Tohoku J. Exp. Med., 2017, **241**, 131-138

Excessive Game Playing Is Associated with Poor Toothbrushing Behavior among Athletic Children: A Cross-Sectional Study in Miyagi, Japan

Masahiro Tsuchiya,[1,2] Haruki Momma,[3,4] Takuya Sekiguchi,[5] Kaoru Kuroki,[3,6] Kenji Kanazawa,[5] Makoto Watanabe,[1,7] Yoshihiro Hagiwara[5] and Ryoichi Nagatomi[3,4]

[1]Department of Nursing, Tohoku Fukushi University, Sendai, Miyagi, Japan
[2]Division of Oral Diagnosis, Tohoku University Graduate School of Dentistry, Sendai, Miyagi, Japan
[3]Department of Medicine and Science in Sports and Exercise, Tohoku University Graduate School of Medicine, Sendai, Miyagi, Japan
[4]Division of Biomedical Engineering for Health and Welfare, Tohoku University Graduate School of Biomedical Engineering, Sendai, Miyagi, Japan
[5]Department of Orthopaedic Surgery, Tohoku University Graduate School of Medicine, Sendai, Miyagi, Japan
[6]Department of Rehabilitation, Tohoku Fukushi University, Sendai, Miyagi, Japan
[7]Department of Social Welfare, Tohoku Fukushi University, Sendai, Miyagi, Japan

Dental problems among athletes have been cautioned due to negative impacts not only on their oral health but also on athletic performance. Acquirement of appropriate oral health behavior mainly composed of toothbrushing in childhood can be one of the most important strategies for advancing children's athletic possibilities. Although habits of screen viewing, including game playing, and TV viewing have direct impacts on children's health and behavioral development, little is known about the association between these habits and toothbrushing frequency. A cross-sectional survey examining sports activities was conducted using a self-report questionnaire among school-aged athletic children belonging to the Miyagi Amateur Sports Association (n = 6,658). All statistical analyses were performed with SPSS, and P-values less than 0.05 were considered statistically significant. The association between a lower brushing frequency (< 2 times a day) and screen-viewing behavior was examined using multivariate logistic models after adjusting for sex, age, body mass index (BMI), studying time, and sleep duration. After adjustment for all covariates, longer game playing (> 2 hrs a day), but not TV viewing, significantly correlated with lower brushing frequency (P for trend < 0.001). Importantly, longer game-playing behavior was also associated with unhealthy dental behavior defined as a lower brushing frequency regardless of the awareness of dental caries (P for trend < 0.001). In conclusion, this is the first study indicating a type-specific unfavorable impact of screen viewing on oral health behavior among athletic children. Excessive game playing may adversely affect oral health literacy more strongly than TV viewing.

Keywords: children; cross-sectional study; dental caries; screen-time; toothbrushing
Tohoku J. Exp. Med., 2017 February, **241** (2), 131-138.

Introduction

Oral health is one of the most important concerns among athletes due to a high prevalence of dental trauma and diseases, such as dental caries, erosion, and periodontal disease (Ashley et al. 2015; Inouye and McGrew 2015; Needleman et al. 2016). Although oral conditions have direct impacts on sports performance (Ashley et al. 2015), athletes tend to receive examinations/treatments only when needed, and do not attend regular check-ups due to low oral health literacy (Hanke-Herrero et al. 2013; McGovern et al. 2015). Maintenance and improvement of oral health in athletes could be a crucial target for promoting sports performance as well as maintaining health. Lifestyle and health

Received December 22, 2016; revised and accepted January 24, 2017. Published online February 11, 2017; doi: 10.1620/tjem.241.131.
Correspondence: Yoshihiro Hagiwara, M.D. Ph.D., Department of Orthopaedic Surgery, Tohoku University Graduate School of Medicine, 2-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8574, Japan.
e-mail: hagi@med.tohoku.ac.jp
Ryoichi Nagatomi, M.D, Ph.D., Department of Medicine and Science in Sports and Exercise, Tohoku University Graduate School of Medicine, 2-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8574, Japan.
e-mail: nagatomi@med.tohoku.ac.jp

behaviors are formed during one's youth and that it is difficult to improve habitual oral health behaviors in adulthood (Hawkins et al. 2008; Lee et al. 2016). Thus, acquiring appropriate oral health behaviors in childhood can be one of the most effective strategies for advancing health as well as the athletic performance of future athletes.

Due to the removal of dental plaque, brushing your teeth is one of the most cost-effective self-management tools for preventing oral infectious diseases (Murtomaa 1979; Macgregor et al. 1996; Eisalhy et al. 2015; Needleman et al. 2016). The development of habitual behaviors including toothbrushing in childhood is influenced by a variety of other habitual behaviors, such as eating, sleeping, and screen-viewing (Marshall et al. 2004; Ji 2008; Kuwabara and Smith 2012; Tremblay et al. 2012). Therefore, to establish healthy oral conditions during childhood, it is important to consider other behaviors influencing the acquisition of appropriate toothbrushing habits. Previous studies reported that the effective frequency of toothbrushing for preventing dental caries was more than twice a day, which is generally performed prior to going out in the morning and before bedtime at night (Murtomaa 1979; Macgregor et al. 1996; Kobayashi et al. 2012; Elyasi et al. 2015; McKay et al. 2016). Excessive TV viewing, one of the major screen-time behaviors, is associated with a higher frequency of treatment for dental caries (Zeng et al. 2014). These results suggest the possibility that excessive screen-time behavior might be associated with a lower daily frequency of toothbrushing, probably due to watching TV (Zeng et al. 2014; McKay et al. 2016). However, the association between screen time and toothbrushing behavior not only among athletic children but among general children has been unclear. In addition, since game addiction has become more of a concern worldwide owing to the diffusion of handheld game consoles (Chaput et al. 2014), we supposed that excessive game-playing behavior could also be associated with the frequency of toothbrushing.

The purpose of this study was to examine the association between screen-time behaviors (i.e., TV viewing and game playing) and toothbrushing frequency among Japanese school-aged athletic children through a cross-sectional study. We hypothesized that excessive screen time would be associated with a lower daily frequency of toothbrushing.

Methods

Participants

Participants in this study were mostly schoolchildren belonging to the Miyagi Amateur Sports Association, the largest youth group in the Miyagi prefecture, which was established with the aim of improving youth health through various sports (e.g., baseball, soccer, basketball, volleyball, judo, kendo, karate, athletics, skiing, badminton, swimming). The organization possesses the mailing addresses of 25,469 registered children (aged 4 to 18). A self-administered questionnaire and informed consent document were mailed to all children in October 2014. Of these, 7,341 children returned both written informed consent and questionnaire by the end of December 2014 (response rate of 28.8%). This questionnaire has been previously described (von Rosen et al. 2016). Participants were aged 6 to 15 years; those who were not elementary or junior high school students (i.e., outside this age range) were excluded (n = 60). Moreover, participants with missing data on toothbrushing frequency (n = 25) and/or covariates (n = 590) were excluded from the analysis. Finally, a total of 6,658 children (4,710 boys and 1,948 girls) were included in the study (Fig. 1). The study protocol was reviewed and approved by the Ethics Committee on Research of Human Subjects at the Tohoku University Graduate School of Medicine (approval number: 2013-1-564).

Toothbrushing frequency

Toothbrushing frequency was assessed by a self-report questionnaire. The question relating to frequency of toothbrushing was expressed as follows: "How many times do you brush your teeth a

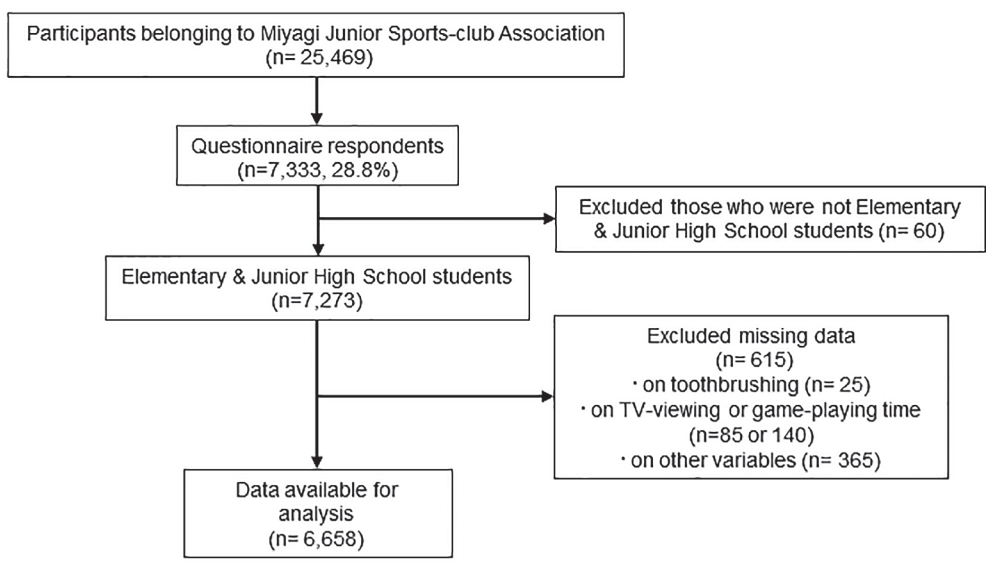

Fig. 1. Flowchart of participant recruitment.

day?" Participants chose from the following five response options: "never," "less than once," "1 time per day," "twice per day," and "three or more times per day." Since twice a day is considered the most suitable frequency for children (Murtomaa 1979; Macgregor et al. 1996; Kobayashi et al. 2012; Elyasi et al. 2015; McKay et al. 2016), participants were categorized into two groups: higher toothbrushing frequency group (two or more times per day), and lower brushing frequency group (less than twice per day). In addition to toothbrushing frequency, the presence of dental caries was collected via a self-report questionnaire with the following question: "Do you have any dental caries?" and response options: "Yes," "No," or "I don't know." We then categorized the children into two groups ("Yes" or "Other") based on the presence of dental caries (Other = "No" or "I don't know"). In Japan, because dental examinations and feedback are performed annually among all Japanese school students, it was assumed that participants would be aware of the presence of dental caries. To identify participants who had brushed their teeth less than twice per day regardless of the awareness of dental caries, we combined toothbrushing frequency with presence of dental caries, and then redefined this variable into two groups: lower brushing frequency with awareness of dental caries (unhealthy dental behavior group) or other (reference group).

Screen-time behavior

Screen-time behavior was assessed by self-report questionnaire and defined as the average number of hours per day spent on game-playing and TV viewing, respectively. The questions relating to screen time were expressed as follows: "How many hours do you play video games in a day?" and "How many hours do you watch TV in a day?" Possible responses were 0 to 24 hours. To equalize the number of participants among groups, we categorized participants by time of use into four time categories: game-playing hours/day: < 1 hr, 1 to < 2 hrs, 2 to < 3 hrs, ≥ 3 hrs; TV viewing hours/day: ≤ 2 hrs, > 2 to 3 hrs, > 3 to 4 hrs, > 4 hrs in Table 3, or into three time categories: game-playing hours/day: < 1 hr, 1 to < 2 hrs, ≥ 2 hrs; TV viewing hours/day: ≤ 2 hrs, > 2 to 3 hrs, > 3 hrs in Table 4.

Covariates

Sex, age, educational stage (elementary or junior high school), self-reported height and weight, and the average amount (hrs per day) of studying time and sleep duration were evaluated by a questionnaire. Weight and height were used to calculate body mass index (BMI; kg/m^2). Participants were divided into the following groups according to studying time (< 1 hr, 1 hr, and > 1 hr) and sleep duration (≤ 8 hrs, > 8 to 8.5 hrs, > 8.5 to 9 hrs, > 9 to 9.5 hrs, and > 9.5 hrs).

Statistical analysis

Categorical and continuous variables were presented as percentages and as the median, respectively. To compare participant characteristics, we used Pearson's chi-squared test and analysis of variance (ANOVA) for categorical and continuous variables, respectively. Multiple logistic regression analysis was used to examine the association between daily frequency of screen time and toothbrushing. The frequency of toothbrushing (i.e., time category) was the dependent variable, and game-playing and TV-viewing time were the independent variables, respectively. The odds ratio (OR) and 95% confidential intervals (CI) for lower brushing frequency were calculated using the lowest game-playing and TV-viewing groups as the reference groups, respectively. These analyses were performed after adjustment for potential confounding factors, including age (continuous variable), BMI (continuous variable), and sex (binary; male vs. female) (model 1). All parameters in model 1 plus studying time (model 2) or sleep duration (model 3) were included; the above parameters plus TV-viewing or game-playing time, respectively, were included in model 4. Statistical analyses were performed with SPSS version 23.0 (SPSS Japan Inc., Tokyo, Japan). All tests were 2-tailed, and $P < 0.05$ was considered statistically significant.

Results

Participant characteristics

Out of the 6,658 participants, 747 (11.2%) and 27 (0.4%) spent no time playing games or viewing TV, respectively; these participants were categorized into the first group with the shortest screen-time behavior. Other baseline characteristics of the participants are presented according to game-playing and TV-viewing time categories in Table 1 (elementary school participants) and 2 (junior high school participants). The percentage of participants who were aware of dental caries was 20.5% (n = 1,363). Regardless of educational stage, there were significant differences in sex, age, toothbrushing frequency, awareness of dental caries, studying time, and sleep duration across the game-playing groups ($P < 0.05$). In elementary school but not junior high school, children in the longer category of game-playing time showed a higher BMI ($P < 0.001$). Sex and awareness of dental caries were significantly different across TV-viewing groups in both educational stages ($P < 0.05$). In elementary school children only, BMI ($P < 0.05$), age, studying time, and sleep duration ($P < 0.01$) were significantly different across TV-viewing categories.

Association between screen time and toothbrushing frequency

The percentage of those who had brushed their teeth less than twice per day was 13.9% (n = 924). The crude and adjusted ORs (95% CI) for the prevalence of lower brushing frequency among the game-playing and TV-viewing categories are shown in Table 3, respectively. In both elementary and junior high school children, the levels of game-playing time were significantly associated with the prevalence of lower brushing frequency (P for trend < 0.001). These associations remained significant after adjustment for potential confounders, including sleep duration (P for trend < 0.001). In model 4, the ORs (95% CI) for the prevalence of lower brushing frequency from the second through the fourth group, using the shortest game-playing time category as a reference, were 1.09 (0.90-1.36), 1.53 (1.20-1.95), and 1.76 (1.30-2.39) in elementary school children, and 0.85 (0.56-1.30), 1.32 (0.84-2.09), and 2.53 (1.60-4.00) in junior high school children, respectively. Levels of TV-viewing time were not associated with the prevalence of lower brushing frequency in elementary or junior high school children.

We next focused on the participants who had unhealthy

Table 1. Baseline characteristics of the elementary school participants in relation to behavioral-time of game playing or TV viewing.

	Game playing (hrs)					TV viewing (hrs)				
	< 1	1 to < 2	2 to < 3	≥ 3	P-value	≤ 2	> 2 to 3	> 3 to 4	> 4	P-value
n	1,941	2,104	763	390		1,675	1,353	836	1,334	
Dental caries prevalence, n (%)	323 (16.6)	462 (22.0)	205 (26.9)	97 (24.9)	P < 0.001[b]	264 (15.8)	307 (22.7)	208 (24.9)	308 (23.1)	P < 0.001[b]
Age (years)	10 (9, 11)	10 (9, 11)	11 (9, 11)	11 (10, 12)	P < 0.001[a]	10 (9, 11)	10 (9, 11)	10 (9, 11)	11 (9, 11)	P < 0.001[a]
BMI	16.6 (15.5, 18.2)	16.9 (15.6, 18.7)	17.4 (15.9, 19.3)	17.5 (16.0, 19.7)	P = 0.002[a]	16.6 (15.4, 18.1)	16.8 (15.6, 18.5)	17.1 (15.6, 18.8)	17.3 (15.9, 19.3)	P = 0.02[a]
Sex, n (%)					P < 0.001[b]					P = 0.02[b]
Male	1,206 (62.1)	1,624 (77.2)	657 (86.1)	329 (84.4)		1,261 (75.3)	1,009 (74.6)	604 (72.2)	942 (70.6)	
Female	735 (37.9)	480 (22.8)	106 (13.9)	61 (15.6)		414 (24.7)	344 (25.4)	232 (27.8)	392 (29.4)	
Studying (hr), n (%)					P < 0.001[b]					P < 0.01[b]
< 1	839 (43.2)	669 (31.8)	239 (31.3)	120 (30.8)		665 (39.7)	478 (35.3)	274 (32.8)	450 (33.7)	
1	555 (28.6)	936 (44.5)	332 (43.5)	172 (44.1)		600 (35.8)	538 (39.8)	347 (41.5)	510 (38.2)	
> 1	547 (28.2)	499 (23.7)	192 (25.2)	98 (25.1)		410 (24.5)	337 (24.9)	215 (25.7)	374 (28.0)	
Sleep duration (hrs), n (%)					P < 0.001[b]					P < 0.001[b]
≤ 8	107 (5.5)	175 (8.3)	89 (11.7)	90 (23.1)		104 (6.2)	107 (7.9	86 (10.3)	163 (12.2)	
8.5 to > 8	293 (15.1)	313 (14.9)	139 (18.2)	65 (16.7)		234 (14.0)	196 (14.5)	135 (16.1)	245 (18.4)	
9 to > 8.5	591 (30.4)	652 (31.0)	250 (32.8)	111 (28.5)		499 (29.8)	453 (33.5)	259 (31.0)	394 (29.5)	
9.5 to > 9	542 (27.9)	602 (28.6)	186 (24.4)	66 (16.9)		474 (28.3)	354 (26.2)	228 (27.3)	339 (25.4)	
> 9.5	408 (21.0)	362 (17.2)	99 (13.0)	58 (14.9)		364 (21.7)	243 (18.0)	128 (15.3)	193 (14.5)	

All values are medians (interquartile range) for continuous variables or N (%) for categorical variables.
[a]Analysis of variance (ANOVA; for continuous variables) or [b]Pearson's chi-square test (for categorical responses) by Game or TV Time groups, with p-value indicating statistical significances on variable distribution in comparison across groups.

Table 2. Baseline characteristics of the junior-high school participants in relation to behavioral-time of game playing or TV viewing.

	Game playing (hrs)					TV viewing (hrs)				
	< 1	1 to < 2	2 to < 3	≥ 3	P-value	≤ 2	> 2 to 3	> 3 to 4	> 4	P-value
n	418	541	289	212		420	344	249	447	
Dental caries awareness, n (%)	59 (14.1)	108 (20.0)	59 (20.4)	50 (23.6)	P = 0.02[b]	63 (15.0)	54 (15.7)	51 (20.5)	108 (24.2)	P = 0.002[b]
Age (years)	13 (13, 14)	13 (13, 14)	14 (13, 14)	13 (13, 14)	P = 0.01[a]	13 (13, 14)	13 (13, 14)	13 (13, 14)	13 (13, 14)	P = 0.55[a]
BMI	18.7 (17.4, 20.2)	18.8 (17.6, 20.7)	19.3 (17.8, 21.1)	19.4 (17.7, 21.4)	P = 0.57[a]	18.7 (17.3, 20.6)	19.1 (17.7, 20.7)	18.9 (17.7, 20.4)	19.1 (17.8, 20.8)	P = 0.67[a]
Sex, n (%)					P < 0.001[b]					P = 0.02[b]
Male	191 (45.7)	367 (67.8)	200 (69.2)	136 (64.2)		282 (67.1)	207 (60.2)	149 (59.8)	256 (57.3)	
Female	227 (54.3)	174 (32.2)	89 (30.8)	76 (35.8)		138 (32.9)	137 (39.8)	100 (40.2)	191 (42.7)	
Studying (hr), n (%)					P < 0.001[b]					P = 0.35[b]
< 1	65 (15.6)	52 (9.6)	35 (12.1)	33 (15.6)		65 (15.5)	34 (9.9)	27 (10.8)	59 (13.2)	
1	50 (12.0)	154 (28.5)	87 (30.1)	64 (30.2)		95 (22.6)	87 (25.3)	61 (24.5)	112 (25.1)	
> 1	303 (72.5)	335 (61.9)	167 (57.8)	115 (54.2)		260 (61.9)	223 (64.8)	161 (64.7)	276 (61.7)	
Sleep duration (hrs), n (%)					P < 0.001[b]					P = 0.07[b]
≤ 8	209 (50.0)	268 (49.5)	172 (59.5)	130 (61.3)		235 (56.0)	183 (53.2)	128 (51.4)	233 (52.1)	
> 8 to 8.5	98 (23.4)	125 (23.1)	64 (22.1)	40 (18.9)		104 (24.8)	74 (21.5)	53 (21.3)	96 (21.5)	
> 8.5 to 9	77 (18.4)	91 (16.8)	36 (12.5)	18 (8.5)		49 (11.7)	63 (18.3)	39 (15.7)	71 (15.9)	
> 9 to 9.5	24 (5.7)	38 (7.0)	11 (3.8)	7 (3.3)		21 (5.0)	11 (3.2)	22 (8.8)	26 (5.8)	
> 9.5	10 (2.4)	19 (3.5)	6 (2.1)	17 (8.0)		11 (2.6)	13 (3.8)	7 (2.8)	21 (4.7)	

All values are medians (interquartile range) for continuous variables or N (%) for categorical variables.
[a]Analysis of variance (ANOVA; for continuous variables) or [b]Pearson's chi-square test (for categorical responses) by Game or TV Time groups, with p-value indicating statistical significances on variable distribution in comparison across groups.

Table 3. Adjusted odds ratios and 95% confidence intervals for lower brushing frequency. Longer game playing, but not TV viewing, significantly correlates with lower brushing frequency.

	Game playing (hrs)					TV viewing (hrs)				
	< 1	1 to < 2	2 to < 3	≥ 3	P for trend[a]	≤ 2	> 2 to 3	> 3 to 4	≥ 4	P for trend[a]
Elementary school	1,941	2,104	763	390		1,675	1,353	836	1,334	
Toothbrushing (< 2/day), n (%)	225 (11.6)	271 (12.9)	136 (17.8)	78 (20.0)		217 (13.0)	181 (13.4)	115 (13.8)	197 (14.8)	
Crude	1.00	1.13 (0.93-1.36)	1.65 (1.31-2.09)	1.91 (1.44-2.53)	P < 0.001	1.00	1.04 (0.84-1.28)	1.07 (0.84-1.37)	1.16 (0.95-1.43)	P = 0.15
Model 1[b]	1.00	1.08 (0.89-1.30)	1.53 (1.20-1.94)	1.82 (1.36-2.43)	P < 0.001	1.00	1.04 (0.84-1.29)	1.08 (0.85-1.38)	1.19 (0.97-1.47)	P = 0.10
Model 2[c]	1.00	1.04 (0.91-1.34)	1.57 (1.23-1.99)	1.86 (1.39-2.49)	P < 0.001	1.00	1.05 (0.85-1.30)	1.10 (0.86-1.40)	1.20 (0.97-1.48)	P = 0.08
Model 3[d]	1.00	1.07 (0.88-1.30)	1.51 (1.19-1.91)	1.76 (1.31-2.37)	P < 0.001	1.00	1.03 (0.83-1.27)	1.07 (0.84-1.37)	1.18 (0.95-1.45)	P = 0.13
Model 4[e]	1.00	1.09 (0.90-1.33)	1.53 (1.20-1.95)	1.76 (1.30-2.39)	P < 0.001	1.00	1.02 (0.82-1.26)	1.03 (0.81-1.32)	1.06 (0.85-1.32)	P = 0.55
Junior high school	418	541	289	212		420	344	249	447	
Toothbrushing (< 2/day), n (%)	48 (11.5)	61 (11.3)	48 (16.6)	57 (26.9)		58 (13.8)	59 (17.2)	33 (13.3)	64 (14.3)	
Crude	1.00	0.98 (0.67-1.46)	1.54 (1.00-2.36)	2.84 (1.85-4.34)	P < 0.001	1.00	1.29 (0.87-1.92)	0.95 (0.60-1.51)	1.04 (0.71-1.53)	P = 0.85
Model 1[b]	1.00	0.82 (0.55-1.24)	1.28 (0.82-1.99)	2.45 (1.59-3.80)	P < 0.001	1.00	1.36 (0.91-2.02)	1.01 (0.64-1.61)	1.08 (0.73-1.59)	P = 0.99
Model 2[c]	1.00	0.86 (0.57-1.31)	1.31 (0.84-2.06)	2.46 (1.58-3.84)	P < 0.001	1.00	1.42 (0.95-2.12)	1.05 (0.66-1.67)	1.09 (0.74-1.61)	P = 0.99
Model 3[d]	1.00	0.82 (0.54-1.23)	1.29 (0.83-2.01)	2.42 (1.55-3.77)	P < 0.001	1.00	1.36 (0.91-2.03)	1.01 (0.63-1.60)	1.07 (0.72-1.58)	P = 1.00
Model 4[e]	1.00	0.85 (0.56-1.30)	1.32 (0.84-2.09)	2.53 (1.60-4.00)	P < 0.001	1.00	1.46 (0.97-2.21)	1.00 (0.62-1.61)	0.98 (0.66-1.47)	P = 0.61

Odds ratio (95% confidence interval) (all such values).
[a]Multiple logistic regression analysis, with p-value indicating statistically significant incline depending upon length of the behavioral-time.
[b]Adjusted for age, sex, BMI.
[c]Additionally adjusted for studying-time with Model 1.
[d]Additionally adjusted for sleep duration with Model 1.
[e]Additionally adjusted for TV viewing or Game playing time, respectively.

Table 4. Adjusted odds ratios and 95% confidence intervals for lower frequency of toothbrushing with caries prevalence. Longer game playing, but not TV viewing is associated with unhealthy dental behavior defined as a lower brushing frequency regardless of the awareness of dental caries.

	Game playing (hrs)				TV viewing (hrs)			
	< 1	1 to < 2	≥ 2	P for trend[a]	≤ 2	> 2 to 3	> 3	P for trend[a]
Total	2,359	2,645	1,654		2,095	1,697	2,866	
Unhealthy dental behavior, n (%)	66 (2.8)	97 (3.7)	96 (5.8)		64 (3.1)	74 (4.4)	121 (4.2)	
Crude	1.00	1.32 (0.96-1.82)	2.14 (1.56-2.95)	P < 0.001	1.00	1.45 (1.03-2.04)	1.40 (1.03-1.90)	P < 0.05
Model 1[b]	1.00	1.35 (0.98-1.86)	2.36 (1.69-3.29)	P < 0.001	1.00	1.47 (1.04-2.07)	1.48 (1.08-2.02)	P < 0.05
Model 2[c]	1.00	1.40 (1.01-1.93)	2.43 (1.73-3.40)	P < 0.001	1.00	1.48 (1.05-2.09)	1.49 (1.09-2.04)	P < 0.05
Model 3[d]	1.00	1.36 (0.98-1.87)	2.34 (1.68-3.28)	P < 0.001	1.00	1.47 (1.04-2.07)	1.48 (1.08-2.02)	P < 0.05
Model 4[e]	1.00	1.36 (0.98-1.88)	2.31 (1.63-3.26)	P < 0.001	1.00	1.41 (1.00-1.99)	1.29 (0.94-1.77)	P = 0.17

Odds ratio (95% confidence interval) (all such values).
[a]Multiple logistic regression analysis, with p-value indicating statistically significant incline depending upon the length of behavioral-time.
[b]Adjusted for age, sex, BMI.
[c]Additionally adjusted for studying-time with Model 1.
[d]Additionally adjusted for sleep duration with Model 1.
[e]Additionally adjusted for TV viewing or Game playing time, respectively.

dental behavior, defined as toothbrushing less than twice per day regardless of the awareness of dental caries (Table 4). The level of game-playing time was significantly associated with the prevalence of unhealthy dental behavior. In model 3, the ORs (95% CI) for unhealthy dental behavior for the second and third group, using the shortest game-playing time category as a reference, were 1.36 (0.98-1.88), and 2.31 (1.63-3.26), respectively (P for trend < 0.001). Although TV-viewing time had a tendency to associate with unhealthy dental behavior, the significance was nullified after the adjustment for game-playing time (P for trend = 0.15).

Discussion

Our cross-sectional study, using unique data on a large population sample from Japanese athletic children both in elementary and junior high school, examined the association between screen-time behaviors and toothbrushing fre-

quency. Excessive game-playing behavior, not TV-viewing behavior, was significantly associated with a lower daily frequency of toothbrushing (less than twice per day). Moreover, excessive game-playing behavior was also associated with unhealthy dental behavior defined as a lower brushing frequency despite the awareness of dental caries. Our results suggest a type-specific unfavorable influence of screen-time behavior affecting the frequency of toothbrushing among athletic children.

Longer screen-time increases the risk of cardiovascular diseases (CVD) due to less physical activity and more sugar consumption (Marshall et al. 2004; Rey-Lopez et al. 2008; Salmon et al. 2011; Tremblay et al. 2012; Stamatakis et al. 2013; Carson et al. 2015). Lower toothbrushing frequency also increases the risk of CVD (Ahmed et al. 2012; Kobayashi et al. 2012). However, little is known about the negative impacts of screen time on oral health behavior. A previous study reported that participants with excessive TV viewing showed a higher prevalence of dental caries among schoolchildren in China (Zeng et al. 2014). Given that dental caries are adversely associated with the frequency of toothbrushing (Murtomaa 1979; Macgregor et al. 1996; Eisalhy et al. 2015; Needleman et al. 2016), excessive TV viewing could also be associated with a lower brushing frequency. However, our results showed an adverse impact of game-playing, but not TV viewing on toothbrushing frequency. One of the strongest risk factors for dental caries is sugar consumption (Kalsbeek and Verrips 1994), and snacking is reportedly more distinct during TV viewing than game playing (Falbe et al. 2014). Moreover, larger amounts of snacking are not necessarily associated with a higher frequency of toothbrushing (Peltzer and Pengpid 2014). Taken together, this discrepancy may have been partially explained by snacking behavior.

One potential explanation of the mechanism behind the association between excessive game playing and a lower daily frequency of toothbrushing is having less free time due to the choice to engage in game playing. Nowadays, game addiction has become a greater concern worldwide because of the diffusion of handheld game consoles. Excessive game playing in the bedroom directly disrupts sleep (Chaput et al. 2014). A national survey conducted in Japan reported that the average time spent playing games among Japanese children is approximately 1.66 hrs per day, and that about 10% of Japanese children spend ≥ 4 hrs per day on game playing (National Institute for Educational Policy Research 2014), which indicates that time is shifted from sleep duration to game playing (Depledge et al. 2011). Considering that toothbrushing is generally performed in the morning and at night (Murtomaa 1979; Macgregor et al. 1996; McKay et al. 2016), sleep-disturbed children also show a higher prevalence of dental caries, likely due to the lower frequency of toothbrushing (McKay et al. 2016). Taken together, we hypothesized that excessive game playing results in a decrease in the available time both for toothbrushing and sleep. However, the significant association between game-playing time and a lower brushing frequency (< 2 times/day) remained even after adjustment for sleep duration. Therefore, having less available time for toothbrushing due to choosing video games did not solely explain the adverse effects of excessive game-playing on toothbrushing frequency.

Our findings showed that game-playing time was also significantly associated with the prevalence of unhealthy dental behavior. This result suggested that salutogenic characteristics would play a key role in mediating the significant correlations between lower brushing frequency and excessive game-playing. According to a salutogenic concept proposed by Antonovsky, sense of coherence (SOC) has recently been established to estimate a person's health-promoting state (Antonovsky 1980). SOC strongly reflects oral health behaviors, including toothbrushing frequency (Savolainen et al. 2009; Elyasi et al. 2015). A poor SOC results in psychological problems in early childhood, and is also a powerful predictor for future chronic health problems such as morbid obesity and psychiatric disorders (Raty et al. 2005; Honkinen et al. 2009). Thus, although we did not evaluate any variables related to SOC, the association between lower brushing frequency and longer game-playing behavior is partially interpreted as a poor SOC in participants with longer game-playing behavior.

The present study had some limitations. First, we cannot rule out the possibility of a sex bias owing to a higher percentage of male participants, who tend to prefer both playing video games and participating in sports more than females (Robinson et al. 2001; Polman et al. 2008; Ashley et al. 2015). Second, although we considered potential confounders, we cannot disregard the possibility that toothbrushing frequency is affected by other factors; for example, parents' oral health literacy or socio-economic status. Third, a self-report questionnaire was used to evaluate all variables, leading to recall bias. However, because the frequency of daily toothbrushing is relatively constant, the reliability of this variable is not low. Moreover, the self-reported awareness of dental caries in elementary (20.9%) and junior high school students (18.9%) was very similar to the prevalence of dental caries among Japanese school children in elementary (26.3%) and junior high school (18.5%) reported by the Ministry of Education, Culture, Sports, Science and Technology (2014). Finally, because this study had a cross-sectional design, reverse causality could not be ruled out.

In conclusion**,** excessive game playing, but not TV viewing, is significantly associated with a lower daily frequency of toothbrushing. Moreover, excessive game playing was associated with unhealthy dental behavior, defined as a lower brushing frequency despite the awareness of dental caries. Longitudinal studies are needed to confirm the causal relationship and to clarify the underlying mechanisms between game-playing behavior and toothbrushing frequency.

Acknowledgments

The authors are grateful to other members of Hagiwara's Laboratory, Tohoku University Graduate School of Medicine for their assistance.

This study was performed as part of the Miyagi Sports Medical Projects, and supported by Asahi Breweries, the MEXT-Supported Program for the Strategic Research Foundation at Private Universities of the Kansei Fukushi Research Institute, Tohoku Fukushi University (2012–2016), and by grants from the Japan Society for the Promotion of Science, 24390429.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

H.M., T.S., K. Kuroki, K. Kanazawa, Y.H., and R.N. participated in conceptualization of the study, and W.M. performed the data preparation. M.T., H.M., T.S., and Y.H. contributed to the analysis, writing, and proof-reading of this manuscript. All authors read and approved the final manuscript.

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