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Association between semi-solid yogurt intake and periodontitis in Korean adults

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ABSTRACT

Purpose: The purpose of this study was to examine the association between the intake of semi-solid yogurt and periodontitis in Korean adults using a national database.

Methods: The data analyzed in this study are a subset of the sixth Korean National Health and Nutrition Examination Survey conducted in 2015 by the Korea Centers for Disease Control and Prevention. The sample size for this study was 4,727. We collected data on sociodemographic characteristics, oral health-related variables, oral and general health status, and intake of semi-solid yogurt. Semi-solid yogurt intake (YI) was calculated by multiplying the frequency of YI over the previous week by the average intake per serving. We assessed periodontal conditions using the Community Periodontal Index (CPI) and defined periodontitis as a CPI score ≥ 3 . Multivariate logistic regression analyses were performed after adjusting for sociodemographic variables, and oral and general health behaviors and status.

Results: The mean weekly YI among those without periodontitis (1.03 ± 0.06 cups) was significantly higher than among those with periodontitis (0.77 ± 0.08 cups) ($P < 0.001$). Individuals who consumed more than 2 cups of yogurt per day were 76% less likely to have periodontitis than those who consumed less than 1 cup of yogurt per week after adjusting for all covariates (odds ratio, 0.24; 95% confidence interval, 0.10–0.60).

Conclusions: We found a significant association between increased intake of semi-solid yogurt and periodontal health. We therefore recommend daily consumption of semi-solid yogurt as a probiotic to improve periodontal health. Further longitudinal studies are required to elucidate plausible mechanisms through which probiotics impact periodontal disease, considering both periodontal pathogens and clinical periodontal parameters.

Keywords: Periodontitis; Probiotics; Yogurt

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

INTRODUCTION

Dental plaque is a complex microbial mixture that structurally adheres to dental surfaces [1,2]. It develops as a biofilm embedded in a matrix of polymers of bacterial and salivary proteins [2]. Etiologically, dental biofilm is the cause of periodontitis [3]. Dental biofilm contains various types of microorganisms [4], which Socransky and Haffajee [5] classified in terms of potential pathogenicity. The most detrimental pathogens, *Porphyromonas gingivalis* and *Treponema denticola*, are strongly associated with periodontal disease [6].

Although these bacteria are susceptible to antibacterial agents such as mouthwashes containing chlorhexidine and antibiotics, thick biofilms can be resistant to antibacterial agents [7,8]. Moreover, the Centers for Disease Control and Prevention in the United States have suggested that most bacteria can develop resistance to any antibiotic treatment [9], and a disadvantage of chlorhexidine is that it can cause tooth discoloration [8].

Seeking alternative treatment options for periodontitis, Raff and Hunt [10] reviewed several studies and suggested that probiotics could be potentially beneficial for periodontal health. Guarner et al. [11] suggested that yogurt fulfills the current requirements for probiotics. Several studies have investigated the relationship between yogurt intake (YI) and periodontitis [12-14] and found that YI has a preventive effect on periodontitis.

We hypothesized that higher-viscosity and firmer yogurt remains in the periodontal tissues for a longer time, leading to a stronger direct effect of probiotics. However, no previous studies have investigated the association between semi-solid YI and periodontitis. Therefore, we investigated the association between semi-solid YI and the prevalence of periodontitis in Korean adults using a national database.

MATERIALS AND METHODS**Data source and study population**

The data in this study are a subset of the sixth Korean National Health and Nutrition Examination Survey (KNHANES VI) conducted in 2015 by the Korea Centers for Disease Control and Prevention (KCDC). The KNHANES is a nationwide, population-based, cross-sectional survey examining the general health and nutritional status of Koreans. It has been conducted by the Korean Ministry of Health and Welfare and the KCDC since 1998 [15]. The sampling protocol for KNHANES involves a complex, stratified, and multistage probability cluster survey of a representative sample of the noninstitutionalized civilian population of Korea [15].

The number of participants in the KNHANES VI was 6,977 (3,169 males and 3,808 females). The sample size for this study was 4,727, including those in the unweighted study sample who were between 19 and 64 years of age in 2015. The mean age of our sample was 43.39 years (standard deviation, 18.29 years). From the overall KNHANES VI data, we used sociodemographic characteristics (age, sex, household income), oral health-related variables (tooth-brushing frequency, self-oral health cognition, Community Periodontal Index [CPI]), oral and general health status and behavior (smoking status, obesity, diabetes), and YI. The 2015 KNHANES allowed the researchers to obtain national-level estimates with an assigned sampling weight variable that could generate aggregate weighted frequencies [15].

YI

The yogurt type studied was only semi-solid yogurt, not drinkable yogurt. To determine routine YI over the previous week, intake frequency in the last year was classified into 9 categories ranging from “never or almost never” to “3 times per day,” with 1 serving equal to a cup (100 grams). YI was calculated by multiplying the YI frequency over the previous week by the average intake per serving. Participants were divided into 4 categories based on the number of cups of yogurt consumed: 1) <1 cup per week, 2) ≥1 cup per week but <1 cup per day, 3) ≥1 cup but <2 cups per day, and 4) ≥2 cups per day.

Covariates

Sociodemographic variables and risk factors related to periodontal disease were selected as covariates. The confounders in this study were age, sex, household income, tooth-brushing frequency, self-oral health cognition, smoking status, obesity, and diabetes. Household income was adjusted for the number of household members and categorized into 4 quartiles, ranging from quartile 1 (bottom) to quartile 4 (top). Participants were divided by tooth-brushing frequency into 2 groups: 1) less than twice a day and 2) twice or more a day. Self-oral health cognition was categorized into 3 groups: 1) high, 2) moderate, and 3) low. Participants were classified by smoking status into 3 groups: 1) current smokers (smoking currently and smoked ≥100 cigarettes), 2) ex-smokers (smoked in the past but stopped), and 3) non-smokers (never smoked). We followed the guidelines of the Korean Society for the Study of Obesity and the World Health Organization (WHO) [16] in categorizing the participants into 3 groups by body mass index: 1) underweight (<18.5 kg/m²), 2) normal weight (18.5–24.9 kg/m²), and 3) obese (≥25 kg/m²). Diabetes status was categorized into 3 groups: 1) normal, 2) impaired fasting glucose, and 3) diabetes. Diabetes was defined as a fasting glucose level ≥126 mg/dL, current use of anti-diabetic medications, or a self-reported physician's diagnosis of diabetes mellitus. Impaired fasting glucose and normal glucose tolerance were defined as a fasting glucose level of 100–125 mg/dL and <100 mg/dL, respectively [17].

Periodontal examination

Periodontal status was evaluated using the CPI developed by the WHO [18]. Ten index teeth—2 molars in each posterior sextant and the upper right and lower left central incisors—were measured for periodontal pocket depth (PD) using a CPI probe that met the WHO guidelines [19] at 6 sites per tooth (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual). Probing was carried out by 16 dentists who had received calibration training during a 4-day session for the KNHANES. Five CPI scores were recorded: CPI 0, normal; CPI 1, gingival bleeding; CPI 2, presence of gingival calculus; CPI 3, shallow periodontal pocket (>3.5 mm but ≤5.5 mm); and CPI 4, deep periodontal pocket (>5.5 mm). We defined periodontitis as CPI scores of 3 or 4, which were used to dichotomize participants into non-periodontitis and periodontitis groups. Calibration training to ensure reliability of the oral health survey in the KNHANES was conducted in 2015 and included lectures, web-based photo instruction, training using dental models, a simulated oral health examination with human subjects, and field instruction with a reliability assessment. The inter-Kappa index was 0.827–1.000 at the final assessment.

Statistical analysis

The results of the oral examinations and questionnaires were analyzed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). *P* values less than 0.05 were considered to indicate statistical significance for all analyses. Individually weighted factors were considered, and the complex sampling design of the survey was utilized to obtain the variances. Age and YI

were analyzed using the independent *t*-test for continuous variables, and the other variables were analyzed using the χ^2 test for non-continuous variables. Multivariate logistic regression analyses were performed to examine the association between YI and periodontal health, adjusting for sociodemographics, oral health-related variables, and health behaviors and status. The complex sampling design was considered in all analyses.

RESULTS

Characteristics of subjects by periodontal status

The sample consisted of 4,727 participants with a weighted mean age of 43.4 years (range, 19–64 years). Table 1 shows the distribution of sociodemographic characteristics, oral health-related variables, and health status and behavior by periodontitis status. Among the total sample, 30.8% had periodontitis (not presented in tables). There were significant differences in the distribution of periodontitis with regard to all variables. Individuals with periodontitis were older (54.44 ± 0.61 years) than those without periodontitis (39.25 ± 0.43 years) ($P < 0.001$). More men had periodontitis than women (55.8% vs. 44.2%). On an average, participants with periodontitis brushed their teeth less and had lower self-oral health cognition. The proportion of periodontitis was higher among current smokers than among ex- or non-smokers, and was also higher in obese participants and those with diabetes than in others.

Table 1. Characteristics of participants by periodontal status

Variables	Non-periodontitis (n=3,269)		Periodontitis (n=1,458)		P value ^{a)}
	Unweighted	Weighted	Unweighted	Weighted	
Age (n=4,727)	39.25±0.43		54.44±0.61		<0.001 ^{c)}
Sex (n=4,727)					<0.001 ^{c)}
Male	1,295	47.4 (0.9)	715	55.8 (1.2)	
Female	1,974	52.6 (0.9)	743	44.2 (1.2)	
Household income (n=4,703)					<0.001 ^{c)}
<25%	470	11.4 (0.9)	386	22.3 (1.7)	
25%–50%	757	22.4 (1.5)	394	26.3 (1.7)	
50%–75%	969	31.1 (1.5)	342	26.7 (2.0)	
>75%	1,060	35.0 (2.0)	325	24.7 (1.9)	
Tooth-brushing frequency (n=4,612)					<0.001 ^{c)}
Less than twice a day	299	8.3 (0.5)	207	12.8 (1.1)	
Twice or more a day	2,896	91.7 (0.5)	1,210	87.2 (1.1)	
Self-oral health cognition (n=4,718)					<0.001 ^{c)}
Good	555	16.6 (0.8)	170	10.5 (1.0)	
Moderate	1,504	47.7 (1.0)	460	30.9 (1.6)	
Poor	1,204	35.7 (1.1)	825	58.6 (1.7)	
Smoking status (n=4,613)					<0.001 ^{c)}
Current smoker	377	15.9 (0.8)	286	26.0 (1.5)	
Ex-smoker	542	17.7 (0.7)	363	26.2 (1.3)	
Non-smoker	2,277	66.3 (0.9)	768	47.8 (1.3)	
Obesity (n=4,372)					<0.001 ^{c)}
Underweight	126	4.7 (0.5)	38	2.9 (0.5)	
Normal	1,796	64.0 (1.0)	811	54.6 (1.7)	
Obese	898	31.2 (1.0)	603	42.5 (1.6)	
Diabetes (n=3,795)					<0.001 ^{c)}
Normal	1,770	73.4 (1.2)	695	57.2 (1.8)	
Impaired fasting glucose	539	20.3 (1.0)	368	29.1 (1.8)	
Diabetic	219	6.4 (0.6)	204	13.7 (1.1)	
Yogurt intake per week, cups (n=2,807)	1.03±0.06		0.77±0.08		0.015 ^{b)}

Values are presented as number, % (standard error), or mean±standard deviation. 1 cup=100 g.

^{a)}Obtained from complex sample analyses; ^{b)} $P < 0.05$; ^{c)} $P < 0.001$.

Participants without periodontitis showed a significantly higher YI (1.03 ± 0.06 cups/week) than participants with periodontitis (0.77 ± 0.08 cups/week) ($P < 0.001$).

Characteristics of subjects by yogurt consumption

The distribution of subject characteristics by YI is shown in Table 2. Among those who consumed less than 1 cup of yogurt per week, the proportion of men was higher than that of women. However, among those who consumed more than 1 cup of yogurt per week, the proportion of women was higher than that of men. The proportion of families with a high income were higher among those who consumed more than 2 cups per day. People who had never smoked consumed more yogurt than those who were current or ex-smokers. Moreover, people with periodontitis were significantly more common among those who consumed less than 1 cup of yogurt per week than those who consumed more than 2 cups per day.

Association between periodontitis and YI

The results of the multivariate logistic regression analyses are shown in Table 3. With adjustment for age, the risk of periodontitis was 73% lower among individuals in the highest YI group ($P < 0.001$ for trend). In the final multivariate model, the association between YI and periodontitis remained moderately strong and statistically significant ($P = 0.012$ for trend).

Table 2. Characteristics of participants by yogurt consumption

Variables	YI < 1/week		1/week ≤ YI < 1/day		1/day ≤ YI < 2/day		YI ≥ 2/day		P value ^{a)}
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted	
Gender (n=4,727)									<0.001 ^{b)}
Male	1,055	54.9 (1.0)	172	34.6 (2.1)	26	38.0 (6.6)	14	32.2 (7.5)	
Female	1,295	45.1 (1.0)	493	65.4 (2.1)	58	62.0 (6.6)	32	67.8 (7.5)	
Household income (n=4,703)									0.003 ^{b)}
<25%	244	9.6 (1.0)	49	7.2 (1.4)	4	4.1 (2.3)	4	5.1 (2.5)	
25%–50%	573	23.2 (1.5)	128	18.8 (2.1)	22	25.1 (5.5)	6	21.0 (7.9)	
50%–75%	734	33.4 (1.7)	209	30.2 (2.2)	26	36.7 (6.3)	14	27.3 (6.8)	
>75%	785	33.8 (1.9)	279	43.9 (2.9)	32	34.1 (5.9)	22	46.6 (8.5)	
Tooth brushing frequency (n=4,612)									0.004 ^{b)}
Less than twice a day	196	8.5 (0.7)	27	3.8 (0.8)	4	5.8 (3.5)	3	6.0 (3.8)	
Twice or more a day	2,101	91.5 (0.7)	627	96.2 (0.8)	80	94.2 (3.5)	43	94.0 (3.8)	
Self-oral health cognition (n=4,718)									0.458
High	294	13.8 (0.9)	83	13.8 (1.7)	8	10.3 (4.0)	7	19.7 (7.5)	
Moderate	902	43.1 (1.4)	283	48.0 (2.4)	30	44.3 (7.4)	17	40.0 (9.1)	
Low	910	43.1 (1.3)	229	38.2 (2.4)	35	45.4 (7.2)	17	40.3 (8.8)	
Smoking status (n=4,613)									<0.001 ^{b)}
Current smoker	476	25.4 (1.2)	69	13.6 (1.6)	7	7.3 (2.8)	4	11.0 (5.6)	
Ex-smoker	467	21.6 (0.9)	90	15.7 (1.9)	12	16.2 (4.8)	10	19.0 (6.3)	
Non-smoker	1,354	53.0 (1.2)	495	70.7 (2.1)	65	76.4 (5.4)	32	70.0 (7.2)	
Obesity (n=4,372)									0.161
Underweight	100	4.4 (0.5)	28	5.0 (1.0)	0	0.0 (0.0)	1	3.9 (3.8)	
Normal	1,431	61.9 (1.1)	435	64.7 (2.1)	65	75.0 (6.0)	36	74.9 (8.0)	
Obese	803	33.7 (1.2)	196	30.3 (1.8)	18	25.0 (6.0)	8	21.3 (7.5)	
Diabetes (n=3,795)									0.048 ^{b)}
Normal	1,455	71.4 (1.2)	436	75.0 (2.1)	63	87.5 (3.7)	34	76.3 (7.8)	
Impaired fasting glucose	474	21.8 (1.1)	131	20.8 (1.9)	11	9.3 (3.0)	6	15.7 (7.0)	
Diabetic	165	6.8 (0.6)	34	4.2 (0.9)	2	3.1 (2.2)	4	8.0 (4.9)	
Periodontal disease (n=2,807)									0.006 ^{b)}
No	1,473	72.6 (1.4)	459	79.6 (2.1)	56	78.4 (5.6)	34	84.9 (6.0)	
Yes	625	27.4 (1.4)	135	20.4 (2.1)	17	21.6 (5.6)	7	15.1 (6.0)	

Values are presented as number or % (standard error). 1 cup=100 g.

YI: yogurt intake.

^{a)}Obtained from complex sample analyses; ^{b)} $P < 0.05$.

Table 3. Odds ratios (95% confidence interval) of periodontitis by total YI

Total YI	1/week≤YI<1/day	1/day≤YI<2/day	YI≥2/day	P value for trend
Model 1	0.66 (0.50–0.87)	0.51 (0.25–1.03)	0.27 (0.11–0.68)	0.002 ^{a)}
Model 2	0.79 (0.60–1.03)	0.58 (0.28–1.20)	0.32 (0.12–0.84)	0.035 ^{a)}
Model 3	0.69 (0.52–0.92)	0.49 (0.23–1.02)	0.28 (0.11–0.71)	0.004 ^{a)}
Model 4	0.80 (0.59–1.07)	0.69 (0.32–1.49)	0.25 (0.10–0.65)	0.014 ^{a)}
Model 5	0.86 (0.65–1.16)	0.65 (0.29–1.44)	0.24 (0.10–0.60)	0.012 ^{a)}

The reference category is <1/week. Model 1 is adjusted for age only. Model 2 is adjusted for age, gender, and household income. Model 3 is adjusted for age, tooth brushing frequency, and self-oral health cognition. Model 4 is adjusted for age, smoking status, obesity, and diabetes. Model 5 is adjusted for age, gender, household income, tooth brushing frequency, self-oral health cognition, smoking status, obesity, and diabetes.

YI: yogurt intake.

^{a)}P<0.05.

Individuals who consumed more than 2 cups of yogurt per day were 76% less likely to have periodontitis than those who consumed less than 1 cup per week.

DISCUSSION

We conducted this study to examine the association between semi-solid YI and periodontal status through multivariate logistic regression analyses. In particular, participants who consumed 2 or more cups of yogurt every day were 68%–76% less likely to have periodontitis than participants who consumed less than 1 cup of yogurt per week. Thus, increased daily YI could have a beneficial effect on periodontal health.

Probiotics are defined as “live microorganisms which, when administered in adequate amounts, confer a health benefit to the host” [20]. Probiotics can be delivered to the oral cavity in food or beverages (fruit juice), dairy products, prebiotic fibers, milk-based products, and dried cell packages such as powders, capsules, or gelatin tablets [21]. Yogurt is an accessible and convenient way to administer probiotics to the oral cavity. Therefore, we consider semi-solid yogurt to be a probiotic and suggest daily YI.

Çaglar et al. [22] measured the residence time of probiotics in the oral cavity and observed a probiotic effect for several days after discontinuation of ingestion. Furthermore, Horz et al. [23] reported a 35-day follow-up after ingesting probiotics for 3 days, and the probiotic level decreased starting 8 days after discontinuation of ingestion. Their findings show that the effect of probiotics is not immediately curtailed after ingestion. Due to the nature of the probiotic effect, which is not easily lost, it is assumed that semi-solid yogurt, which is highly viscous and rich in probiotics, will more effectively promote oral health.

Several studies have shown associations between probiotics and periodontal disease. Al-Zahrani [13] reported that the intake of dairy products was significantly associated with a low prevalence of periodontitis based on data from the National Health and Nutrition Examination Survey III. Shimazaki et al. [12] conducted a study in Japan to determine whether the routine intake of lactic acid-containing foods had a preventive effect on periodontal disease. They found that increased intake of lactic acid-containing foods was significantly associated with lower mean PD and lower mean clinical attachment loss (CAL), but the consumption of other dairy products did not show a significant association. They reported that consuming yogurt and lactic acid-containing drinks might reduce the level of periodontal parameters such as PD and CAL. Adegboye et al. [14] investigated whether calcium intake from dairy and non-dairy products or the absolute intake of various dairy

products was associated with periodontitis. Using data from the Copenhagen Oral Health Senior Study, they found that fermented food intake was associated with a reduced risk of periodontitis, but intake of cheese and other dairy foods was not. In summary, dairy products or lactic acid-containing foods could have a preventive effect on periodontitis that can be explained, in part, by probiotic mechanisms that might prevent periodontitis by shifting the composition and activity of bacterial biofilms, as well as subsequent host reactions.

The hypothetical mechanisms of action of probiotics could include direct and indirect action [24-26]. Direct interactions with dental plaque include interfering with the attachment of oral microorganisms to proteins, the agility of plaque evolution, and the complex ecosystem of biofilm competing against oral pathogens for attachment sites. Indirect probiotic actions include modulating systemic immune functions, affecting local immunity (including nonimmunologic defense mechanisms), and regulating mucosal permeability. Probiotics function as antioxidants and also produce antioxidants, which hamper plaque induction by neutralizing free electrons. Gruner et al. [27] performed a meta-analysis to assess the effects of probiotics on caries and periodontal disease and found that the periodontal parameters of PD, gingival index, and bleeding on probing were significantly reduced by probiotic therapy, although CAL was not. In addition, the number of periodontal pathogens such as *Aggregatibacter actinomycetemcomitans*, *P. gingivalis*, and *Prevotella intermedia* were not significantly reduced after probiotic therapy, indicating that probiotics might affect the host response rather than periodontal pathogens themselves.

This study has several limitations. Firstly, it was not possible to identify a causal relationship between YI and periodontitis due to the cross-sectional study design. Secondly, periodontal status was assessed using the CPI, which means that the prevalence of periodontitis could have been overestimated or underestimated due to the use of representative teeth and the possibility of pseudo-pockets [28]. Although periodontal disease is usually diagnosed based on the severity and extent of CAL and PD [29], CPI is an epidemiologic tool developed by the WHO for the evaluation of periodontal disease in population-level surveys [30]. The third limitation of this study is that we could not consider the calcium intake from yogurt. Dairy products are rich sources of calcium and have other important nutrients such as branched-chain amino acids, conjugated linoleic acids, proteins, vitamin D, and medium-chain fatty acids [31]. Calcium is one of the widely studied nutrients in relation to periodontitis [32]. However, Shimazaki et al. [12] reported that calcium intake from dairy products may not have a major impact on periodontal disease and that among various dairy products, only intake of lactic acid-containing foods such as yogurt was associated with periodontitis. Kim et al. [33] also inferred that the calcium contained in yogurt is not associated with a decreased prevalence of periodontitis. Therefore, this study focused on the lactic acid bacteria component of yogurt, not calcium.

Moreover, we considered various covariates in multivariate logistic regression models to confirm the effect of probiotics on periodontal health in this study. In addition, these results are representative of the Korean population owing to the sample size and use of complex sample analyses. In particular, we used semi-solid YI to examine the association between probiotics and periodontitis. Semi-solid yogurt not only easily delivers probiotics to the oral cavity, but is also readily obtainable in daily life. Thus, we recommend eating semi-solid yogurt daily as a probiotic to improve periodontal health.

In conclusion, we found a significant association between increased semi-solid YI and improved periodontal status. In order to confirm the causal relationship between YI and

periodontal health, further longitudinal studies are required to elucidate the feasible mechanisms of probiotics on periodontal disease, considering both periodontal pathogens and clinical periodontal parameters.

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