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Association between diet quality and untreated dental caries: results from the Korea National Health and Nutrition Examination Survey

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Conflict of Interest
The authors declare no potential conflicts of interests.

ABSTRACT

BACKGROUND/OBJECTIVES: Few studies have provided evidence of the association between diet quality and dental caries. This study aimed to examine the association between diet quality and untreated dental caries in a Korean representative population.
SUBJECTS/METHODS: The study population included a sample of 13,815 participants, aged ≥ 19 from the Korea National Health and Nutrition Examination Survey during 2013–2015. The explanatory variable was diet quality and the outcome variable was untreated dental caries. Untreated dental caries were defined by the number of decayed teeth recorded according to the criteria established by the World Health Organization. Diet quality was defined by using the Korean Healthy Eating Index (KHEI) through the 24-h recall methods. We assessed the association between diet quality and untreated dental caries while adjusting for age, sex, education, income, smoking status, dental visits, toothbrushing frequencies, obesity, and diabetes mellitus.
RESULTS: The mean overall KHEI scores in the untreated dental caries group were significantly lower than those in the group without untreated dental caries. Significant differences were observed in the untreated dental caries group based on the KHEI quartiles ($P < 0.001$). After adjusting for potential confounders, the quartiles of KHEI scores showed an association with untreated dental caries, demonstrating a dose-effect trend (odds ratio [OR], 1.57; 95% confidence interval [CI], 1.35–1.84 for 1st quartile; OR, 1.38; 95% CI, 1.19–1.59 for 2nd quartile; OR, 1.32; 95% CI, 1.14–1.53 for 3rd quartile; reference quartile highest]).
CONCLUSIONS: The findings indicated an inverse association between diet quality and untreated dental caries in Korean adults. Healthcare providers should take into account the significant role of diet quality in preventing and managing oral health.

Keywords: Healthy Eating Index; dental caries; epidemiological study

INTRODUCTION

Dental caries is the most common cause of tooth loss worldwide with periodontitis [1,2]. Dental caries can be prevented by various oral hygiene practices (appropriate use of fluoride and

Author Contributions

Conceptualization: Sim S, Shin HS; Formal analysis: Moon JY, Shin HS; Investigations: Sim S, Moon JY; Methodology: Sim S, Shin HS; Supervision: Shin HS; Writing - original draft: Sim S, Shin HS; Writing - review & editing: Sim S, Moon JY, Shin HS.

improved biofilm control) and favorable oral health behaviors (reduced sugar intake and regular dental visits) [2]. Recently, research has begun to focus on untreated caries and considers caries experience crucial in evaluating disease burden and dental care services because the caries experience is no longer the cause of the disease burden [2]. According to a systematic review using the resources of the global burden, age-standardized prevalence in untreated dental caries is 35%, affecting 2.4 billion people over 20 yrs [1]. Moreover, untreated caries confirmed that the burden of dental caries is moving from children to adults [1].

The Healthy Eating Index (HEI) was first developed by the United States Department of Agriculture to assess overall diet quality [3]. Recently, the Korean Healthy Eating Index (KHEI) was developed as a valid instrument to evaluate diet quality, including adequacy components, moderation components, balance of energy intake, and adherence to dietary guidelines for Health Plan 2020 [4] in healthy Korean adults, using dietary guidelines [5] and dietary reference intake [6]. Specifically, recommended optimal diet and nutrition are crucial modifiable risk factors for mortality and morbidity in major chronic diseases [7].

Although various studies in dentistry have focused on dental caries and individual nutrition components [8,9], few studies have provided evidence of the association between diet quality, untreated dental caries, and caries experience [10-15]. In the published literature, there are only two cross-sectional studies for adults in the United States [13,14] and four cross-sectional studies for children in Egypt, Turkey, and the United States [10-12,15]. These studies found that high diet quality was significantly associated with lower early childhood caries (ECC), lower untreated dental caries, and caries experience in permanent teeth. Still, there is a need for epidemiological studies in various countries and population groups.

The HEI is a comprehensive item related to preventing chronic metabolic diseases in nutrition. It comprises several HEI items directly associated with caries, such as vegetable and fruit intake, dairy product consumption, carbohydrate intake, sugary drink consumption, and protein intake, which necessitate analysis. It appears that long-term imbalance of overall dietary habits, which reflects the quality of diet, can also impact dental caries. Therefore, there is a need for analysis of the association between HEI and untreated dental caries.

Since diet quality in adults has been investigated in Korea since 2015, there must be an opportunity to add evidence for the association between diet quality and untreated dental caries.

This study hypothesized that diet quality is associated with untreated dental caries, a more important indicator of active disease. This study aimed to examine the distribution of the KHEI and KHEI components according to untreated dental caries and determine the association between diet quality measured by KHEI and untreated dental caries among the Korean representative population.

SUBJECTS AND METHODS

Study participants

The Korea National Health and Nutrition Examination Survey (KNHANES), a study periodically conducted by the Korea Centers for Disease Control and Prevention (KCDC), uses a complex, stratified, multistage, and probability-cluster design of a representative

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sample of non-institutional Korean citizens [16,17]. The survey included a health interview, a nutrition survey, and an oral and general health examination survey. The national survey was approved by the Institutional Review Board of the KCDC (2013-07CON-03-4C in 2013 and 2013-12EXP-03-5C in 2014). Since 2015, the KNHANES has been conducted without the deliberation of the institutional review board, which corresponds to research conducted by the government for public welfare by the Bioethics Act. All participants provided voluntary written informed consent. Detailed information on the sampling methods, study design, and process are available in several reports [16-20].

The total number of participants aged ≥ 19 in the KNHANES 2013–2015 was 22,948. According to the KNHANES statistical guideline, the study included those who participated in KHEI with caries data. The final sample included 13,815 adult participants (5,666 males and 8,149 females).

Assessment of the KHEI

Information on dietary intake was collected by trained interviewers. The frequency of food intake and the amount of food intake were surveyed through the 24-h recall method. The KHEI [21] was developed to assess overall diet quality using a scoring system for adherence to the national diet as a guideline sine for dietary intake [4,5]. The KHEI consists of 14 components, including 8 adequacy components for recommended foods and nutrients (having breakfast, mixed grains intake, total fruit intake, fresh fruit intake, total vegetable intake, vegetable intake, excluding kimchi and pickled vegetables, meat, fish, eggs and beans intake, and milk and milk products intake), three moderation components for restricted food and nutrient (percentage of energy from saturated fatty acids, sodium intake, and percentage of energy from sweets and beverages), and three balance components for energy intake (percentage of energy from carbohydrates, percentage of energy intake from fat, and energy intake). Each of the 14 components has a scoring range of 0 to 5 or 0 to 10, each component according to the KHEI scoring system. The total KHEI score has the sum of 14 dietary component scores. The total KHEI score is calculated from 0 to 100; a high score indicates a higher overall diet quality. For this analysis, the total KHEI score was categorized into quartiles based on the distribution in our sample. Because the score range of the response on 14 components was narrow and not diverse, it was appropriate to categorize them into tertiles rather than quartiles. KHEI measurements have been described in previous studies [20].

Assessment of untreated dental caries

From 2013 to 2016, 84 dentists participated in the oral examination, and the inter-examiner reliability of the oral examination data was secured using various methods, such as lectures for calibration, training using dental models, and simulation. The mean kappa values for dentition status were 0.930 in 2015, 0.945 in 2014, and 0.914 in 2013. Trained, calibrated dentists underwent a full-mouth examination and evaluated each tooth for dental caries status according to World Health Organization (WHO) guidelines [22]. Caries was recorded as present in the following cases: a lesion in a pit or fissure, on a smooth tooth surface, with an unmistakable cavity, undermined enamel, or a detectably soft or floor or wall (coronal caries), or soft or leathery to probing (root caries).

The number of decayed teeth was recorded as the decayed teeth (DT) index, which indicated the number of untreated dental caries. For our analysis, untreated dental caries were dichotomized as either absent (DT = 0) or present (DT ≥ 1) as well as continuous variables.

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Assessment of potential confounders

The study included the following information on potential confounders: demographic factors (age, sex), socioeconomic factors (education, income), oral and health behaviors (smoking status, dental visits, toothbrushing frequency), and systemic health status (obesity, diabetes mellitus). Socioeconomic status was assessed by education level (less than primary school, middle school, high school, college, or greater) and household income (first quartile, second quartile, third quartile, and fourth quartiles). Oral and health behaviors included smoking status, dental visits, and toothbrushing frequency. Smoking status was categorized into 3 groups: never smoker, former smoker, and current smoker. Dental visits were identified by asking, "Have you ever visited a dentist for an oral examination without any specific oral problems during the last year?" The answers were categorized dichotomous. Toothbrushing frequency was identified by asking, "When do you brush your teeth during the day?" Toothbrushing frequency was calculated by adding up all the brushing periods. Response on toothbrushing frequency was divided into less than two times and two or more times. Obesity was defined as a body mass index (BMI) ≥ 25.0 kg/m^2. BMI was calculated by the formula: BMI = Weight (kg)/Height^2 (m^2). Diabetes mellitus was defined as a fasting glucose level > 126 mg/dL or the use of medication for diabetes.

Statistical analysis

All statistical analyses were performed by complex sampling analysis according to the statistical guidelines of KNHANES. The main explanatory variable was KHEI/KHEI 14 components; the outcome variable was untreated dental caries.

All confounders were coded as follows: age (continuous), sex (male: 1, female: 2), education (primary school: 1, middle school: 2, high school: 3, college: 4), income (I = 0–25%, II = 26–50%, III = 51–75%, IV = 76–100%), smoking status (1: never, 2: former, 3: current), dental visits (1: no, 2: yes), toothbrushing frequency (1: < 2 times per day, 2: ≥ times per day), obesity (1: no, 2: yes), diabetes mellitus (1: no, 2: yes).

Distributions of the categorical variable were expressed by weighted percentage and standard error using the χ^2 test. Distributions of the continuous variable were presented with mean and standard error using a t-test. Multivariable linear regression analysis was used to determine whether the KHEI quartiles were associated with untreated dental caries. Logistic regression analysis for each model was applied sequentially and computed unadjusted and adjusted odds ratios (ORs) and confidence intervals (CIs). The crude model was unadjusted. Model 1 was adjusted for demographic and socioeconomic variables, including age, sex, education, and income. Model 2 was adjusted for all potential confounders, including smoking status, dental visits, toothbrushing frequency, obesity, and diabetes mellitus. A multivariable logistic regression analysis was also performed to examine the associations between the KHEI/KHEI 14 components and untreated dental caries. Finally, multivariable linear regression was applied to evaluate the association between KHEI/KHEI 14 components and untreated dental caries.

RESULTS

Characteristics of the study participants

Of the 13,815 participants, the prevalence of untreated dental caries (DT ≥ 1) was estimated at 29.8%. **Table 1** shows the descriptive statistics of the participants according to the untreated dental caries diagnosis. Participants who exhibited untreated dental caries were more likely

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to be male, with lower education and income than those without ($P < 0.001$). For oral health behaviors, participants who exhibited untreated dental caries were more likely to be current smokers, with irregular dental attendance and inappropriate toothbrushing frequency than those without ($P < 0.001$). Untreated dental caries was more prevalent in obese and diabetic participants ($P < 0.001$). The mean overall KHEI scores in the untreated dental caries group were significantly lower than those in the group without untreated dental caries. Significant differences in the untreated dental caries group were observed according to the KHEI quartiles ($P < 0.001$).

Table 1. Characteristics of the study participants according to the untreated dental caries (n = 13,815)

Variables	Overall	Untreated dental caries		*P*-value[1]
		No (n = 9,919)	Yes (n = 3,896)	
Age (yrs)	13,815	47.04 (0.27)[3]	45.20 (0.38)[3]	**< 0.001**[2]
Sex				**< 0.001**
Male	5,666	46.9 (0.5)	55.8 (0.9)	
Female	8,149	53.1 (0.5)	44.2 (0.9)	
Education				**< 0.001**
Primary school	3,172	15.8 (0.6)	18.2 (0.8)	
Middle school	1,385	9.3 (0.4)	8.8 (0.5)	
High school	4,225	35.9 (0.7)	41.5 (1.2)	
College	4,010	38.9 (0.8)	31.5 (1.1)	
Income				**< 0.001**
I (lowest)	2,877	14.6 (0.6)	18.4 (0.9)	
II	3,461	23.1 (0.8)	28.1 (1.0)	
III	3,653	29.7 (0.8)	27.5 (1.0)	
IV (highest)	3,748	32.6 (1.1)	26.0 (1.1)	
Smoking status				**< 0.001**
Never	8,188	60.3 (0.6)	50.0 (1.0)	
Former	2,646	21.2 (0.5)	19.0 (0.8)	
Current	2,283	18.5 (0.5)	31.1 (1.0)	
Dental visits				**< 0.001**
No	9,267	66.3 (0.7)	78.3 (0.8)	
Yes	3,838	33.7 (0.7)	21.7 (0.8)	
Toothbrushing frequencies				**< 0.001**
< 2 times per day	2,309	13.9 (0.4)	18.0 (0.8)	
≥ 2 times per day	11,506	86.1 (0.4)	82.0 (0.8)	
Obesity				**< 0.001**
No	9,191	68.7 (0.6)	62.8 (0.9)	
Yes	4,537	31.3 (0.6)	37.2 (0.9)	
Diabetes mellitus				**< 0.001**
No	10,384	91.0 (0.4)	90.2 (0.6)	
Yes	1,365	9.0 (0.4)	9.8 (0.6)	
Total KHEI scores	13,815	64.33 (0.19)	60.83 (0.28)	**< 0.001**[2]
KHEI quartiles (range)				**< 0.001**
Lowest quartile (0–55.7)	3,390	25.2 (0.6)	34.1 (1.0)	
Second quartile (55.8–64.90)	3,445	24.6 (0.5)	25.9 (0.8)	
Third quartile (64.91–73.55)	3,495	24.8 (0.5)	23.8 (0.8)	
Highest quartile (73.56 over)	3,485	25.4 (0.6)	16.2 (0.7)	

The complex KNHANES sampling design and the sample weights were accounted for in this analysis. Bold denotes statistical significance at $P < 0.05$.
All confounders were coded as follows: age (continuous), sex (male: 1, female: 2), education (primary school: 1, middle school: 2, high school: 3, college: 4), income (I = 0–25%, II = 26–50%, III = 51–75%, IV = 76–100%), smoking status (1: never, 2: former, 3: current), dental visits (1: no, 2: yes), toothbrushing frequencies (1: < 2 times per day, 2: ≥ times per day), obesity (1: no, 2: yes), diabetes mellitus (1: no, 2: yes).
KHEI, Korean Healthy Eating Index; KNHANES, Korea National Health and Nutrition Examination Survey.
[1]Data were presented as weighted percent and standard error using the χ^2 test.
[2]Data were presented as a mean and standard error by t-test.
[3]Data were presented as mean and standard deviation.

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Association of KHEI components with untreated dental caries

Table 2 depicts the association between the KHEI 14 components and untreated dental caries. After controlling for potential confounders, several KHEI components showed a significant association with untreated dental caries: having breakfast, mixed grains intake, total fruit intake, fresh fruit intake, total vegetable intake, vegetable intake, excluding kimchi and pickled vegetables, meat, fish, eggs and beans intake, percentage of energy from sweets and beverages, and energy intake. The components mentioned demonstrated an inverse association, showing a tendency to increase the risk of untreated dental caries more in the lower intake quantile.

Table 2. Association of KHEI components with untreated dental caries (n = 13,815)

KHEI components (score range: min to max)	OR (95% CI) for untreated dental caries		
	Crude	Model 1	Model 2
Adequacy components			
Have breakfast (0 to10)			
I (lowest) (0)	**1.70 (1.47–1.97)**	**1.64 (1.41–1.94)**	**1.55 (1.31–1.83)**
II (3, 6)	**1.41 (1.26–1.57)**	**1.42 (1.26–1.60)**	**1.32 (1.17–1.50)**
III (highest) (10)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Mixed grains intake (0 to 5)			
I (lowest) (0)	**1.26 (1.13–1.40)**	**1.15 (1.03–1.29)**	**1.16 (1.03–1.21)**
II (0.01 to 4.98)	1.04 (0.93–1.17)	1.04 (0.92–1.18)	1.06 (0.92–1.21)
III (highest) (5)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Total fruits intake (0 to 5)			
I (lowest) (0 to 0.01)	**1.71 (1.52–1.91)**	**1.42 (1.26–1.60)**	**1.33 (1.17–1.52)**
II (0.02 to 4.93)	**1.29 (1.15–1.44)**	**1.14 (1.01–1.28)**	**1.13 (1.00–1.28)**
III (highest) (4.94 to 5)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Fresh fruit intake (0 to 5)			
I (lowest) (0)	**1.54 (1.40–1.70)**	**1.31 (1.18–1.45)**	**1.26 (1.12–1.41)**
II (0.07 to 4.97)	**1.31 (1.14–1.52)**	**1.17 (1.01–1.37)**	**1.17 (1.00–1.38)**
III (highest) (5)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Total vegetable intake (0 to 5)			
I (lowest) (0 to 2.96)	**1.18 (1.05–1.32)**	**1.17 (1.04–1.32)**	**1.15 (1.01–1.31)**
II (2.97 to 4.99)	**1.13 (1.01–1.25)**	**1.18 (1.06–1.32)**	**1.16 (1.03–1.30)**
III (highest) (5)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Vegetables intake excluding Kimchi and pickled vegetables (0 to 5)			
I (lowest) (0 to 2.51)	**1.27 (1.13–1.42)**	**1.18 (1.05–1.33)**	**1.16 (1.02–1.32)**
II (2.52 to 4.99)	**1.14 (1.02–1.28)**	1.10 (0.97–1.23)	1.09 (0.96–1.24)
III (highest) (5)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Meat, fish, eggs and beans intake (0 to 10)			
I (lowest) (0 to 5.19)	**1.22 (1.09–1.36)**	**1.20 (1.07–1.34)**	**1.19 (1.05–1.35)**
II (5.20 to 9.99)	1.07 (0.96–1.18)	1.06 (0.95–1.18)	1.05 (0.93–1.18)
III (highest) (10)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Milk and milk products intake (0 to 5)			
I (lowest) (0)	**1.20 (1.07–1.34)**	**1.15 (1.02–1.29)**	1.09 (0.96–1.24)
II (0.01 to 4.18)	1.04 (0.91–1.20)	1.04 (0.89–1.20)	1.04 (0.89–1.22)
III (highest) (4.19 to 10)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Moderation components			
% of energy from saturated fatty acid (o to 10)			
I (0 to 9.99)	**1.10 (1.00–1.20)**	1.00 (0.90–1.11)	0.99 (0.89–1.10)
II (10)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Sodium intake (o to 5)			
I (lowest) (0 to 5.14)	1.02 (0.92–1.14)	0.93 (0.82–1.05)	0.92 (0.81–1.06)
II (5.15 to 9.01)	0.95 (0.85–1.07)	0.90 (0.80–1.02)	0.90 (0.79–1.03)
III (highest) (9.02 to 10)	1.00 (ref)	1.00 (ref)	1.00 (ref)
% of energy from sweets and beverages (o to 10)			
I (0 to 9.99)	**1.27 (1.13–1.42)**	**1.20 (1.07–1.36)**	**1.14 (1.00–1.29)**
II (10)	1.00 (ref)	1.00 (ref)	1.00 (ref)

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Table 2. (Continued) Association of KHEI components with untreated dental caries (n = 13,815)

KHEI components (score range: min to max)	OR (95% CI) for untreated dental caries		
	Crude	Model 1	Model 2
Balance of energy intake			
% of energy from carbohydrate (0 to 5)			
I (lowest) (0)	1.05 (0.94–1.18)	1.03 (0.91–1.17)	1.05 (0.92–1.20)
II (0.002 to 3.84)	1.05 (0.94–1.17)	1.07 (0.95–1.21)	1.07 (0.94–1.21)
III (highest) (3.85 to 5)	1.00 (ref)	1.00 (ref)	1.00 (ref)
% of energy intake from fat (0 to 5)			
I (lowest) (0 to 1.56)	1.04 (0.94–1.15)	1.01 (0.90–1.14)	1.04 (0.92–1.18)
II (1.57 to 4.99)	0.98 (0.88–1.10)	1.00 (0.88–1.13)	0.99 (0.86–1.13)
III (highest) (5)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Energy intake (0 to 5)			
I (lowest) (0 to 1.63)	1.10 (1.00–1.21)	1.08 (0.98–1.20)	1.05 (0.94–1.17)
II (1.64 to 4.18)	**1.16 (1.03–1.31)**	**1.17 (1.03–1.34)**	**1.18 (1.03–1.35)**
III (highest) (4.24 to 5)	1.00 (ref)	1.00 (ref)	1.00 (ref)

The complex KNHANES sampling design and the sample weights were accounted for in this analysis. Crude was an unadjusted association. Bold denotes statistical significance at $P < 0.05$.
Model 1 was adjusted for age, sex, education, and income; Model 2 was adjusted for age, sex, education, income, smoking status, dental visits, toothbrushing frequencies, obesity, and diabetes mellitus.
KHEI, Korean Healthy Eating Index; OR, odds ratio; CI, confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey.

Association of KHEI scores with untreated dental caries

The overall KHEI quartiles were consistently associated with untreated dental caries in the multivariable logistic regression models throughout the adjustment (**Table 3**). In crude ORs and CI of the KHEI quartiles for untreated dental caries were: 2.13 (1.86–2.43) for the 1st quartile, 1.65 (1.46–1.87) for the 2nd quartile, and 1.51 for the 3rd quartile. During confounder adjustment, the strength of the association between quartiles of overall KHEI scores weakened but remained significant, adjusting for age, sex, education, income, smoking status, dental visits, toothbrushing frequency, obesity, and diabetes mellitus, showing a dose-effect trend (OR, 1.57; 95% CI, 1.35–1.84 for 1st quartile; OR, 1.38; 95% CI, 1.19–1.59 for 2nd quartile; OR, 1.32; 95% CI, 1.14–1.53 for 3rd quartile).

In the linear association analyses, the above KHEI components showed significant associations with the extent of untreated dental caries in fully adjusted moles (**Table 4**).

Table 3. Association of KHEI scores with untreated dental caries (n = 13,815)

Variable	OR (95% CI) for untreated dental caries		
	Crude	Model 1	Model 2
KHEI quartiles (range)			
I (lowest) (0–55.7)	**2.13 (1.86–2.43)**	**1.69 (1.47–1.96)**	**1.57 (1.35–1.84)**
II (55.8–64.90)	**1.65 (1.46–1.87)**	**1.46 (1.28–1.66)**	**1.38 (1.19–1.59)**
III (64.91–73.55)	**1.51 (1.33–1.72)**	**1.37 (1.20–1.56)**	**1.32 (1.14–1.53)**
IV (highest) (73.56 over)	1.00 (ref)	1.00 (ref)	1.00 (ref)
P-trend	**< 0.001**	**< 0.001**	**< 0.001**

The complex KNHANES sampling design and the sample weights were accounted for in this analysis. Outcome variables were untreated dental caries. Crude was an unadjusted association. Bold denotes statistical significance at $P < 0.05$.
Model 1 was adjusted for age, sex, education, and income; Model 2 was adjusted for age, sex, education, income, smoking status, dental visits, toothbrushing frequencies, obesity, and diabetes mellitus.
KHEI, Korean Healthy Eating Index; OR, odds ratio; CI, confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey.

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Table 4. Linear association of KHEI 14 components with untreated dental caries (n = 13,815)

KHEI/KHEI 14 components	B	95% CI
Total KHEI scores	**−0.009**	**−0.012, −0.006**
Adequacy components		
Have breakfast	**−0.029**	**−0.041, −0.017**
Mixed grains intake	**−0.026**	**−0.041, −0.011**
Total fruits intake	**−0.030**	**−0.044, −0.016**
Fresh fruit intake	**−0.025**	**−0.038, −0.011**
Total vegetables intake	**−0.030**	**−0.055, −0.005**
Vegetables intake excluding Kimchi and pickled vegetables	**−0.023**	**−0.045, −0.001**
Meat, fish, eggs and beans intake	**−0.020**	**−0.032, −0.008**
Milk and milk products intake	**−0.008**	**−0.016, 0.000**
Moderation components		
Percentage of energy from saturated fatty acid	0.009	−0.001, 0.018
Sodium intake	0.004	−0.007, 0.014
Percentage of energy from sweets and beverages	−0.014	−0.031, 0.002
Balance of energy intake		
Percentage of energy from carbohydrate	−0.018	−0.034, −0.002
Percentage of energy intake from fat	−0.017	−0.034, 0.001
Energy intake	**−0.016**	**−0.032, −0.001**

The complex KNHANES sampling design and the sample weights were accounted for in this analysis. All explanatory variables are continuous variables. Untreated dental caries is quantified as the sum of the number or DT from 28 teeth assessed. Bold denotes statistical significance at $P < 0.05$.
Each model was adjusted for age, sex, education, income, smoking status, dental visits, toothbrushing frequencies, obesity, and diabetes mellitus.
KHEI, Korean Healthy Eating Index; B, regression coefficient; 95% CI, 95% confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey; DT, decayed teeth.

DISCUSSION

Findings from this study demonstrated that better diet quality was inversely associated with untreated dental caries in Korean adults. The overall KHEI scores and several KHEI components were higher in untreated dental caries, and the prevalence of untreated dental caries increased considerably from KHEI quartile 4 to quartile 1. More intake of grains, fruits, vegetables, sweets, and beverages was also inversely associated with untreated dental caries. These results are consistent with previous epidemiological studies on diet quality, untreated coronal caries [13], and dental caries experience [14].

Research involving preschool children [10-12,15] revealed that caries-free children had higher HEI scores than those with early childhood caries. Nunn *et al.* [10] found that the HEI could predict the prevalence of ECC using data from the National Health and Nutrition Examination Survey (NHANES). Despite the sample size limitations in Turkish children, İnan-Eroğlu *et al.* [12] showed that a high-quality, healthy diet was vital for preventing ECC.

Kaye *et al.* [13] reported that participants who met the dietary guidelines had lower prevalence and odds of untreated caries among 7,751 US adults from NHANES. An analysis of data from 14,517 participants in the Hispanic Community Health Study/Study of Latinos [14] demonstrated that an increase in each 10-unit scores in diet quality score was associated with a 2.5 less decayed, missing, and filled surfaces index. This study suggested that data on dietary quality based on adherence to diet recommendations not only predicts general health status but also contains beneficial information that may be helpful for oral health [12].

For the association between the KHEI 14 components and untreated dental caries, insufficient intake of grains, fruits, and vegetables was more likely to result in untreated

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dental caries, showing a linear association. This result is consistent with the studies by Kaye *et al.* [13] and Sanders *et al.* [14] in adults and children. Our results also showed that higher sweet and sugar intake resulted in a higher prevalence of untreated dental caries, with well-established evidence. In particular, free sugar in sweets and beverages increases overall caloric intake, leading to dental caries, obesity, and associated non-communicable diseases [23,24]. Therefore, the WHO recommended reduced intake of the overall amount and frequency of sugar consumption throughout life [25].

The biological plausibility that fruit and vegetable intake has a protective effect on dental caries can be partially explained as follows. These food groups are rich in polyphenols and isothionates and have substantial antimicrobial properties that can potentially prevent dental caries [8,13,26,27]. Milk and milk products containing phosphate, protein, casein, and calcium can also exert a protective effect through antibacterial activity, acidogenicity reduction, and enhanced remineralization [8]. The dietary habit of these functional foods may inhibit the progression of dental caries.

This study has some limitations. First, since the KNHANES survey items do not include key information on the use and degree of fluoride (fluoride in toothpaste, community water fluoridation, fluoride application) that affects the occurrence of dental caries, it is difficult to determine the impact of fluoride in the reduction of dental caries. Thus, our findings on diet quality and dental caries could show overestimation due to the effects of fluoride. Second, we could not exclude the possibility that the value was underestimated or overestimated by calculating the HEI based on the contents of intake during the day. Third, because our research was cross-sectional, we could not confirm the temporal relationships between the main variables. Future well-designed longitudinal studies should assess the effect of diet quality on dental caries.

Notwithstanding the above limitations, the results of this study are reliable enough to test the hypothesis that diet quality is associated with untreated dental caries. Moreover, this study provides the first evidence from a representative Korean population.

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