 1 The relationships between sleep disturbances and dietary behaviors. **a** The prevalence of each sleep disturbance by breakfast habits. **b** The prevalence of each sleep disturbance by family meals habits. **c** The prevalence of each sleep disturbance by subjective diet quality

Table 3 Multiple logistic regression analysis of the association between each sleep disturbance and each dietary behavior

Sleep disturbances	SIS				SSD				Insomnia			
	AOR	99% CI		*P* value	AOR	99% CI		*P* value	AOR	99% CI		*P* value
Dietary behaviors												
Breakfast habit												
Almost all day	1.00				1.00				1.00			
Sometimes	1.47	1.37	1.58	< 0.001	1.24	1.15	1.33	< 0.001	1.52	1.41	1.64	< 0.001
No	1.74	1.58	1.91	< 0.001	1.55	1.41	1.70	< 0.001	1.63	1.48	1.80	< 0.001
Family meals												
All family	1.00				1.00				1.00			
Some of family	1.27	1.22	1.33	< 0.001	1.10	1.05	1.15	< 0.001	1.11	1.05	1.17	< 0.001
Alone	1.72	1.62	1.84	< 0.001	1.54	1.44	1.64	< 0.001	1.45	1.35	1.56	< 0.001
Diet quality												
Very good	1.00				1.00				1.00			
Good	1.28	1.23	1.34	< 0.001	0.96	0.92	1.01	0.031	1.12	1.06	1.18	< 0.001
Bad	1.44	1.35	1.53	< 0.001	0.93	0.87	0.99	0.003	1.33	1.24	1.43	< 0.001
Very bad	1.78	1.53	2.07	< 0.001	1.05	0.91	1.22	0.361	1.77	1.52	2.06	< 0.001

Participants with missing data were excluded from the analysis

Adjusted for sex, grade, club activity, exercising habit, mental health, long time internet user, alcohol drinking, smoking, and concern for own health by multiple logistic regression

P value was calculated by multiple logistic regression analysis

AOR adjusted odds ratio, *CI* confidence interval, *SIS* subjectively insufficient sleep, *SSD* short sleep duration (< 6 h), *Insomnia* participants who had one or more symptoms of insomnia (DIS or DMS or EMA) were diagnosed as having insomnia

sleep duration and sleep quality affect levels of cortisol (a hormone involved in stress response) [45], while Taheri et al. identified the role of leptin and ghrelin—hormones that shape appetite [21]. Leptin suppresses appetite while ghrelin stimulates it. Experiments show that participants with short sleep have elevated ghrelin and reduced leptin, causing sustained feelings of hunger and increased appetite, and thus encouraging the person to snack, creating a vicious cycle [21, 46]. Sleep disturbances increase the risk of metabolic disorders and obesity [46]. As for the mechanism thereof, some studies suggest that children with shorter sleep duration are more likely to consume energy-rich foods [16, 23], that adolescents with shorter sleep duration consume a higher proportion of calories from fats, and may have more frequent energy-dense snacks at night [16]. The present study indicated a close relationship between diet and sleep. We believe that there are three possible mechanisms behind this association: first, unhealthy dietary behaviors lead to unhealthy sleep patterns; second, unhealthy sleep patterns lead to unhealthy dietary behaviors; third, unhealthy sleep patterns and unhealthy dietary behaviors arise simultaneously. To better understand the relationship between dietary behaviors and sleep, it will be necessary to conduct a longitudinal study. Therefore, we consider it a future research task to conduct a high-quality longitudinal study to ascertain the causal relationship between dietary behaviors and sleep.

This study has several limitations. First, it was a cross-sectional study. Second, we adopted a self-administered questionnaire format. For questions about diet quality, for example, we may have yielded more robust findings if we had used a stronger query, such as asking participants to recall what they ate in a 24-h period. Third, we could not obtain sociological data such as the family's socioeconomic status or the parents' academic history. Such factors may have shaped the participants' dietary behaviors and sleep patterns; it would be desirable to verify their influence in a future study. The fourth is a non-response bias. Over 40% of the recruited adolescents did not participate in the study. That said, the response rate for the questionnaire was over 50%, which is satisfactory for this type of epidemiological survey [24]. Notwithstanding these limitations, this study was a large-scale survey of Japanese adolescents that demonstrated an association between unhealthy dietary behaviors and risk of sleep disturbances. While we were unable to show a causal relationship between diet and sleep, as Rothman et al. would argue, the fact that we showed a direct correlation between the two is strong evidence that such a causal relationship does exist [47]. Although adolescent smoking and drinking are now on the decline, adolescent sleep patterns and dietary behaviors remain a social concern. Accordingly, those involved in public health education should encourage adolescents to establish healthy sleep patterns and dietary behaviors.

Conclusion

Adolescents with unhealthier dietary behaviors are more likely to have sleep disturbance. Sleep deficiency coupled with a poor diet environment contributes to adolescents' future dietary behaviors and meal choices and increases the risk of developing sleep disturbances.

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Compliance with ethical standards

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the Ethics Committee of Nihon University School of Medicine.

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest Y. Otsuka, Y. Kaneita, O. Itani, Y. Osaki, S. Higuchi, H. Kanda, S. Nakagome, M. Jike, and T. Ohida declare that they have no conflicts of interest.

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Original Article

The relationship between subjective happiness and sleep problems in Japanese adolescents

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ABSTRACT

Objectives: Low sleep quality in adolescents is an important public health concern, as it relates to both their current and future physical and mental health. Furthermore, subjective happiness is also often regarded as a major life goal. Although Japan is an economically powerful country, the reported levels of subjective happiness among Japanese adolescents is low. Thus, this study aims to examine the relationship between subjective happiness and sleep problems in Japanese adolescents.
Methods: We conducted a nationally representative cross-sectional study of adolescents enrolled in junior and senior high schools in Japan. We used a questionnaire to determine the prevalence of sleep problems (eg, insomnia, short sleep duration (SSD) and poor sleep quality) and to evaluate the participants' reported levels of subjective happiness. Multivariable logistic regression analyses were used to examine the associations between subjective happiness and sleep problems. Adjusted variables were basic demographic characteristics (eg, gender and school grade), lifestyle behaviors, and mental health status.
Results: Data from 64,329 students were analyzed (age range 12–18 years, mean age 15.7 years, 53.9% male). The results indicated that reported levels of subjective happiness were strongly associated with the prevalence of sleep problems. Linear relationships can be observed between sleep problems and subjective happiness scores. The multivariable logistic regression analysis showed that dose–response association of subjective happiness score was observed with all three sleep problems.
Conclusions: Due to these findings, we recommend that policy makers and school officials educate adolescents on the importance of both subjective happiness and good sleep hygiene.

1. Introduction

Sleep problems in adolescents are recognized internationally as a major health concern. Previous studies have reported that 11%–30% of adolescents suffer from sleep problems [1,2]. According to a study performed in 2004, the prevalence of Japanese adolescents (junior and senior high school students) who sleep for less than 6 h at night is 28.7% for male students and 32.6% for female students [3]. In particular, insomnia is common among Japanese adolescents, with a prevalence rate of 23.5%, as reported in a nationwide study performed in 2006 [4]. Sleep problems (eg, insomnia and short sleep duration) in adolescents have been associated with physical health problems such as obesity, insulin resistance, and a higher risk for cardiovascular abnormalities [5–7]. Sleep problems have also been shown to negatively impact adolescents' mental health, increasing the risk of several mental health concerns including

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anxiety, depression, suicidal behavior, and attention disorders [8–10]. Furthermore, poor well-being [11] and emotional dysregulation [12] were associated with sleep problems as well. Thus, sleep problems are one of the important public health problems related to adolescents' present and future physical and mental health.

Subjective happiness has received increasing attention from academics and policymakers around the world. Furthermore, subjective happiness is often regarded as a major life goal [13]. "Happiness" broadly refers to a general assessment of well-being and is a low arousal positive emotion [14,15]. Subjective happiness assesses the levels of positive and negative influences on one's well-being over a specific brief period of time [14] The Organization for Economic Cooperation and Development (OECD) reported that the subjective happiness levels of 15-year old students in Japan ranked 42 out of 47 countries [16]. Subjective happiness levels in adolescents are associated with lifestyle behaviors such as physical activity, eating habits, smoking, and drinking alcohol [17,18], and can also be negatively correlated with problematic Internet usage [19]. It has also numerous positive effects on physical and mental health in adult populations, including improved cardiovascular functioning [20], a stronger immune system [21], an increased survival rate [22], and an appropriate sleep duration [23].

Good sleep quality and fewer sleep problems have been associated with subjective happiness and positive affect in adult populations [24–26]. Pressman and Cohen [21] propose two general models by which responses to stress and positive affect (eg, happiness, joy, excitement, and contentment) can promote health. In the first model, positive affect directly influences overall-health related behavior regardless of its impact on stress responses. In the second model, positive affect may work to reduce negative assessments of distress and, therefore, facilitate adaptive coping [21]. Other studies have further examined the influence of sleep problems on subjective happiness [23,27]. In one study, the relationship between subjective happiness and sleep duration was found to be J-shaped, with women who reported sleeping for an average of 8 h per night also more likely to report being generally happy [22]. Thus, research has suggested that sleep and happiness may be associated through a bidirectional relationship [28,29].

However, previous research has primarily focused on adult populations. There is limited research on the association between subjective happiness and sleep problems in adolescents [14,18]. Moreover, there has been little investigation into possible differential effects of subjective happiness on different sleep problems, and there have been no nationwide studies conducted in Japan investigating their relationship. Therefore, in this study, we used three different sleep problems to examine the relationship between subjective happiness and sleep problems in adolescents. Previous studies have been limited by relatively-small sample sizes and a poor representation of the study population. In order to address these issues, we secured and analyzed a sufficient sample population with high representative quality. Based on the findings in previous research, we hypothesized that adolescents' lower subjective happiness levels would be negatively associated with sleep problems (eg, insomnia, short sleep duration, and poor sleep quality). Each region of the world has its own culture and tradition. However, physiological needs like sleep are important for all adolescents, regardless of culture. The exploration performed in this study of the associations between subjective happiness and sleep problems should result in findings that can be used to inform future research and policy on the importance of subjective happiness as it relates to good sleep hygiene in adolescents in Japan as well as other countries.

2. Methods

2.1. Survey procedure, design, and participants

We previously conducted cross-sectional nationwide surveys of lifestyle habits (eg, alcohol consumption, smoking habits, eating, and sleeping among Japanese adolescents) [4,30,31]. This was the eighth survey of its kind. Of the 10,235 junior and 4907 senior high schools registered in Japan in May 2017, we sampled from 98 junior and 86 senior high schools using a stratified, single-stage cluster-sampling method, which involved dividing Japan into regional blocks and selecting schools from each block at random. This method was used to limit sampling bias. The sample size was determined using the response rates and confidence intervals obtained from a previous study [30]. We sent a letter to the principals of selected schools requesting their cooperation, along with questionnaire forms and envelopes for enrolled students. In cooperating schools, classroom teachers were asked to inform students of the study, including its confidentiality and voluntary participation, and to ensure the protection of privacy. Written informed consent was obtained from all study participants. We used questionnaires devoid of all identifying information to safeguard participants' privacy and anonymity. Teachers delivered the completed questionnaires in sealed envelopes back to our department. We obtained replies from 48 junior high schools (response rate: 49.0%) and 55 senior high schools (response rate: 64.0%; response rate for all schools: 56.0%), for a total of 118,303 enrolled students. A total of 64,417 individuals responded. From those 64,417 responses, we excluded 265 questionnaires that were missing information regarding gender or had inconsistent responses or missing variables. Thus, 64,152 questionnaires were analyzed (effective response rate = 54.4%). The age range was 12–18 years (mean = 15.7 ± 1.7 years).

The survey period was from December 2017 to February 2018. This survey was approved by the Ethics Committee of Tottori University, School of Medicine. Financial support for this study was provided by a health science research grant from the Japanese Ministry of Health, Labor, and Welfare.

2.2. Measures

The questionnaire collected information on the following: (1) personal data, (2) sleep status, (3) subjective happiness, (4) lifestyle behaviors, and (5) mental health status. Personal data included gender, age, school grade, and school type (junior high school or senior high school).

For sleep status, we surveyed insomnia, sleep duration, and subjective sleep quality. To assess for symptoms of insomnia, we asked participants if they had difficulty in initiating sleep (DIS), difficulty in maintaining sleep (DMS), and/or early morning awakening (EMA) in the past 30 days. Participants could indicate "yes" or "no" to whether they experienced these symptoms, and participants who indicated experiencing at least one of the symptoms were considered to experience insomnia. These items are frequently used to assess sleep problems in epidemiologic studies [4,9,31]. Sleep duration was measured by self-report of average hours of sleep per night in the past 30 days, which was categorized into six groups: (1) less than 5 h, (2) 5–6 h, (3) 6–7 h, (4) 7–8 h, (5) 8–9 h, and (6) 9 h or more. We defined "short sleep duration" as a reported average of less than 6 h of sleep per night [31]. For subjective sleep quality, four options were provided: "very good," "good," "bad," and "very bad." Participants who responded with "bad" or "very bad" were considered to have poor sleep quality [31].

Subjective happiness was assessed using a single question: "In general, how would you describe your happiness right now?"

Participants responded using a visual analogue scale. Participants were instructed to: (a) focus on their global estimation and general feelings, (b) take note that 0 is the minimum and 10 is the maximum, and (c) select the number that best described their feelings. This single-item scale has been shown to have good concurrent, convergent, and divergent validity [32], and single-item happiness measures have been used widely throughout the world [33,34]. We categorized this scale into five groups and analyzed the resulting data.

For lifestyle behaviors, we assessed participants for the following: frequency of eating breakfast ("every day," "sometimes," or "seldom"), participation in sports club activities ("participation" or "no participation"), drinking and smoking habits, and Internet usage. For eating breakfast, respondents who selected "daily" in the "yes" category and those who selected "sometimes" or "never" in the "no" category were used for analysis. Participants were considered current smokers and/or drinkers if they indicated they engaged in these activities one day or more per week. To assess Internet usage, we used the 8-item version of the Young Diagnostic Questionnaire for Internet Addiction (YDQ) [35], translated into Japanese [36]. Each item on the YDQ is rated dichotomously ("yes" or "no"), and total scores range from 0 to 8. As in previous studies of adolescents, problematic Internet use was defined as providing affirmative answers to at least 5 YDQ items [37,38]. To evaluate participants' future direction, we used the following question: "What is your plan for your future life course?" Participants selected one of 7 options: "high school," "vocational school," "college," "university," "postgraduate school," "taking a job after leaving the current school," or "not decided yet." Those who selected "university" or "postgraduate school" were grouped as students who intended to go to university; otherwise, participants were grouped as students who did not intend to go to university or those who had not yet decided on their future direction [4].

Mental health status was assessed using the 12-item General Health Questionnaire (GHQ-12) [39]. A GHQ-12 score of 4 or higher has been used in prior studies to indicate poor mental health [40]; however, we used the GHQ-2 due to space limitations on the questionnaire. The GHQ-2 has been indicated to show good sensitivity and specificity (87.0% and 85.1%, respectively) and to provide a cut-off of ≥ 1 [41]. The GHQ-2 provides one item from the depression/anxiety factor (asking whether respondents felt an anxiety and depression in the previous 30 days; response options were "not at all," "no more than usual," "more than usual," and "much more than usual") and one from the decrease in positive feelings factor (asking whether respondents could enjoy normal activities in the previous 30 days; response options were "more so than usual," "same as usual," "less than usual," and "much less than usual").

2.3. Data analysis

First, we identified participants' demographics by gender. Second, we calculated the prevalence and 95% confidence intervals (CI) of each sleep problem by gender using the χ^2 test. Third, we calculated the distribution of subjective happiness scores by gender. Fourth, we calculated the prevalence of each sleep problem in relation to subjective happiness scores. Finally, we conducted univariable and multivariable logistic regression analyses, calculating the adjusted odds ratios (ORs) of subjective happiness and its 95% CI for each sleep problem. The explanatory variables in the multivariable logistic regression analysis included basic demographic characteristics (gender and school grade), lifestyle behaviors (eating breakfast, club participation, drinking habits, smoking habits, Internet usage, and future direction), and mental health status. To determine explanatory variables, we referred to factors associated with sleep problems in previous studies [17,19,31,35,42–44]. A previous study found a weak correlation between happiness and GHQ [45]; however, multivariate analysis have shown mental health and happiness to have different psychological strains [46]. This finding have suggested that the change of happiness scores is an emotion that appears earlier than depressed mood. In addition, the relationship between sleep and mental health is important [9]. Thus, we added mental health status to the explanatory variables. Participants for whom data were missing were excluded from the analyses. We set the significance level at $p < 0.01$. All analyses were performed using SPSS Statistics 22.0 [47].

3. Results

Table 1 shows the participant demographics by gender. The lowest subjective happiness scores (0–2), were reported by 5.6% of male students and 4.4% of female students. The highest subjective happiness scores (9–10), were reported by 19.5% of male students and by 20.2% of female students. In general, female students tended to report higher subjective happiness scores than male students.

Most male and female students ate breakfast everyday (81.2% and 85.2%, respectively). Almost all male and female students did not smoke or drink (97.5% and 98.9%; 93.8% and 95.3%,

Table 1
Characteristics of the participants.

	Boys (N = 34,582)		Girls (N = 29,570)	
	N	%	N	%
Subjective happiness				
0-2	1869	5.4	1270	4.4
3-4	3739	10.8	3668	12.6
5-6	10,926	31.6	9125	31.4
7-8	10,119	29.3	9128	31.4
9-10	6447	18.6	5858	20.2
Unknown	1482	4.3	521	1.8
Grade				
Grade 7	3740	10.8	3644	12.3
Grade 8	3687	10.7	3642	12.3
Grade 9	3702	10.7	3713	12.6
Grade 10	7963	23.0	6238	21.1
Grade 11	7903	22.9	6309	21.3
Grade 12	7470	21.6	5934	20.1
Unknown	117	0.3	90	0.3
Having breakfast				
Everyday	28,070	81.2	25,192	85.2
Sometimes/Seldom	5248	15.2	3921	13.3
Unknown	1264	3.7	457	1.5
Participating in club activities				
No	8477	24.5	8646	29.2
Yes	24,773	71.6	20,368	68.9
Unknown	1332	3.9	556	1.9
Intending to study at university				
No	19,620	56.7	17,017	57.5
Yes	14,962	43.3	12,553	42.5
Presently smoking				
No	33,726	97.5	29,243	98.9
Yes	856	2.5	327	1.1
Presently drinking				
No	32,431	93.8	28,135	95.1
Yes	2151	6.2	1435	4.9
Mental health status				
Good	16,535	47.8	11,510	38.9
Poor	16,649	48.1	17,507	59.2
Unknown	1398	4.0	553	1.9
Problematic Internet use				
No	30,142	87.2	24,379	82.4
Yes	4230	12.2	5063	17.1
Unknown	210	0.6	128	0.4

Table 2
Prevalence of each sleep problem.

		Insomnia	SSD	Poor sleep quality
Total	N	62,018	62,299	62,192
	%	19.3	30.1	37.3
	95% CI	19.0–19.6	29.7–30.4	36.9–37.7
Males	N	33,079	33,249	33,173
	%	18.7	28.4	36.3
	95% CI	18.3–19.1	27.9–28.8	35.7–36.8
Females	N	28,939	29,050	29,019
	%	20.1	32.0	38.5
	95% CI	19.6–20.5	31.5–32.5	37.9–39.0
p-value		<0.001	<0.001	<0.001

p-values were calculated by X2-test (gender; male or female) ×2 (each sleep problem; yes or no).
Participants with missing data were excluded from the analysis.
Insomnia: participants who had one or more symptoms of insomnia; SSD: Short sleep duration (<6 h).

respectively). However, 48.1% of male students and 59.2% of female students reported poor mental health, while 12.2% of male students and 17.1% of female students reported problematic Internet use.

Table 2 shows the prevalence of each sleep problem by gender. The prevalence of insomnia symptoms was 19.3% (males: 18.7%, females: 20.1%), short sleep duration (SSD) was 30.1% (males: 28.4%, females: 32.0%), and poor sleep quality was 37.3% (males: 36.3%, females: 38.5%). Gender differences were observed across all sleep problems.

Fig. 1 shows the relationship between each sleep problem and subjective happiness scores. Linear relationships can be observed between sleep problems and subjective happiness scores. Among the lowest subjective happiness group (0–2), the prevalence of insomnia, SSD, and poor sleep quality were 40.0%, 49.5%, and 62.2%, respectively. However, among the highest subjective happiness group (9–10), the prevalence of insomnia, SSD, and poor sleep quality were 13.6%, 23.7%, and 23.7%, respectively.

Table 3 shows the univariate logistic regression analysis for associations between each sleep problem and subjective happiness. Compared to those students who reported the highest levels of subjective happiness, those who reported the lowest levels of subjective happiness displayed 4.25 (95% CI: 3.89–4.64, $p < 0.001$) times higher ORs for insomnia, 3.14 (95% CI: 2.90–3.41, $p < 0.001$) times higher ORs for SSD, and 5.29 (95% CI: 4.86–5.75, $p < 0.001$) times higher ORs for poor sleep quality. Thus, we found that the lower the reported subjective happiness score, the higher the unadjusted ORs for each sleep problem.

Table 4 shows the multivariable logistic regression analysis for associations between each sleep problems and subjective happiness after adjustment for variables related to demographics, lifestyle behaviors, and mental health status. Compared to students who reported the highest subjective happiness scores, those who reported the lowest subjective happiness scores had 2.64 (95% CI: 2.41–2.90, $p < 0.001$) times higher ORs for insomnia, 3.27 (95% CI: 2.99–3.57, $p < 0.001$) times higher ORs for SSD, and 2.48 (95% CI: 2.27–2.70) times higher ORs for poor sleep quality. Thus, our findings showed that the lower the reported subjective happiness score, the higher the ORs after adjusting the related factors for each sleep problem.

4. Discussion

The present study is the first nationwide, representative cross-sectional study to examine the association between subjective happiness and sleep problems among Japanese adolescents. Specifically, we found that adolescents who reported lower levels of subjective happiness also reported a higher prevalence of sleep disturbances, including insomnia, SSD, and poor sleep quality, compared to adolescents who reported higher levels of subjective happiness. This association was consistent in the fully adjusted model, which controlled for the variables of demographics, lifestyle behaviors, and mental health status. Linear relationships were

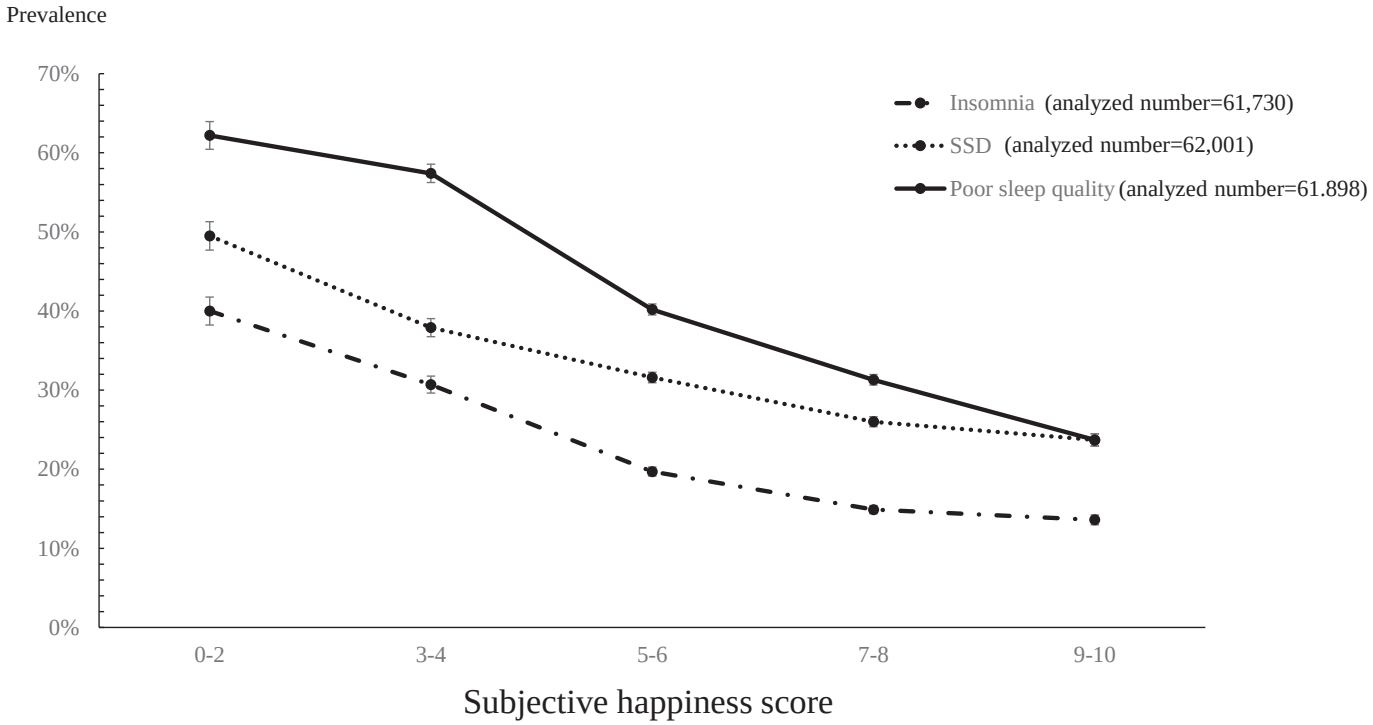

Fig. 1. Prevalence of each sleep problem by subjective happiness score.

Table 3
Univariate logistic regression analysis for association between subjective happiness and sleep problems in Japanese adolescents.

Subjective happiness	Insomnia				SSD				Poor sleep quality			
	N	Crude OR	95% CI	p-value	N	Crude OR	95% CI	p-value	N	Crude OR	95% CI	p-value
0–2	3120	4.25	3.89–4.64	<0.001	3126	3.14	2.90–3.41	<0.001	3121	5.29	4.86–5.75	<0.001
3–4	7349	2.83	2.63–3.04	<0.001	7388	1.96	1.84–2.09	<0.001	7378	4.33	4.07–4.61	<0.001
5–6	19,920	1.56	1.47–1.66	<0.001	20,003	1.49	1.41–1.57	<0.001	19,966	2.16	2.06–2.28	<0.001
7–8	19,122	1.12	1.05–1.20	0.001	19,202	1.13	1.07–1.19	<0.001	19,177	1.46	1.39–1.54	<0.001
9–10	12,219	Ref.			12,282	Ref.			12,256	Ref.		

Abbreviations: OR = odds ratio, CI = confidence interval, SIS: Subjectively insufficient sleep, SSD: short sleep duration (<6 h).
Insomnia: Participants who had one or more symptoms of insomnia (DIS or DMS or EMA).
Participants for whom data were missing were excluded from the analyses.

indicated between subjective happiness level and sleep problems. These findings have important implications for public health, as they show the magnitude of the association between subjective happiness and sleep problems.

As hypothesized, lower subjective happiness scores were significantly related to insomnia, SSD, and poor sleep quality. Previous cross-sectional studies showed that lower subjective happiness was associated with a higher risk for sleep problems [24–26,48]. For example, those with insomnia are 3.27 times more likely to describe themselves as being unhappy compared to those who do not have insomnia [48]. In contrast, a cross-sectional study of 750 American adolescents revealed that subjective happiness had a significant correlation with sleep duration, but not with sleep deprivation [49]. With regard to the association between bedtime and feeling unhappy at school, a cross-sectional study of Japanese adolescents found the adjusted odds ratios (AORs) for those with a late bedtime (after midnight) to be 1.45 times that of adolescents with an early bedtime [50]. As SSD is frequently linked to a delay in bedtime [51], these results are similar our findings.

Notably, adjusted ORs for SSD were higher than unadjusted ORs in all subjective happiness variables. The reason for this difference was the confounding factors that influenced the relationship between subjective happiness and SSD [52]. That is, the statistical control of a third variable altered the strength of association between SSD and subjective happiness. Thus, the strength of the relationship between subjective happiness and SSD may be stronger than between subjective happiness and either insomnia or poor sleep quality.

Our results showed further evidence that linear relationships such as the dose–response subjective happiness score are associated with sleep problems. That is, the lower the subjective happiness score, the higher the ORs for sleep problems. This finding was important because subjective happiness has been reported to be associated with adverse health outcomes in areas such as cardiovascular functioning [20], immune system strength [21], survival rate [22], and quality of life [53]. Furthermore, subjective happiness has been widely studied due to its interactive effects on mental health [54]. For example, higher levels of subjective happiness may serve as a protective factor for depression [55]. As the findings of the present study suggest, subjective happiness is a major public health concern related to the goal of life. Furthermore, awareness among educators and policy makers in Japan on the importance of subjective happiness is low. Therefore, public health interventions to raise awareness of the benefits of increased levels of subjective happiness may play an important role in promoting the improvement of sleep hygiene and other positive physical and mental health outcomes for adolescents.

The causal pathways linking sleep problems with subjective happiness are still not clear. As in the present study, previous studies have cited subjective happiness to be a sleep-related factor [21,25,28]. There are two possible mechanisms by which subjective happiness can promote higher sleep quality [21]. One is that subjective happiness can directly influence overall health-related behavior regardless of its impact on responses to stress. Thus, adolescents with high levels of subjective happiness may be more likely to engage in maintaining good sleep hygiene [28]. The second is that subjective happiness may help to reduce negative feelings and promote better adaptive coping skills. Adolescents with higher levels of subjective happiness may then cope more effectively with stressors. Thus, they may not experience the effects of stress in a way that leads to sleep problems. The strong associations found in our study between subjective happiness levels and sleep problems independent of poor mental health support this second method.

Some studies have further examined the influence of sleep problems on subjective happiness [23,24,27]. In one study, insomnia symptoms were inversely related to subjective happiness, when adjusted for emotional disorders [27]. A longitudinal study conducted with adult females in the UK found a J-shaped relationship between subjective happiness and sleep duration, indicating that subjective happiness decreased along with either shorter or longer sleep duration [23]. These finding suggested that getting adequate sleep was associated with increased subjective happiness. There are some theories to explain the connection between sleep deprivation and subjective happiness. One study

Table 4
Multivariate logistic regression analysis for association between subjective happiness and sleep problems in Japanese adolescents.

Subjective happiness	Insomnia				SSD				Poor sleep quality			
	N	AOR	95% CI	p-value	N	AOR	95% CI	p-value	N	AOR	95% CI	p-value
0–2	3077	3.45	3.14–3.78	<0.001	3084	2.69	2.47–2.93	<0.001	3078	4.31	3.96–4.71	<0.001
3–4	7269	2.44	2.27–2.63	<0.001	7310	1.66	1.56–1.77	<0.001	7301	3.63	3.40–3.87	<0.001
5–6	19,705	1.48	1.39–1.58	<0.001	19,788	1.32	1.25–1.39	<0.001	19,753	1.96	1.86–2.07	<0.001
7–8	18,966	1.11	1.04–1.18	0.003	19,044	1.03	0.98–1.09	0.242	19,021	1.38	1.31–1.46	<0.001
9–10	12,094	Ref.			12,156	Ref.			12,132	Ref.		

Abbreviations: AOR = adjusted odds ratio, CI = confidence interval, SSD = short sleep duration (<6 h).
Insomnia: Participants who had one or more symptoms of insomnia (DIS or DMS or EMA).
Participants for whom data were missing were excluded from the analyses.
Adjusted for gender, grade, club activity, problematic Internet use, having breakfast, drinking, smoking, and intending to study at university by multivariate logistic regression.

proposed that sleep deprivation affects positive emotions such as subjective happiness through networks in the brain related to emotion, rapid eye movement (REM) sleep, emotional information processing, and the cognitive-energy model [56]. From the above findings, it can be posited that a bidirectional relationship exists between sleep problems and subjective happiness [28,29,54,56].

However, the relationship between sleep problems and subjective happiness may also be influenced by several confounding factors, such as cultural differences and socioeconomic status (SES). Adolescents in East Asia generally have lower subjective happiness levels and shorter sleep durations compared to adolescents in other parts of the word (eg, Australia and Scandinavia) where adolescents tend to have higher subjective happiness levels and longer sleep durations [16,57]. Moreover, a study of adolescents in Portugal reported SES was modestly associated with subjective happiness [58]. Mezick et al. [59], reported that lower SES was associated with poor sleep quality in American adults. Thus, we consider it a possibility for future research to conduct a high-quality longitudinal study to ascertain the causal relationship between subjective happiness and sleep quality in adolescents.

The present study showed that female students report more depressive symptoms but also tend to report higher subjective happiness levels than male students. Previous studies have reported that females are superior to males in expressing emotions. For example, LaFrance et al. [60], reported that women use emotional expressions more often than men. In subjective emotional experiments involving looking at facial expression stimuli, females were shown to be more strongly rated as expressing pleasant emotions than males [61]. In addition, gender differences in depressive symptoms have been reported, and males are less likely than females to notice depressive symptoms in themselves [62]. These findings suggest that females experience emotions more strongly than males and express them more frequently or richly.

Based on our findings, we propose the following measures for improving happiness among adolescents, by improving their sleep. School teachers, administrators, and parents must consider the status and importance of adolescents' subjective happiness when providing them with education or discipline. Specifically, we believe it would be effective to educate children on cultivating a sense of happiness by conducting classes that consider the mechanism of happiness and the practice of happy life design in school education. For example, such a lecture could include an overview of the scientific evidence showing that happiness improves sleep problems. Further, if educators and parents do not understand happiness, they will not be effective in teaching children, and we therefore consider it important for them to understand happiness.

This study had three main strengths. First, it is a nationwide survey. Thus, the results of this study can be considered as highly representative of adolescents in Japan. Second, the study had a sample population appropriately large enough for us to establish strong results. This also increased credibility by minimizing the impact of potential random errors in self-reporting, especially among adolescents. Third, it has a survey response rate over 50%, which is high for this type of epidemiological study [63].

Some limitations of this study should also be acknowledged. First, because this was a cross-sectional study, we cannot determine the causal relationships between sleep problems and subjective happiness, or how these relationships might change over time. Thus, future studies should use a longitudinal design. Second, we had to adjust for several potential confounding variables. No data were obtained on factors related to participants' SES (eg, family income or parental educational levels) despite some studies reporting an association between sleep problems and SES [59,64]. Thus, future research should include factors related to SES. Third, due to limited space on the questionnaire, insomnia in this study could not include the entire clinical diagnostic criteria found in the International Classification of Sleep Disorders (ICSD-3) [65]. Therefore, insomnia as presented in this study may have differed from clinical insomnia. Fourth, objective data could not be used for the present evaluation of sleep habits. A previous study reported that self-reported sleep durations were systematically biased by gender and race when compared with those measured objectively using an actigraph [66]. In addition, according to general recommendations, the average sleep duration for adolescents should be around 8–10 h. However, Japanese adolescents are characterized by taking little time for sleep, and many sleep under 6 h on average per night. Therefore, we considered that measurements of this group with high health risks were important, and defined less than 6 h as SSD. Finally, a non-response bias existed, as over 40% schools and students did not participate. This could be due to some schools refusing to participate in the survey at the discretion of the school principals.

In conclusion, this large-scale cross-sectional study of adolescents in Japan showed that low subjective happiness was strongly associated with sleep problems such as insomnia and poor sleep quality. Considering this association, educators and policymakers should promote the importance of subjective happiness and sleep hygiene education for adolescents. Longitudinal research is needed to further identify the mechanism regulating the relationship between subjective happiness and sleep problems.

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CRediT authorship contribution statement

Yuichiro Otsuka: Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Visualization, Writing - original draft. **Yoshitaka Kaneita:** Conceptualization, Data curation, Investigation, Resources, Writing - review & editing. **Osamu Itani:** Data curation, Investigation, Resources, Software. **Maki Jike:** Data curation. **Yoneatsu Osaki:** Conceptualization, Data curation, Funding acquisition, Resources, Supervision. **Susumu Higuchi:** Conceptualization, Data curation, Resources. **Hideyuki Kanda:** Conceptualization, Data curation, Resources. **Aya Kinjo:** Data curation. **Yuki Kuwabara:** Data curation. **Hisashi Yoshimoto:** Data curation.

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Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2020.01.008.

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