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Evaluation of the association between sleep duration and tooth loss among Korean adults: data from the Korean National Health and Nutrition Examination Survey (KNHANES 2012–2014)

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ABSTRACT

Objectives This study assessed the association between sleep duration and tooth loss using nationally representative data. In this study, a cross-sectional analysis was performed using multivariable logistic regression analysis models.

Setting The present study analysed data from the Korean National Health and Nutrition Examination Survey between 2012 and 2014.

Participants A total of 14 675 respondents over 19 years old without missing values were included in this study.

Exposure and primary outcome measures Sleep duration and tooth loss.

Results Participants with a sleep duration of 6–8 hours showed the lowest prevalence of diabetes mellitus, hypertension, metabolic syndrome, periodontitis and meeting the waist circumference criteria for metabolic syndrome. Adjusted OR and their 95% CI of male individuals with fewer than 25 natural teeth were 1.426 (1.113 to 1.827), 1.290 (1.074 to 1.548), 0.988 (0.853 to 1.145), 1 (reference), 1.058 (0.907 to 1.235) and 1.620 (1.287 to 2.038) for sleep duration of 4 hours or less, 5 hours, 6 hours, 7 hours, 8 hours and 9 hours or more, respectively ($p<0.05$), after adjustments for age, sex, smoking, drinking, walking, frequency of tooth brushing per day, body mass index and periodontitis.

Conclusions Our findings showed the U-shaped association between sleep duration and tooth loss was suggested by multiple logistic regression analyses after adjusting for confounding factors. Moreover, subgroup analyses showed that short and long sleep duration were associated with greater tooth loss in participants without diabetes mellitus, those without hypertension and those without metabolic syndrome.

Strengths and limitations of this study

- ► This study used nationally representative data with multistage clustered probability design, and the dental examinations were performed by trained dentists.
- ► The design of this study is cross-sectional, and the causal direction cannot be evaluated.
- ► The duration of sleep was evaluated via interviews with the participants, and there may be recall bias.

INTRODUCTION

Previous studies have shown that sleep duration is associated with systemic diseases.[1] Sleep was reported to be associated with cardiovascular function, including physiological conditions.[2] The quantity of sleep is reported to be associated with the incidence of type 2 diabetes mellitus.[3] Previous research showed that higher prevalence of obesity was associated with short sleep duration.[4] In addition, prevalence of depression was independently associated with poor sleep.[5] The previous results showed that increased OR of being obese were noted in individuals with ≤5 hours of sleep (OR of 1.7) and participants with more than 5 to less than 6 hours of sleep (OR of 1.4) after controlling for compounding factors.

Previous studies have shown the association of severity of periodontal disease with poor sleep.[1 6 7] Additionally, deep sleep deprivation is reported to worsen systemic health in rodent models showing increase of alveolar bone loss and gingival inflammation.[6] However, a nationally representative study of participants who were aged 30 years analysed the relationship between periodontal disease and poor sleep, and the study did not show statistical significance.[7] More recently, direct and independent association between sleep duration and the prevalence of periodontitis was found.[8] Moreover, the association between tooth loss and obstructive sleep apnoea has

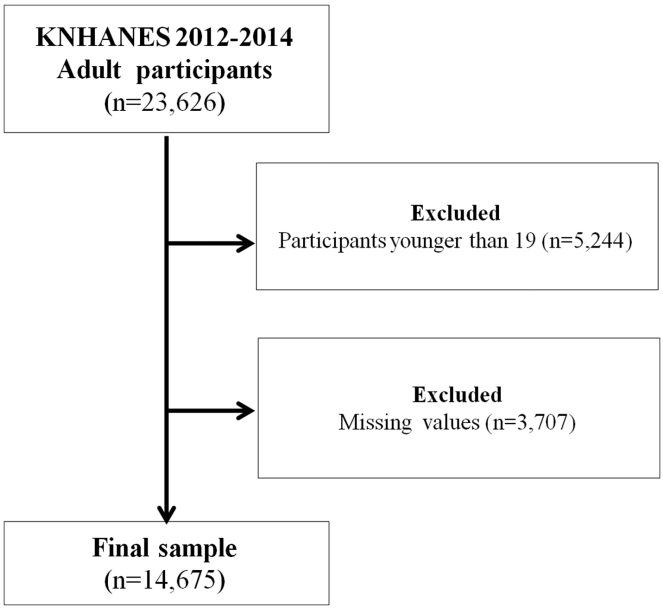

Figure 1 Participant flow chart. KNHANES, Korean National Health and Nutrition Examination Survey.

been evaluated in the previous studies.[9 10] Prevalence of high risk for obstructive sleep apnoea increased by 2% for each additional lost tooth and tooth loss was suggested to be an independent risk factor for obstructive sleep apnoea.[10] However, the relationship between sleep duration and tooth loss has not been proven yet. It was hypothesised in this study that there is no significant association between short sleep duration and tooth loss. This study was performed to assess the association between sleep duration and tooth loss using nationally representative data.

METHODS

Survey and subjects

This study used data from the Korean National Health and Nutrition Examination Survey (KNHANES), which was conducted between 2012 and 2014 by the Division of Chronic Disease Surveillance under the Korean Centre for Disease Control and Prevention and the Korean Ministry of Health and Welfare.[11–13] The KNHANES is a nationwide survey of non-institutionalised civilians that uses a stratified and multistage probability sampling design with a rolling survey sampling model. The sampling units were based on the population and housing consensus from the National Census Registry in Korea. Sample weights were used to calculate all statistics of this survey. The sample weights were created by considering survey non-response, the complex survey design and post-stratification to represent the Korean population with sample participants. Trained interviewers administered the standardised health examination and questionnaire. Initially, a total of 23 626 individuals were candidates in the KNHANES survey. The analysis in this study was confined to a total of 18 382 respondents over the course of 19 years (n=5233 excluded). Finally, 14 675 individuals whose responses contained no missing values for the outcome variables were analysed (n=3707 excluded, figure 1 and table 1).

All participants in the survey signed an informed consent prior to participation. This study was conducted according to the Helsinki Declaration-Based Ethical Principles for Medical Research Involving Human Subjects. This is a secondary data analysis, and the institutional reviewer board at Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, approved this study protocol (KC14EISI0636 and KC18ZESI0150). The analysis was performed after planning the research question.

Patient and public involvement

Neither patients nor public were involved in the development of the research question, in the analysis and in drawing conclusions from the results.

Sociodemographic and lifestyle variables

Participants' smoking status was categorised into two groups in accordance with respondents' answers on the self-report questionnaire: current smoker or not. Participants were categorised into the current drinker group by using the criterion of alcohol consumed within 1 month of the interview.[14] The amount of pure alcohol consumed was calculated using the average number of alcoholic beverages consumed and the frequency of alcohol consumption based on the survey. Individuals were regarded as regular walkers if they walked at least five times per week for more than 30 min per session. Sleep duration was self-reported based on the survey. In this study, a short sleep was considered 5 hours or less; a long sleep was defined as 9 hours or more and the reference category was 6 to 8 hours.[15]

Anthropometric and biochemical measurements

Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with participants in light indoor clothing and without shoes. Body mass index was calculated as body weight (kg) divided by the squared height (m^2). Waist circumference was measured at the narrowest point between the lower border of the rib cage and the iliac crest while the participant was in a standing position.[16 17]

A blood sample was collected from the antecubital vein of each participant after a fasting period of 8 hours. Concentrations of serum fasting plasma glucose, total cholesterol, triglycerides, high-density lipoprotein cholesterol and white cell count were measured from the sample. To measure the levels of serum fasting plasma glucose, total cholesterol, triglycerides and high-density lipoprotein cholesterol, an automated chemistry analyser (Hitachi Automatic Analyzer 7600, Hitachi, Tokyo, Japan) and commercially available kits (Daiichi, Tokyo, Japan) were used.[18]

Table 1 The baseline characteristics of the study individuals according to the number of natural teeth divided by 25

Variables	Number of natural teeth ≥25	<25	P value*	Missing n
Unweighted n	10307	4368		
Age (years)	41.05±0.18	58.65±0.39	<0.0001	0
Body mass index (kg/m^2)	23.69±0.05	23.82±0.07	0.0991	0
Waist circumference (cm)	80.16±0.15	82.43±0.21	<0.0001	0
Number of natural teeth	27.37±0.01	18.57±0.12	<0.0001	0
White cell count (x10^3/μL)†	5.92 (5.88 to 5.96)	5.99 (5.92 to 6.06)	0.0815	982
Sex (male)	4269 (50 to 0.5)	1848 (46.8 to 0.9)	0.0033	0
Smoking (current)	1772 (21.8 to 0.6)	692 (19.4 to 0.8)	0.0178	6
Drinking (current)	5769 (60.8 to 0.6)	1908 (49.2 to 1)	<0.0001	1
Walking (yes)	3955 (40 to 0.7)	1570 (36.9 to 1)	0.0058	225
Frequency of tooth brushing per day			<0.0001	175
≤1	816 (8.3 to 0.3)	682 (15.3 to 0.7)		
2	3822 (36.9 to 0.6)	1818 (41.4 to 0.9)		
≥3	5594 (54.8 to 0.6)	1768 (43.3 to 1)		
Self-reported oral status			<0.0001	4
Favourable	15.6 (0.5)	9.2 (0.5)		
Average	45.9 (0.6)	27.7 (0.9)		
Problematic	38.6 (0.7)	63.1 (1)		
Body mass index ≥25 (kg/m^2)	3199 (31.7 to 0.6)	1513 (34.1 to 0.9)	0.0185	0
Diabetes mellitus (yes)	674 (5.9 to 0.3)	729 (17.8 to 0.8)	<0.0001	1345
Hypertension (yes)	2269 (19.1 to 0.5)	2024 (41.8 to 1)	<0.0001	251
Metabolic syndrome (yes)	2357 (22.1 to 0.5)	1716 (40.8 to 1)	<0.0001	1150
Periodontitis (yes)	2348 (21.2 to 0.6)	1881 (42.8 to 1.1)	<0.0001	0
Sleep duration (hours)			<0.0001	7
≤5	1338 (12.2 to 0.4)	1019 (21.4 to 0.7)		
6–8	8325 (81.2 to 0.5)	2974 (70.3 to 0.8)		
≥9	644 (6.6 to 0.3)	375 (8.3 to 0.5)		

Data are presented as means±SE for continuous variables.
Data are presented as unweighted n (weighted percentage, SE) for categorical variables.
*P values were obtained by independent t-test for continuous variables or X^2 test for categorical variables.
†Log transformation was applied to the value, and the geometric mean (95% CI) was shown.

Metabolic syndrome was determined if three or more of the following criteria were fulfilled[19]: waist circumference ≥90 cm in men and ≥80 cm in women, fasting triglycerides ≥150 mg/dL or use of lipid-lowering medication, high-density lipoprotein cholesterol <40 mg/dL in men and <50 mg/dL in women or use of medication, blood pressure ≥130/85 mm Hg or use of antihypertensive medication and, finally, fasting blood glucose ≥100 mg/dL or current use of antidiabetes medication. Diabetes was diagnosed when fasting blood sugar was >126 mg/dL or when the individual was currently using antidiabetic medications with diabetes as a component of the fasting glucose component of metabolic syndrome.[20] Hypertension was defined as a systolic blood pressure of >160 mm Hg, a diastolic blood pressure of >90 mm Hg or the current use of systemic antihypertensive drugs.[21 22]

Oral health behaviours, periodontal disease and the evaluation of the number of natural teeth

The time of day when participants brushed their teeth and used secondary oral products was recorded as oral health behaviours.[23] We calculated the frequency of daily tooth brushing by the total number of times the teeth were brushed per day. Secondary oral products included the following: dental floss, mouthwash, interdental brushes, electric toothbrushes, irrigation devices, tongue cleaners, end-tufted brushes and a special device for dentures. Self-reported oral status was categorised into favourable, average and problematic. The presence of periodontal disease was evaluated using the WHO's community periodontal index. Periodontal disease was defined if the community periodontal index score was ≥3.[24] The status of natural teeth was categorised as

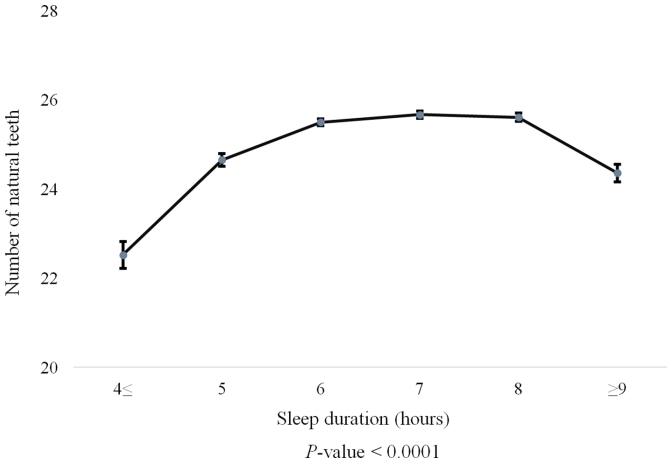

Figure 2 The number of natural teeth of the individuals according to sleep duration after adjustments for age, sex, smoking, drinking, walking, frequency of tooth brushing per day, body mass index and periodontitis.

primary tooth presence, permanent tooth presence, lack of tooth presence or permanent dental root fragment presence. In this study, the natural tooth was considered present if the status was among the first two categories and absent if the status was among the last two categories. We categorised the subjects' two groups according to the total number of natural teeth: ≥25 teeth and <25 teeth. Trained and calibrated dentists examined the oral status of the participants, and training was provided to minimise the errors in the measurement by each examiner during the examination as a part of quality control.

Statistical analyses

All data are presented as mean±SE or unweighted n (weighted percentage, SE). Logarithmic transformation was performed to achieve a normal distribution when necessary. Statistical analyses were performed using the survey procedure of the statistical software package (SAS V.9.2 for Windows, SAS Institute, Cary, North Carolina, USA) to account for the complex sampling design considering strata, cluster and weight. A X^2 test for categorical variables or an independent t-test for continuous variables was performed to assess the differences in characteristics according to the number of natural teeth. A multivariable logistic regression analysis was used to evaluate the risk of tooth loss in relation to sleep duration, and OR and 95% CI were calculated after adjusting for potential confounders. Model 1 was adjusted for age and sex. In Model 2, adjustments were made for the variables in Model 1, plus smoking, drinking and walking habits and the frequency of tooth brushing. Model 3 was adjusted for the variables that were adjusted in Model 2, plus body mass index and periodontitis.

RESULTS

Figure 2 describes the number of natural teeth of the individuals according to sleep duration after adjustments for age; sex; smoking, drinking and walking habits; frequency of tooth brushing per day; body mass index and periodontitis (p<0.05). Statistically significant differences were noted regarding the duration of sleep (hours) and tooth loss, showing a U-shaped association.

Table 1 shows the baseline characteristics of the study's individuals according to the number of natural teeth, which is standardised as 25. Significant differences were noted between the groups according to the participants' mean age; waist circumference; white cell count; smoking, drinking and walking habits; frequency of tooth brushing per day; self-reported oral status; body mass index ≥25 (kg/m^2); diabetes mellitus; hypertension; metabolic syndrome and periodontitis (p<0.05).

Table 2 shows the baseline characteristics of the study's individuals according to sleep duration. Participants with a sleep duration of 6–8 hours showed the lowest prevalence of diabetes mellitus, hypertension, metabolic syndrome, periodontitis and meeting the waist circumference criteria for metabolic syndrome. The subgroup analysis categorised by age, sex, body mass index, diabetes mellitus, hypertension and metabolic syndrome (group 1: sleep duration ≤5 hours, group 2: 6–8 hours and group 3:≥9 hours) is shown in figure 3. The association between short and long sleep duration and tooth loss was evident in both of the following groups: 19–64 years and ≥65 years. The adjusted OR and their 95% CI from multivariate logistic regression analyses for individuals with fewer than 25 natural teeth were significantly higher in short sleep and long sleep groups than in the group that slept 6–8 hours with participants who had a body mass index ≤25, without diabetes mellitus, without hypertension or without metabolic syndrome.

Table 3 shows the adjusted OR and their 95% CI from multivariate logistic regression analyses for individuals with fewer than 25 natural teeth according to sleep duration. The adjusted OR and the 95% CI of the male individuals with fewer than 25 natural teeth were 1.426 (1.113 to 1.827), 1.290 (1.074 to 1.548), 0.988 (0.853 to 1.145), 1 (reference), 1.058 (0.907 to 1.235) and 1.620 (1.287 to 2.038) for sleep durations of 4 hours or less, 5 hours, 6 hours, 7 hours, 8 hours and 9 hours or more, respectively (p<0.05), after adjustments for age; sex; smoking, drinking and walking habits; frequency of tooth brushing per day; body mass index and periodontitis.

DISCUSSION

The aim of this study was to identify the associations between tooth loss and sleep duration. The results showed an increased OR of tooth loss with short and long sleep duration in adults at a statistically significant level.

Sleep problems have emerged as a significant medical and social concern.[25] In general, younger people and women in the population reported more somatic and psychological complaints.[26] In previous research, using a questionnaire, the overall prevalence of insomnia was 21.4% during the preceding month.[27] The percentage of difficulty in initiating sleep was 8.3%, the percentage

Table 2 The baseline characteristics of the study individuals according to sleep duration

Variables	Sleep duration (hours) ≤5	6–8	≥9	P value*
Unweighted n	2357	11 299	1019	
Age (years)	51.23±0.48	44.28±0.23	42.54±0.8	<0.0001
Body mass index (kg/m^2)	24.15±0.09	23.68±0.05	23.35±0.17	<0.0001
Waist circumference (cm)	82.02±0.26	80.54±0.14	79.67±0.47	<0.0001
Number of natural teeth	24.08±0.14	25.59±0.06	24.84±0.2	<0.0001
White cell count (x10^3/μL)†	6 (5.91 to 6.09)	5.91 (5.87 to 5.95)	6.07 (5.92 to6.22)	0.0206
Sex (male)	798 (42.2 to 1.2)	4948 (51.4 to 0.5)	371 (39.5 to 2)	<0.0001
Smoking (current)	356 (20.8 to 1.1)	1947 (21.4 to 0.5)	161 (20 to 1.8)	0.6914
Drinking (current)	1065 (52 to 1.2)	6122 (59.7 to 0.6)	490 (53.6 to 2)	<0.0001
Walking (yes)	906 (40.3 to 1.3)	4303 (39.7 to 0.6)	316 (32.7, 1.8)	0.0011
Frequency of tooth brushing per day				<0.0001
≤1	303 (12.5 to 0.8)	1033 (9 to 0.3)	162 (14.2 to 1.3)	
2	927 (38.9 to 1.3)	4302 (37.6 to 0.6)	411 (39.4 to 1.9)	
≥3	1086 (48.6 to 1.3)	5859 (53.3 to 0.6)	417 (46.4 to 2)	
Self-reported oral status				<0.0001
Favourable	284 (12 to 0.9)	1663 (14.6 to 0.5)	138 (12.5 to 1.3)	
Average	863 (37.7 to 1.3)	4790 (42.7 to 0.6)	396 (39.9 to 1.8)	
Problematic	1209 (50.3 to 1.3)	4844 (42.8 to 0.7)	484 (47.6 to 1.9)	
Body mass index ≥25 (kg/m^2)	826 (36.7 to 1.2)	3576 (31.7 to 0.6)	310 (29 to 1.7)	<0.0001
Diabetes mellitus (yes)	297 (11.3 to 0.8)	995 (8 to 0.3)	111 (9.8 to 1.1)	<0.0001
Hypertension (yes)	929 (32.4 to 1.2)	3043 (23.1 to 0.6)	321 (22.7 to 1.6)	<0.0001
Metabolic syndrome (yes)	845 (34.6 to 1.2)	2933 (25 to 0.5)	295 (25 to 1.7)	<0.0001
Periodontitis (yes)	766 (30.3 to 1.3)	3144 (25.6 to 0.7)	319 (25.2 to 1.7)	0.0004
Number of natural teeth (<25)	1019 (34.8 to 1.2)	2974 (20.8 to 0.5)	375 (27.8 to 1.7)	<0.0001

*P values were obtained by independent t-test for continuous variables or X^2 test for categorical variables.
†Log transformation was applied to the value, and the geometric mean (95% CI) was shown.

of difficulty in maintaining sleep was 15.0% and the percentage of early morning awakening was 8.0%. The overall prevalence of male and female insomnia was reported in another study.[28] The percentage of male participants who had difficulty initiating sleep, difficulty maintaining sleep and poor perceived quality of sleep were 8.6%, 12.9% and 17.8%, respectively. The percentage of female individuals who had difficulty initiating sleep, difficulty maintaining sleep and poor perceived quality of sleep were 12.6%, 16.2% and 20.2% respectively. It was also shown that 8%–18% of the general population reported sleep dissatisfaction.[29]

Previous studies continuously reported the association between health issues and sleep duration.[4 7 30 31] Higher total mortality was associated with both short and long sleep duration.[30 31] Similarly, both short and long sleep duration were associated with higher type 2 diabetes mellitus, cardiovascular disease, respiratory diseases and obesity.[30 31] Previous studies suggested a U-shaped association between health outcomes and sleep duration.[30 31] Similarly, this study clearly showed that tooth loss associated with the duration of sleep (hours) presented a U shape after the adjustments of covariates. A subgroup analysis revealed that the U-shape association was maintained in the following groups: 19–64 years and ≥65 years. Moreover, subgroup analyses showed that short and long sleep duration were associated with higher incidence of tooth loss in participants without diabetes mellitus, those without hypertension and those without metabolic syndrome.

The definition of short and long sleep duration varies among different studies.[15 32–34] In previous studies, the reference category was defined as 7 hours,[32] 7 to 8 hours,[35] 7 to 9 hours,[36] 6 to 8 hours,[37] and 9 hours.[34] In this study, the reference was considered as 6 to 8 hours in the categorical evaluation.

This association between sleep duration and tooth loss may be explained by the following. Monocyte production of interleukin-6 and tumour necrosis factor alpha was significantly higher in the morning after poor sleep, compared with the morning levels following uninterrupted sleep.[38] Similarly, sleep deprivation induced a

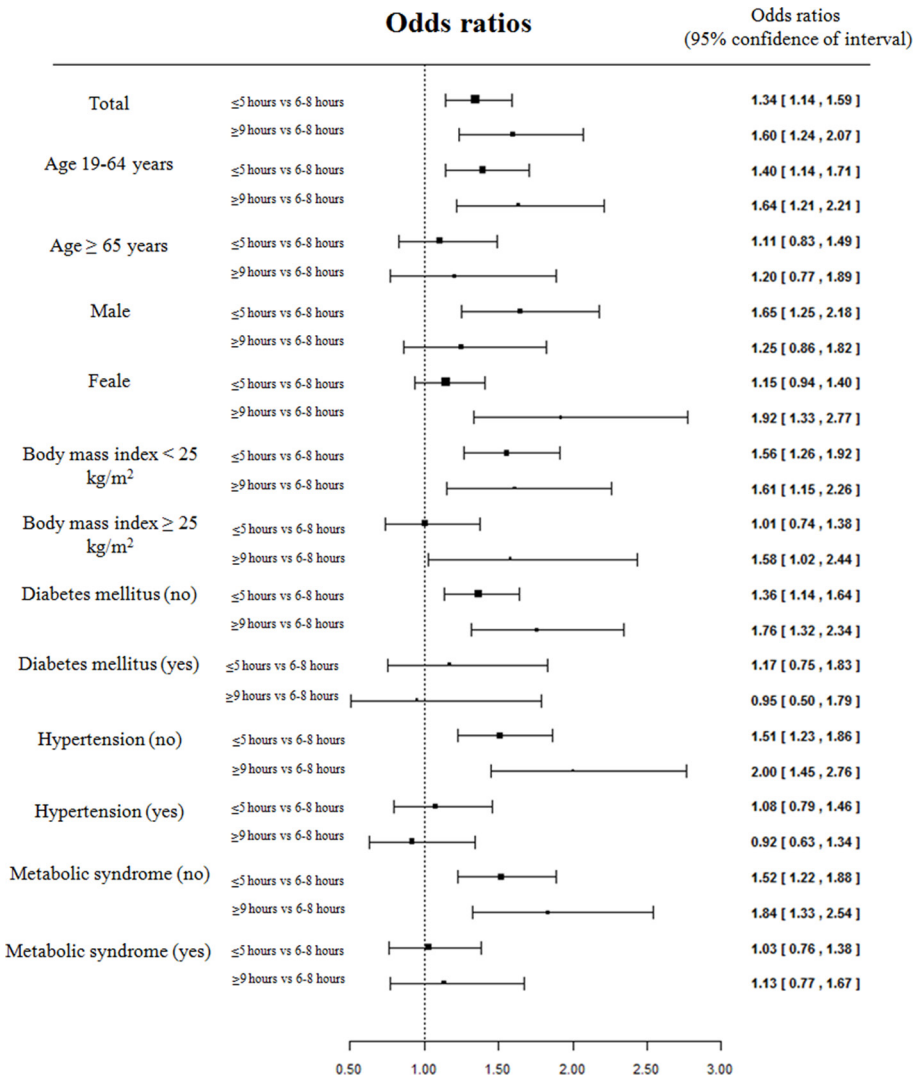

Figure 3 Subgroup analysis categorised by age, sex, body mass index, diabetes mellitus, hypertension and metabolic syndrome (group 1: sleep duration ≤5 hours, group 2: 6–8 hours and group 3: ≥9 hours) as well as the adjusted OR and their 95% CI from multivariate logistic regression analyses for individuals with fewer than 25 natural teeth.

significant increase in E-selectin, intracellular adhesion molecule-1, interleukin-1 beta and anti-inflammatory cytokine interleukin-1 receptor antagonist; a significant decrease in C reactive protein and interleukin-6; and no significant change in vascular adhesion molecule-1.[39] It should also be considered that sociodemographic factors

Table 3 The adjusted OR and their 95% CI from multivariate logistic regression analyses for individuals <25 natural teeth according to sleep duration

Variables	Number of natural teeth <25		
Sleep duration (hours)	**Model 1**	**Model 2**	**Model 3**
≤4	1.533 (1.23 to 1.91)	1.506 (1.203 to 1.884)	1.53 (1.223 to 1.915)
5	1.295 (1.087 to 1.542)	1.264 (1.059 to 1.51)	1.274 (1.066 to 1.523)
6	1.018 (0.884 to 1.172)	0.999 (0.867 to 1.152)	1.001 (0.868 to 1.155)
7	1 (reference)	1 (reference)	1 (reference)
8	1.085 (0.936 to 1.257)	1.048 (0.903 to 1.215)	1.04 (0.897 to 1.206)
≥9	1.677 (1.345 to 2.09)	1.633 (1.306 to 2.041)	1.621 (1.298 to 2.024)
P value	<0.0001	<0.0001	<0.0001

Model 1: Age and sex adjusted.
Model 2: Model 1+smoking, drinking, walking and frequency of tooth brushing per day adjusted.
Model 3: Model 2+body mass index, and periodontitis adjusted.

may be associated with sleep disorders.[28] Among men, difficulty maintaining sleep and poor perceived quality of sleep were associated with never having married with the OR of 2.8 and 2.1, respectively. Difficulty maintaining sleep was also associated with being over 60 years old and/or divorced with OR of 2.7 and 3.7, respectively. Among women, difficulty maintaining sleep was associated with being widowed (OR=1.65) and unemployed (OR=1.60), and poor perceived quality of sleep was associated with advancing age (OR=0.63–0.50). The association of sleep deprivation with severity of periodontal disease was suggested in the previous study.[1] Previous report suggested the association between the difficulty in sleep and the presence of dental caries.[40] It is not rare that sleep problems are reported in individuals with headache and chronic orofacial pain.[25 41] Researchers suggested the need to refer patients with temporomandibular joint disorder complaining of sleep disturbance for polysomnographic evaluation, considering the high rates of primary insomnia and sleep apnoea.[41] Another report showed that periodontitis prevalence was higher in individuals with long sleep duration.[8] Interleukin-1 and tumour necrosis factor may be involved in tooth loss in participants with long sleep duration.[42]

The present study had several limitations to consider. The design of this study is cross-sectional, and the causal direction cannot be evaluated.[43] The duration of sleep could be an influencing factor for tooth loss, but the opposite may be true. The duration of sleep was evaluated via interviews with the participants, and there may have been recall bias.[44] It should also be considered that there may be residual confounding factors and there may be missing factors that affect sleep duration. Intrinsic need, sleep disorders, external environmental pressure, quality of sleep, naps and simple category in smoking state may also need to be considered. In spite of these limitations, this study used very well-organised and reliable data with complex, stratified and multistage clustered probability design.[45] The dental examinations were performed by trained dentists.[24] Collectively, these results can be considered as nationally representative data but limited to South Korean population.

CONCLUSIONS

Conclusively, the U-shaped association between sleep duration and tooth loss was suggested by multiple logistic regression analyses after adjusting for confounding factors. Moreover, subgroup analyses showed that short and long sleep duration were associated with greater tooth loss in participants without diabetes mellitus, those without hypertension and those without metabolic syndrome.

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Contributors KH and J-BP conceived experiments, analysed the data, wrote the manuscript, reviewed the manuscript and approved the final manuscript.

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Competing interests None declared.

Patient consent Obtained.

Ethics approval This study was approved by institutional review board of Korean Center for Disease Control and Prevention (2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-12EXP-03-5C), and conducted according to the Helsinki Declaration based Ethical Principles for Medical Research Involving Human Subjects.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement All data generated or analysed during this study are included in this article.

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