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Effect of the number of existing permanent teeth and removable dentures on nutrient and mineral intake in Korean adults aged 55 years or more

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Abstract

Objectives: The aim of this study was to analyse the association between the 'number of existing permanent teeth' and 'energy source and mineral intake' in adults aged 55-84 years by using data from the 6th Korea National Health and Nutrition Examination Survey (KNHANES) (2013-2015).

Methods: The study included 5750 subjects aged 55 years or more who received oral examinations and answered questions on household income, smoking status, and diet. Complex samples general linear model was applied to analyse the effect of nutrient intake on the number of existing permanent teeth and removable dentures adjusted for age, sex, household income, and smoking status. The mean intake of nutrients was calculated according to the number of existing teeth and removable dentures.

Results: The amount of protein intake was lower among subjects with 20 teeth or less than in those with 21-32 teeth. The amount of fat and potassium intake was lower among edentulous subjects than among those whose with 21-32 teeth. The amount of fat and potassium intake was also lower among those wearing complete dentures on the upper and lower jaws than among those not wearing dentures.

Conclusions: Prevention of tooth loss is needed to reduce the imbalance in nutrient intake. Wearing removable dentures was negatively correlated with fat and potassium intake. The increase in potassium intake from fruits and vegetables among adults with tooth loss is needed to prevent systemic diseases caused by an imbalance in nutrient intake.

Introduction

Feeding is an essential element for human survival, and food is ingested mostly through masticatory movements of the teeth and swallowing in the mouth. However, adults lose teeth because of oral diseases such as caries and periodontal disease [1]. In Korea, 31.35%, 37.75%, and 37.7% of subjects aged 55-64, 65-74, and 75+ years, respectively, receive illegal dental treatments performed by unlicensed persons [2]. Masticatory ability depends on the number of functional tooth units (FTUs), and a loss of FTUs is a key variable in the decrease of masticatory performance [3]. The oral health of older people is changing with decreasing numbers of people relying on complete dentures for function and retaining some natural teeth. Despite this, the ability to chew foods is compromised in a substantial number of older people because of their oral health status, either because they have few or no natural teeth. This alteration results in individuals selecting a diet that they can chew in comfort. Such diets are low in fruits and vegetables and are associated with a reduction in the intake of both non-starch polysaccharides and micronutrients [4,5]. The relationship between ingestion frequency, a general measure of food acceptability, and the perceived ease of chewing showed that significant shifts in ingestion frequency were associated with harder food items; thus, differences in ingestion frequency were dependent on the integrity of the masticatory apparatus [6].

Women with fewer teeth have unhealthier diets, including a decreased intake of fruits and vegetables, which could increase

cardiovascular disease risk. Diet may also partially explain the associations between oral health and cardiovascular disease [7,8]. Retaining more teeth might be a useful indicator of longevity in older people [9,10]. Low potassium intake in the diet, mostly accompanied by low vegetable and fruit intake, increases blood pressure as well as periodontal inflammation [11].

To date, Korean studies on older people have focused on the number of teeth and the intake of calcium, phosphorus, vitamin, and other nutrients, but few studies have been conducted on the relationship between periodontal disease and minerals, including potassium, which are reported to be closely related to cardiovascular disorders. In addition, few studies have focused on nutrition in denture wearers [12].

Accordingly, for our analysis of nutrients, we selected energy sources (protein, fat, and carbohydrate) and dietary fibre, which are

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nutrients, and calcium, phosphorus, sodium, and potassium, which are minerals, described in the Dietary Reference Intakes for Koreans presented by The Korean Nutrition Society. We included adults aged 55-84 years old and who had considerably decreased number of existing teeth from among the subjects of The Sixth Korea National Health and Nutrition Examination Survey (KNHANES VI) [13,14]. We corrected the age, sex, income level, smoking status, and food intake, and analysed the relationship between the intake of energy sources, dietary fibre, and minerals and the number of teeth and denture-wearing status to highlight the necessity of tooth loss prevention, while providing fundamental data for correcting the nutritional imbalance in people who have lost many teeth or are wearing dentures.

Materials and methods

Study population

This research used data from the Sixth Korea National Health and Nutrition Examination Survey (KNHANES VI) of the Korea Centers for Disease Control and Prevention [14]. KNHANES VI used the enumeration districts of the "2010 Population and Housing Census (Korea National Statistical Office)" as the sampling frame. The research surveyed household members aged 1 year or more, of approximately 13 800 selected households sampled from 600 enumeration districts. In particular, the yearly rolling samples in 2013-2015 selected using a rolling-sampling survey method from the fourth period were used as the probability sample representing the country; the rolling samples were independent and identical. We used a three-step stratified cluster sampling, and the primary sampling units were dong, eup, and myeon; the secondary sampling unit was the enumeration district; and the tertiary sampling unit was the household.

The KNHANES comprises health, nutrition, and examination surveys. The surveys in the first and second years (2013 and 2014) of KNHANES VI were approved by relevant IRBs (2013-07CON-03-4C, 2013-12EXP-03-5C), but the survey in the third year (2015) corresponded to a research directly performed by the nation for public benefits, and was thus performed without IRB consideration. The KNHANES VI included 7662 subjects aged 55-84 years who were involved in the examination, health, and nutrition surveys, 6612 subjects except for those who did not respond to the sociodemographic survey, and 5750 subjects except for those not responding to the nutrition survey (Table 1).

Methods

Variable selection

The independent variables were the number of existing teeth and denture-wearing status. The number of existing teeth was calculated excluding lost and unerupted teeth from the whole set of teeth including the third molar. Both full and partial dentures were included in the analysis.

The dependent variables were the analysed nutrients, including protein, fat, and carbohydrate, which are nutrients acting as energy sources, and potassium and sodium, which are minerals included in the Dietary Reference Intakes for Koreans 2015 [13]. The nutritional factor variables analysed were food, energy, carbohydrate, protein, fat, potassium, and sodium intake.

The exogenous variables, such as age, sex, income level, and smoking status, were selected as sociodemographic variables. The age groups used in the analysis were 55-64 years, 65-74 years, and 75-84

years. For obtaining the income level, the monthly household equalized income (monthly household income / $\sqrt{\text{number}}$ of household members) was divided into quartiles, and the variables distinguished into upper, upper-intermediate, lower-intermediate, and lower levels were used. Because smoking is considered a strong confounder and may spuriously inflate the association between periodontitis and vascular diseases, the smoking statuses were classified into currently smoking, quit smoking (smoked before), and never smoked [12,15].

Statistical analysis

IBM SPSS Statistics 23.0[®] (IBM Corp., Armonk, NY, USA) was used for analysis. A complex sampling procedure was used to analyse the KNHANES VI (2013-2015) data. A plan file was produced by calculating the stratified variables with a layer for dispersion estimation, cluster variables with enumeration districts, and weight with an integral weight of 3 years of existing examination survey-nutrition relation weight. In accordance with the number of existing teeth and denture-wearing status for each age group, the average food intake was compared, and the total food intake depending on the number of existing teeth and denture-wearing status with respect to each age, income level, and smoking status was analysed after correcting for age. The relationship between nutrient intake and the number of existing teeth and denture-wearing status was corrected for age, sex, income level, smoking status, and food intake, and the relationship between the intake of energy sources, such as carbohydrate, protein, and fat, and minerals, such as potassium and sodium, and the number of teeth and denture-wearing status was analysed using a complex samples linear analysis. Depending on the number of existing teeth, the subjects were classified into the following groups: 0, 1-10, 11-20, and 21-32, according to the recommendations of Sheiham, et al [5]. The analysis results were indicated using the B estimate, standard error, and P-value; the intergroup differences were determined to a significance level of type I error of 0.05; and the trend was reviewed at 0.1 or less.

Results

Demographic, socioeconomic behavioural, and denture-wearing status of subjects by age

The fractions of income level, education level, smoking status, denture-wearing status, etc, of each age group were different. Moreover, as the age increased, the 'lower level' fraction which represents the lowest 25% of income level increased (P<0.001), the education level decreased (P<0.001), the number of people currently smoking decreased (P<0.001), and the number of denture wearers increased (P<0.001) (Table 2).

Distribution of the number of existing permanent teeth, intake of energy-source nutrients (g/day) and minerals (mg/ day) by demographic and socioeconomic behavioural status variables

As the age increased, the number of existing teeth decreased (P<0.001). The number of existing permanent teeth, corrected for age, was higher among women than among men (P=0.004), and increased as the household income (P<0.001) and education level increased (P<0.001). The number of existing permanent teeth according to the smoking status was higher among people who had never smoked (P<0.001), and the number of teeth was higher among those not wearing dentures than among denture wearers (P<0.001).

A linear analysis was performed to confirm whether the energysource nutrient and mineral intake depended on age, sex, household Jung-Ha L (2018) Effect of the number of existing permanent teeth and removable dentures on nutrient and mineral intake in Korean adults aged 55 years or more

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Age	All	Non-denture wearer	Denture wearer
Total	5750	4027	1723
55-64	2409	2083	326
65-74	2199	1422	777
75-84	1142	522	620

Table 1. Number of subjects who responded to the dental examinations and nutrition questionnaires

Table 2. Demographic, socioeconomic behavioural, and denture-wearing statuses of the subjects according to age

Variables	Contonto	Total		55-	-64	65-	-74	75	в	
	Contents	N	%	N	%	N	%	N	%	P
	Total	5750	100.0	2409	100.0	2199	100.0	1142	100.0	
Carr	Male	2448	45.4	987	45.6	980	46.8	481	42.2	< 0.083
Sex	Female	3302	54.6	1422	54.4	1219	53.2	661	57.8	
	Low	2015	31.8	409	15.7	893	39.7	713	61.4	< 0.001
Household	Middle-low	1574	26.9	665	26.9	673	30.1	236	20.3	
income*	Middle-high	1136	21.4	646	27.5	368	17.9	122	11.5	
	High	1025	19.9	689	29.8	265	12.3	71	6.9	
	Primary	2880	46.2	799	30.0	1264	56.8	817	70.9	< 0.001
Education	Middle	968	17.8	519	22.4	343	15.3	106	9.5	
Education	High	1211	23.0	673	29.5	394	18.8	144	13.2	
	College	691	13.0	418	18.1	198	9.1	75	6.4	
	Current	735	14.3	379	17.9	262	12.1	94	8.7	< 0.001
Smoking	Stop	1454	26.3	523	23.5	607	29.2	324	28.4	
	Never	3561	59.4	1507	58.6	1330	58.6	724	62.9	
Dontano	Non-wear	4027	72.5	2083	86.8	1422	65.1	522	46.5	< 0.001
Denture	Wear	1723	27.5	326	13.2	777	34.9	620	53.5	

income, education level, smoking status, and new denture-wearing status by correcting for daily food intake. Carbohydrate intake was the highest in the 65-74 year age group (P=0.001), was higher in men than in women (P<0.001), was lower in the high household income than in the low household income group (P=0.067), was higher in the low education level group than in the other groups (P<0.001), was lower in the never-smoked group than in the other groups (P<0.001), and was lower in the no-denture-wearing group than in the denture-wearing group (P=0.040). Protein intake was the lowest in the 75-84 year age group (P<0.001), was lower in women than in men (P<0.001), was lower in the 'lower' and 'lower-intermediate' household income groups than in the other groups (P<0.001), was lower in the elementary graduate group than in the other groups (P<0.001), and was lower in the neversmoked group than in the other groups (P<0.001); however, protein intake was not dependent on the denture-wearing status (P=0.196). Fat intake decreased as the age increased (P<0.001), was lower in women than in men (P<0.001), was higher in the 'upper-intermediate' and 'upper' household income groups than in the other groups (P<0.001), was the highest in the college graduate group (P<0.001) and in the currently smoking group (P<0.001), and was higher in the no-denturewearing group than in the denture-wearing group (P<0.001).

Potassium intake was lower in the 75-84 year age group than in the other groups (P<0.001), was lower in men than in women (P=0.095), was lower in the 'lower' household income group than in the other groups (P=0.006), was lower in the elementary graduate group than in the other groups (P=0.048), was higher in the never-smoked group than in the other groups (P=0.076), and was lower in the denture-wearing group than in the no-denture-wearing group (P=0.031).

Sodium intake was higher in men than in women (P<0.001), was lower in the college graduate group than in the other groups (P=0.001), was the highest in the currently smoking group (P<0.001), and was higher in the denture-wearing group than in the no-denture-wearing group (P=0.065) (Table 3).

Intake of energy-source nutrients (g/day) and minerals (mg/ day) according to the number of existing permanent teeth

The analysis after correcting for all the research subjects showed that the daily average intake of carbohydrate, protein, and fat were 310.92 g, 60.47 g, and 30.34 g, respectively. The number of teeth was not associated with carbohydrate intake. However, protein intake (P=0.002) and fat intake (P=0.021) were higher in the groups with higher numbers of teeth. On comparing protein intake in the edentulous jaw group and no-denture-wearing group, protein intake was not different between the 1-10 teeth group (P=0.367) or 11-20 teeth group (P=0.141) and the edentulous jaw group. However, protein intake was higher in the 21-32 teeth group than in the edentulous jaw group (P=0.037). Moreover, the number of teeth in the denture-wearing group was not dependent on protein intake (P=0.265). Fat intake was not associated with the number of teeth in the no-denture-wearing group (P=0.376). On comparing the denture-wearing and edentulous jaw groups, protein intake was not different between the 1-10 teeth group (P=0.467) or 11-20 teeth group (P=0.551) and the edentulous jaw group; however, protein intake was higher in the 21-32 teeth group than in the edentulous jaw group (P=0.037).

An analysis of all the research subjects after correcting for age showed that the daily average intake of potassium and sodium were 2896.57 mg and 3572.64 mg, respectively. For all the research subjects, as the number of teeth increased, potassium intake also increased (P<0.001), and compared to the edentulous jaw group, the 21-32 teeth group showed higher potassium intake (P<0.001). In the no-denturewearing group, the number of teeth and potassium intake were not related (P=0.425), but in the denture-wearing group, the number of teeth increased as the potassium intake increased (P=0.068); moreover, potassium intake in the 21-32 teeth group was higher than that in the edentulous jaw group (P=0.014). For all the research subjects, the number of teeth and sodium intake were not related (P=0.978), and in the no-denture-wearing group (P=0.522) and denture-wearing group (P=0.943), the number of teeth and sodium intake were not related (Table 4).

Conten	Contonto	NT *,†		n	Carbohydrate P		n	Protein		n	Fat		D	Potassium		n	Sodium		n
Variables	Contents	Mean	SE	ľ	Mean	SE	1	Mean	SE	r	Mean	SE	r	Mean	SE	r	Mean	SE	1
	Total	20.85	0.15		314.65	2.41		61.80	0.62		31.48	.49		3012.99	32.44		3577.11	46.20	
	55-64	24.01ª	0.16	< 0.001	309.02ª	2.22	< 0.001	63.03ª	0.69	< 0.001	34.60ª	0.63	< 0.001	3053.93ª	25.47	< 0.001	3597.78	57.61	0.659
Age 65- 75-	65-74	19.49 ^b	0.22		322.27ь	2.80		61.74ª	0.69		29.65 ^b	0.55		3016.63ª	27.75		3577.25	52.83	
	75-84	14.56°	0.36		315.27 ^{ab}	3.31		58.41 ^b	0.82		26.28°	0.70		2888.66 ^b	35.19		3517.76	75.93	
C	Male	20.32	0.19	< 0.001	326.95	2.32	< 0.001	67.20	0.67	< 0.001	34.33	0.58	< 0.001	2982.99	24.53	0.095	3934.32	57.50	< 0.001
Sex Fe	Female	21.29	0.15		304.41	2.07		57.31	0.53		29.11	0.48		3037.97	24.66		3279.72	45.68	
Household Income	Low	19.72ª	0.26	< 0.001	319.01ª	3.02	0.067	58.94ª	0.65	< 0.001	27.48ª	0.57	< 0.001	2927.03ª	32.37	0.006	3588.84	66.15	0.629
	Middle- low	20.76 ^b	0.23		315.52 ^{ab}	3.11		60.32ª	0.65		30.58 ^b	0.75		3024.56 ^b	37.58		3580.28	79.55	
	Middle- high	22.18 ^b	0.27		315.64 ^{ab}	3.54		64.75 ^b	1.11		34.24°	0.87		3065.95 ^b	39.12		3639.35	82.24	
	High	22.42°	0.24		305.46 ^b	3.95		65.19 ^b	1.18		36.10°	.93		3077.51 ^b	42.12		3486.98	86.39	
	Primary	19.96ª	0.20	< 0.001	321.23ª	2.64	< 0.001	59.10ª	.62	< 0.001	27.57ª	.51	< 0.001	2960.09ª	29.75	0.048	3570.20ª	51.75	0.001
E da continue	Middle	20.80 ^b	0.28		317.91 ^{ab}	3.43		63.16 ^b	.97		32.24 ^b	.87		3088.24 ^b	42.36		3715.68ª	101.82	
Education	High	21.59°	0.26		308.95 ^b	3.29		65.27 ^b	1.03		34.71 ^b	.85		3046.65 ^{ab}	33.20		3669.48ª	76.05	
	College	22.74 ^d	0.26		296.92°	4.79		63.36 ^b	1.15		38.59°	1.28		3038.39 ^{ab}	52.07		3248.39 ^b	83.42	
	Current	17.64ª	0.36	< 0.001	319.07ª	5.04	< 0.001	68.78ª	1.60	< 0.001	36.84ª	1.34	< 0.001	2940.37	56.70	0.076	4148.12ª	119.48	< 0.001
Smoking	Stop	20.80 ^b	0.23		325.84ª	2.86		66.25ª	0.74		33.42 ^b	0.68		2979.92	28.62		3810.93 ^b	65.57	
	Never	21.64°	0.15		308.63 ^b	1.99		58.15 ^b	0.50		29.33°	0.46		3045.17	23.44		3335.74°	41.76	
Dantana	Non-wear	24.55	0.10	< 0.001	312.80	1.82	0.040	62.11	0.51	0.196	32.27	0.49	< 0.001	3035.90	20.78	0.031	3537.85	43.56	0.065
Denture	Wear	11.11	0.22		319.52	3.02		60.98	0.74		29.39	0.64		2952.72	34.17		3680.40	68.21	

Table 3. Distribution of the number of existing permanent teeth and intake of energy-source nutrients (g/day) and minerals (mg/day) according to demographic and socioeconomic behavioural status variables

The data were analysed using a complex samples general linear model with estimated marginal means.

*Number of permanent teeth

 † Covariates showing the number of permanent teeth (NT) are fixed at the following values: age = 65.75.

Covariates showing energy-source nutrients and minerals are fixed at the following values: food intake = 1440.49.

 abcd Groups with different letters are significantly different (P<0.05).

Table 4. Intake of energy-source nutrients (g/day) and potassium (mg/day) according to the number of existing permanent teeth

Number	То	talª	D	Non-dent	ure wearer ^b	2	Dentur	D	
of teeth	Mean	SE	P	Mean	SE	P	Mean	SE	P
Protein									
Total	60.47	0.88	0.002	59.33	1.78	0.020	56.76	1.09	0.295
0	61.16	2.76	Ref.	52.95	5.55	Ref.	57.58	2.84	Ref.
1-10	58.20	1.33	0.331	58.49	3.11	0.367	54.42	1.38	0.322
11-20	59.37	1.11	0.546	61.27	1.57	0.141	55.10	1.49	0.441
21-32	63.14	0.72	0.483	64.59	.74	0.037	59.94	2.73	0.548
Fat									
Total	30.34	0.56	0.021	32.25	1.93	0.372	26.97	0.75	0.227
0	28.78	1.24	Ref.	28.95	6.56	Ref.	25.19	1.21	Ref.
1-10	30.34	1.07	0.296	34.95	3.25	0.408	26.31	1.08	0.467
11-20	29.92	.91	0.433	31.48	1.35	0.704	26.17	1.18	0.551
21-32	32.32	.58	0.008	33.61	0.60	0.479	30.22	2.13	0.037
Potassium									
Total	2896.57	38.43	<0.001	3075.64	169.03	0.425	2698.98	50.89	0.068
0	2751.35	86.14	Ref.	3077.75	619.27	Ref.	2551.63	82.77	Ref.
1-10	2815.92	68.34	0.518	3036.38	210.82	0.949	2603.60	68.24	0.610
11-20	2929.47	58.71	0.070	3026.69	82.77	0.934	2709.20	82.43	0.163
21-32	3089.53	36.63	<0.001	3161.74	37.69	0.892	2931.50	131.70	0.014

The data were analysed using a complex samples general linear model with estimated marginal means.

^aCovariates appearing in the model are fixed at the following values: age = 65.75 ^bCovariates appearing in the model are fixed at the following values: age = 64.04 ^cCovariates appearing in the model are fixed at the following values: age = 70.25 ^bCovariates appearing the testinical are fixed at the following values: age = 70.25

Bold values denote statistical significance at P < 0.05.

Relationship between 'socioeconomic behavioural status variables and the number of existing permanent teeth' and 'intake of each energy-source nutrient and mineral'

A linear analysis of the relationship between 'socioeconomic behavioural status variables and the number of existing permanent teeth' and 'intake of each nutrient' was performed.

In the total group, carbohydrate intake decreased as the age increased (P<0.001). Carbohydrate intake was higher in men than in women (P<0.001) and was lower or showed a decreasing trend in the 'lower' (P<0.001), 'lower-intermediate' (P=0.011), and 'upper-intermediate' household income groups (P=0.063) than in the 'upper' group. However, the education level was not related to carbohydrate intake. In addition, carbohydrate intake was lower in the smoking group than in the non-smoking group (P=0.006), but it was not related to the number of teeth.

Protein intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). Moreover, protein intake was lower in the 'lower' (P<0.001), 'lower-intermediate' (P<0.001), and 'upperintermediate' household income groups (P=0.023) than in the 'upper' group. Protein intake was lower or showed a decreasing trend in the elementary-school graduate group (P<0.001) and middle-school graduate group (P=0.068) than in the college graduate group, was higher in the group that smoked before than in the non-smoker group (P=0.043), and was lower in the 1-10 teeth group (P=0.023) and 11-20 teeth group (P=0.017) than in the 21-32 teeth group. Fat intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). Fat intake was lower in the 'lower' (P<0.001) and 'lower-intermediate' household income groups (P<0.001) than in the 'upper' household income group. Moreover, it was higher in the elementary-school graduate group (P<0.001), middle-school graduate group (P<0.001), and high-school graduate group (P=0.010) than in the college graduate group. It was higher in the currently smoking group (P=0.023) and group that smoked before (P=0.034) than in the non-smoker group and was lower in the edentulous jaw group than in the 21-32 teeth group (P=0.014).

Potassium intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). It was lower in the 'lower' (P<0.001), 'lower-intermediate' (P=0.001), and 'upper-intermediate' household income groups (P=0.005) than in the 'upper' household income group. Moreover, it was lower in the elementary-school graduate group (P<0.001) and middle-school graduate group (P=0.002) than in the college graduate group, was lower in the currently smoking group than in the non-smoker group (P=0.004), and was lower or showed a decreasing trend in the edentulous jaw group (P=0.014) and 1-10 teeth group (P=0.060) than in the 21-32 teeth group.

Sodium intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). It was lower or showed a decreasing trend in the 'lower' (P=0.003) and 'lower-intermediate' household income groups (P=0.051) than in the 'upper' household income group and was higher in the high-school graduate group (P=0.029) than in the college graduate group. However, the smoking status and number of teeth had no relationship with sodium intake. (Table 5)

Parameters	Contents	Carbo (Carbohydrate (g/day) (R ² =0.067)			Protein (g/day) (R ² =0.141)			Fat (g/day) (R ² =0.133)			Potassium (mg/day) (R ² =0.104)			Sodium (mg/day) (R ² =0.072)		
		Estimate	SE	Р	Estimate	SE	Р	Estimate	SE	Р	Estimate	SE	Р	Estimate	SE	Р	
(Intercept)		400.51	19.54	0.000	97.39	4.85	0.000	72.43	3.76	0.000	5321.86	245.98	0.000	5451.83	396.84	0.000	
Age		-1.35	0.32	0.000	46	0.08	0.000	48	0.06	0.000	-26.14	3.73	0.000	-33.56	6.59	0.000	
Sav	Male	56.82	6.14	0.000	13.26	1.52	0.000	4.87	1.14	0.000	366.12	71.54	0.000	946.38	112.08	0.000	
Sex	Female	Ref.			Ref.			Ref.			Ref.			Ref.			
	Low	-29.92	6.63	0.000	-13.38	1.80	0.000	-8.01	1.35	0.000	-579.22	85.40	0.000	-457.16	155.14	0.003	
Household income	Middle-low	-16.69	6.56	0.011	-9.53	1.81	0.000	-5.33	1.37	0.000	-301.13	89.71	0.001	-307.32	157.41	0.051	
	Middle-high	-11.70	6.28	0.063	-4.74	2.07	0.023	-2.41	1.50	0.108	-238.77	85.19	0.005	-192.89	139.10	0.166	
	high	Ref.			Ref.			Ref.			Ref.			Ref.			
	Primary	-3.63	7.55	0.631	-7.56	1.92	0.000	-11.33	1.64	0.000	-559.23	91.10	0.000	44.10	133.19	0.741	
Education	Middle	-1.50	8.06	0.853	-3.81	2.09	0.068	-8.13	1.71	0.000	-330.73	104.53	0.002	173.58	155.93	0.266	
Education	High	2.84	7.55	0.707	0.67	2.09	0.748	-4.45	1.72	0.010	-150.93	98.61	0.126	296.66	135.25	0.029	
	College	Ref.			Ref.			Ref.			Ref.			Ref.			
	Current	-22.05	7.91	0.006	2.42	2.23	.278	3.75	1.64	0.023	-276.71	94.69	0.004	213.75	141.04	0.130	
Smoking	Stop	-3.34	6.91	0.629	3.39	1.67	0.043	2.88	1.36	0.034	-31.90	85.57	0.709	107.60	120.67	0.373	
	Never	Ref.			Ref.			Ref.			Ref.			Ref.			
	0	-12.49	7.79	0.110	-2.41	2.79	0.389	-3.27	1.33	0.014	-228.00	92.30	0.014	-148.97	138.25	0.282	
Number of teeth	1-10	-4.01	6.27	0.523	-3.18	1.40	0.023	49	1.14	0.670	-131.53	69.74	0.060	-19.47	132.78	0.883	
	11-20	0.29	5.26	0.956	-3.01	1.25	0.017	-1.57	1.01	0.122	-78.61	65.53	0.231	11.24	106.60	0.916	
	21-32	Ref.			Ref.			Ref.			Ref.			Ref.			

Table 5. Relationship between 'socioeconomic behavioural status variables and the number of existing permanent teeth' and 'intake of energy-source nutrients and minerals'

The data were analysed using a complex samples general linear model with parameter estimates.

Model: Each nutrient intake = (Intercept) + sex + household income + education + smoking status + number of existing teeth + age.

Bold values denote statistical significance at P<0.05.

Relationship between 'socioeconomic behavioural status variables and each denture type' and 'intake of energy-source nutrients and minerals'

In the model of socioeconomic variables and type of dentures, carbohydrate intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). It was lower or showed a decreasing trend in the 'lower' (P<0.001), 'lower-intermediate' (P=0.011), 'upper-intermediate' household income groups (P=0.060) than in the 'upper' household income group. However, the education level had no relationship with carbohydrate intake. It was lower in the currently smoking group than in the never-smoked group (P=0.005) but showed no significant difference between each denture-wearing group and the no-denture-wearing group.

Protein intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). It was lower in the 'lower' (P<0.001), 'lower-intermediate' (P<0.001), and 'upper-intermediate' household income groups (P=0.019) than in the 'upper' household income group. Moreover, it was lower or showed a decreasing trend in the elementaryschool graduate group (P<0.001) and middle-school graduate group (P=0.052) than in the college graduate group and showed an increasing trend in the group that quit smoking than in the never-smoked group (P=0.051). It was also lower in the 1-10 teeth group (P=0.023) and 11-20 teeth group (P=0.017) than in the 21-32 teeth group and showed a decreasing trend in the group wearing one partial denture and one full denture than in the no-denture-wearing group (P=0.084).

Fat intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). It was lower or showed a decreasing trend in the 'lower' (P<0.001), 'lower-intermediate' (P<0.001), and 'upper-intermediate' household income groups (P=0.093) than in

the 'upper' household income group. It was also lower or showed a decreasing trend in the elementary-school graduate group (P<0.001), middle-school graduate group (P<0.001), and high-school graduate group (P=0.093) than in the college graduate group, and was higher in the currently smoking group (P=0.029) and group that smoked before (P=0.039) than in the never-smoked group. Fat intake was lower in the group wearing two full dentures for each jaw than in the no-denture-wearing group (P=0.018).

Potassium intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). It was lower in the 'lower' (P<0.001), 'lower-intermediate' (P=0.001), and 'upper-intermediate' household income groups (P=0.005) than in the 'upper' household income group. It was also lower in the elementary-school graduate group (P<0.001) and middle-school graduate group (P=0.001) than in the college graduate group and was lower in the currently smoking group (P=0.002) than in the never-smoked group. Potassium intake was lower or showed a decreasing trend in the group wearing two full dentures for each jaw (P=0.058) than in the no-denture-wearing group.

Lastly, in the model of socioeconomic variables and type of dentures, sodium intake decreased as age increased (P<0.001) and was higher in men than in women (P<0.001). It was lower in the 'lower' (P<0.003) and 'lower-intermediate' household income groups (P=0.048) than in the 'upper' household income group. It was higher in the high-school graduate group (P=0.031) than in the college graduate group but showed no relationship to the smoking status and denture-wearing status. (Table 6)

Discussion

Daily food intake depends on the demographic and socioeconomic behavioural statuses, and thus, the relationship between 'the number

Parameters	Contents		Fat (g/day) Model (R ² =.133)		Potassium (mg/day) Model (R ² =.104)					
		Estimate	SE	Р	Estimate	SE	Р			
(Intercept)		73.25	3.74	0.000	5371.99	249.22	0.000			
Age		50	0.06	0.000	-27.06	3.81	0.000			
Car	Male	4.93	1.14	0.000	370.04	70.96	0.000			
Sex	Female	Ref.			Ref.					
	Low	-8.07	1.36	0.000	-579.74	85.29	0.000			
Household	Middle-low	-5.43	1.38	0.000	-304.00	89.65	0.001			
income	Middle-high	-2.52	1.50	0.093	-240.52	84.79	0.005			
	high	Ref.			Ref.					
	Primary	-11.44	1.64	0.000	-567.33	90.42	0.000			
Education	Junior-high	-8.25	1.70	0.000	-337.71	103.97	0.001			
Education	High	-4.53	1.72	0.009	-154.72	98.24	0.116			
	Colleage	Ref.			Ref.					
Smoking	Current	3.60	1.64	0.029	-292.71	92.39	0.002			
	Stop	2.79	1.35	0.039	-39.45	84.94	0.643			
	Never	Ref.			Ref.					
	2 CD	-3.07	1.29	0.018	-186.56	91.22	0.041			
	1 PD & 1 CD	47	1.55	0.761	-158.86	83.71	0.058			
Donturo	1 CD	50	2.23	0.824	179.78	232.03	0.439			
Denture	2 PD	14	1.74	0.934	-118.40	99.34	0.234			
	1 PD	0.94	1.27	0.459	4.74	82.03	0.954			
	Non-wearer	Ref.			Ref.					

Table 6. Relationship between 'socioeconomic behavioural status variables and each denture type' and 'intake of fat (g/day) and potassium (mg/day)'

CD: Complete denture; PD: Partial denture

The data were analysed using a complex samples general linear model with parameter estimates.

Model: (Intercept) + age + sex + household income + education + smoking status + denture.

Bold values denote statistical significance at P < 0.05.

of existing permanent teeth' and 'the intake of energy-source nutrients and minerals' was analysed by adjusting for age, sex, income level, and smoking status. As age increased, food intake in the denturewearing group was lower than that in the no-denture-wearing group. Carbohydrate intake as an energy source was higher in the denturewearing group than in the no-denture-wearing group, but protein intake was not different between groups, and fat intake was higher in the denture-wearing group than in the no-denture-wearing group. Furthermore, potassium intake was lower in the denture-wearing group than in the no-denture-wearing group, and sodium intake was higher in the denture-wearing group than in the no-denture-wearing group. Potassium intake was not related to the number of teeth in the denture-wearing group but increased in the no-denture-wearing group as the number of teeth increased. Sodium intake was not related to the number of teeth in both the denture-wearing and no-denturewearing groups. As shown in the KNHANES III and IV, the reduction in the number of existing permanent teeth correlated with an increased carbohydrate intake and a decreased potassium intake. Carbohydrate intake was lower in subjects with 25 or more teeth than that in those with 9 or less teeth. Potassium intake was higher in subjects with 20 or more teeth [16,17].

Kim, et al. [18] proposed a daily carbohydrate intake of 292.5 g calculated as a proper percentage of 65% among Koreans aged 55 years or older, and the Dietary Reference Intakes for Koreans 2015 suggested a daily carbohydrate intake of 55-65% as an energy source [13]. In this study, the daily carbohydrate intake was 310.92 g which was higher than the recommended intake, and the percentage of carbohydrate intake was 72.4% which exceeded the proper percentage of total energy intake. Meanwhile, the Dietary Reference Intakes for Koreans 2015 suggests a daily average protein intake of 40 g with a recommended intake of 50-45 g, a sufficient daily potassium intake of 3500 mg, and a sufficient daily sodium intake of 1500-1100 mg with a target intake of 2000 mg. In this study, the average daily protein intake was 60.47 g which exceeded the recommended intake, and the average daily potassium intake was 2896.57 mg which was lower than the recommended intake. Moreover, the average daily sodium intake was 3572.64 mg which exceeded the sufficient daily intake or target intake.

After adjusting for socioeconomic and health behaviours and age, carbohydrate intake was not related to the number of teeth, and protein intake increased as the number of teeth increased in those not wearing dentures. However, in denture wearers, the number of teeth was not related to nutrient intake, and fat intake was low in those with both edentulous jaws or with full dentures on both jaws. These subjects avoided the intake of meat, which is tougher than grains, and thus had insufficient fat intake. However, protein intake was not different because of the high fish intake as a protein supplement by Koreans. After adjusting for the socioeconomic variables, health behaviour, and age, potassium intake had no relationship with the number of teeth in those not wearing dentures, but in denture wearers, potassium intake among those with edentulous upper and lower jaws, with full dentures on both jaws, with 10 or less teeth, or with a full denture on one jaw and a partial denture on the other jaw was insufficient. Sodium intake was not related to the number of teeth.

Shin, *et al.* [16] analysed the KNHANES IV data and reported that the percentage of people aged 65 years or older who had less than the standard nutrient intake was lower in the group with fewer number of teeth. Moreover, the edentulous jaw group had a higher risk of lower than standard intake of nutrients, except calcium, riboflavin, and vitamin C, than did a reference group which had more than 20

natural teeth. In the edentulous jaw group, the percentage of people having insufficient nutrient intake was approximately 10% higher than average. Participants in the poor dentition group had significantly lower energy intake than those with moderate dentition. Moreover, after adjusting for sociodemographic characteristics, physical activity, smoking status, and energy intake, protein intake as well as the intake of most vitamins and minerals were positively associated with the total number of natural teeth; however, an inverse association was observed for carbohydrate intake. Diet quality was inversely associated with tooth loss [5,19]. Park, et al. [4] examined the characteristics of dietary intake in the Korean elderly according to chewing ability by using data from the KNHANES 2007-2010. The chewing group had lower nutrient and food intake than did those with no difficulty chewing. Findings showed that subjects in the chewing group consumed fewer foods, especially fruits and vegetables. When vegetable intake decreases, potassium intake also decreases. Wakai, et al. [20] reported that the mean intake of some key nutrients and food groups, such as carotene, vitamins A and C, milk and dairy products, and vegetables including greenyellow vegetables, decreased with a decrease in the number of teeth. In contrast, the mean intake of carbohydrate, rice, and confectioneries increased among those with fewer teeth. The dietary change due to tooth loss can cause cardiovascular disease. Diet may partially explain the associations between oral health and cardiovascular disease, and low-potassium intake in the diet, mostly accompanied by low vegetable and fruit intake, increases blood pressure as well as periodontal inflammation [7,11]. Increased fruit and vegetable intake in the range commonly consumed is associated with a reduced risk of stroke [21,22].

Potassium and sodium intake plays an important role in acid-base balance in several physiological functions, osteoporosis development, aging, and hormonal interactions. The high salt intake together with low potassium intake in the typical American diet substantially contributes to acid-base imbalance. Consequently, low-grade metabolic acidosis can develop, which could considerably contribute to impairments of numerous body functions, the best studied among which is the maintenance of bone function. Because the skeleton represents a large but not endless alkaline reservoir, even mild forms of long-term lowgrade metabolic acidosis can impair skeletal architecture and stability [23]. Therefore, both decreasing sodium chloride intake and increasing potassium intake may likely not just help the aging skeleton but also provide other potential health benefits [24].

Our research showed that potassium intake related to vegetable and fruit intake was especially high in the group having 21-32 existing teeth, and as the number of existing teeth increased, potassium intake also increased. Based on nutrient intake standard data, the sufficient daily potassium intake in Koreans aged 55 years or older was 3.5 g, but the 21-32 teeth group whose intake was the highest could not reach the intake level [13]. Potassium intake used in analysis was calculated using the ingredient analysis value of the food composition table by using food codes and a 24-h podogram. However, the loss of minerals is great when food is cooked, and thus, the actual intake from cooked foods would be lower than the analysis amount [25]. The 2011 KNHANES also reported that potassium intake was 3201.5 mg for people aged 50-64 years and 2345.8 mg for those aged 65 years or older; thus, the intake fraction based on sufficient intake was 91.5% and 67.0%, respectively, which was less than the sufficient intake. In particular, sodium intake was three times higher than the sufficient intake for people aged 65 years or older, and thus, potassium intake was significantly insufficient [26]. In this study, potassium intake in the 21-32 teeth group which had subjects with the most teeth were 3089 mg which was considered significantly insufficient.

Meanwhile, in the denture-wearing group, as the number of teeth decreased, potassium intake also decreased. The reason the intake in subjects with edentulous upper and lower jaws and those with full dentures on both jaws or with 0-10 teeth was low was the lack of masticatory power of the denture compared to that of the natural teeth. Sodium intake was not related to the number of teeth, as was the denture-wearing status. This could be because sodium intake is not related to masticatory movement.

When correcting for demographic and socioeconomic behavioural status variables, household income, education level, and smoking status by using confounding variables, the number of teeth did not have a significant relationship with the intake of each energy-source nutrient, but it was related to potassium intake.

A comparison between the denture-wearing and no-denturewearing groups showed that food intake was lower in the denturewearing group than in the no-denture-wearing group, but energysource intake was not significantly different between the two groups. Carbohydrate intake was not related to the denture-wearing status, protein intake did not show a significant difference between the two groups, and fat intake in the group with edentulous upper and lower jaws and with dentures on both jaws was lower than that in the no-denture-wearing group. The denture-wearing group had a carbohydrate-based meal, and thus, total energy-source intake was not different, but they avoided tough meat, and thus, animal fat intake was reduced, resulting in insufficient fat intake. Potassium intake was lower in the groups with edentulous upper and lower jaws, with full dentures on both jaws, with 10 or less teeth, and wearing a total denture and partial denture than in the no-denture-wearing group.

Miyaura, et al. [27] reported that the biting forces of fixed partial, removable partial, and complete denture wearers were 80%, 35%, and 11%, respectively, when expressed as a percentage of the subjects with natural dentition. Complete denture wearers showed the highest biting pressure among the four groups, followed by the removable partial denture wearers. Therefore, when teeth are lost, the dental prosthesis cannot replace natural teeth, and thus, denture wearers and those not wearing dentures prefer different foods and have different nutrient intake. The older people in Seongnam-si had a percentage composition of carbohydrate, protein, and fat of 70%, 15%, and 15%, respectively, among men and 73%, 13%, and 14%, respectively, among women; thus, the calorie intake from carbohydrate was high when compared to the recommended percentage of 65%, 15%, and 20% for Koreans. Moreover, older people having a high carbohydrate intake percentage also consume a high proportion of the traditional rice-based meal lacking in various animal nutrients. In this study, the energy composition ratio of carbohydrate, protein, and fat was 77:15:8, showing that the ratio of calorie intake from carbohydrate was high and that from fat was low when compared to the Korean recommended ratio of 65:15:20; this finding was similar to that of Kim and Kwon [28].

Miyaura, *et al.* [29] reported that the number of teeth is the most important factor to maintain biting ability, and that the presence of mobile teeth does not always reduce biting ability. Intake of carrots, tossed salads, and dietary fibre among denture-wearers was, respectively, 2.1, 1.5, and 1.2 times lower than that among fully dentate subjects [30]. Wayler and Chauncey reported that shifts in food selection patterns result from impairments in masticatory ability, and the extent to which any dietary alterations occur appears to be influenced by the degree of impairment [31]. The softer, easier-to-chew foods selected by persons with complete dentures should meet their daily nutritional

requirements. Considering the large proportion of individuals with complete dentures, an understanding of how these multiple factors affect the nutritional status of edentulous elderly persons may lead to more rational dietary approaches to the maintenance of health.

This research has the limitations of not having considered other variables such as family members and diseases affecting dietary intake. An integral analysis considering various variables related to dietary intake is warranted in future studies.

Conclusion

This study included adults aged 55-84 years with a significantly reduced number of existing teeth, from among the subjects of the KNHANES VI, and analysed the effect of the number of existing teeth and denture-wearing status on energy-source nutrient and mineral intake by correcting for age, sex, income level, smoking status, etc. The main findings were as follows:

- 1. Carbohydrate intake was not related to the number of existing teeth.
- 2. Protein intake was low in the group with 20 or fewer teeth, and fat and potassium intake was low when both the upper and lower jaws were edentulous.
- 3. People wearing full dentures on both jaws had low fat and potassium intake than did those without dentures.

Tooth loss should be prevented to avoid obstacles to nutrition intake, and even when teeth are lost, sufficient vegetables and fruits should be consumed to increase potassium intake, thereby preventing diseases caused by an imbalance in nutrient intake.

Conflict of interest

The authors declared no conflict of interest

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