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Dietary Mineral Intake from Nuts and Its Relationship to Hypertension Among Korean Adults

Yun-Jung Bae[1] · **Mi-Hyun Kim**[2] · **Mi-Kyeong Choi**[2]

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Abstract

Accumulating evidence shows that nut consumption beneficially affects health outcomes. The purpose of this study was to investigate the association between the intake of nuts, focusing on their mineral contents, and the risk of hypertension in nationally representative samples in Korea. A cross-sectional study was conducted among 12,113 subjects (4762 men and 7351 women) aged 19–64 years using raw data from KNHANES 2016–2019. Daily intake of 20 nuts and 9 minerals from nuts was assessed using the 24-h recall method. The risk of hypertension according to the median mineral intake from nuts and nuts themselves was assessed using logistic regression analysis with adjustment for potential confounders. The average daily nut intake was 4.34 g for females and 3.78 g males. Among nut intake, chestnuts represented the highest value at 0.95 g/day, followed by peanuts (0.72 g/day), almonds (0.62 g/day), sesame seeds (0.62 g/day), perilla seeds (0.33 g/day), and walnuts (0.32 g/day). The daily intake of minerals from nuts was significantly higher in the nut-overmedian (OM) group than in the nut-undermedian (UM) group. Regarding mineral intake from nuts, each mineral-UM group showed higher odds of hypertension than the mineral-OM group in women, but not in men. After adjustment for potential confounders, an inverse association between nut consumption, including minerals obtained from nuts, and hypertension prevalence, especially in women, was observed. Based on our results, it is suggested that incorporation of nuts into a daily diet may yield beneficial effects and lower the risk of hypertension in adult Korean women.

Keywords Nuts · Mineral · Hypertension · Adults · Population

Introduction

Hypertension is an important global health issue because of its high prevalence, and it represents a major risk factor for cardiovascular disease and all-cause mortality [1]. Hypertension alone is associated with 14% of mortality worldwide [2]. In 2010, 30–32.2% of the global adult population had hypertension, defined as systolic blood pressure (SBP) ≥140 mmHg and/or diastolic blood pressure (DBP) ≥90 mmHg [3]. Moreover, the prevalence of hypertension is increasing due to aging of the population and increases in exposure to lifestyle risk factors, including unhealthy diets and lack of physical activity. Korea is no exception with respect to the increasing prevalence of hypertension. It was reported that 32.9% of Korean adults aged over 30 years and 64.4% of Korean adults aged over 65 years had hypertension [4].

For preventing and treating hypertension, it is important to control lifestyle factors such as diet, sodium (Na) consumption, weight loss, maintenance of ideal body weight, regular physical activity, and abstinence from smoking. Among the primary lifestyle factors, diet serves a predominant role in the prevention and control of hypertension [5]. As part of hypertension prevention efforts, current dietary guidelines recommend diets with generous intake of plant foods, such as fruits, vegetables, whole grains, legumes, and nuts, and lower intake of animal-derived foods, saturated fat, sugar-sweetened beverages, and Na.

Nuts are nutrient-dense foods known as rich sources of unsaturated fatty acids, fiber, protein, vitamins, phytosterols, and phytochemicals. They are also rich in non-Na minerals, including calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), phosphorus (P), potassium (K), and zinc (Zn). With respect to distinct nutrient compositions, nuts

✉ Mi-Kyeong Choi
mkchoi67@kongju.ac.kr

1 Major in Food and Nutrition, Korea National University of Transportation, Jeungpyeong 27909, South Korea

2 Department of Food and Nutrition, Kongju National University, Yesan 32439, South Korea

may be considered suitable foods for preventing and treating hypertension. Therefore, it is important to elucidate whether and how nuts can exert beneficial effects on the control of hypertension.

In a prospective cohort of 15,966 participants from Physicians' Health Study I, Djoussé et al. [6] reported a lower incidence of hypertension in usual consumers of nuts than in nonconsumers. However, another study, which involved 9919 Spanish university graduates followed up for a median of 4.3 years in the SUN cohort [7], found no association between nut consumption and the incidence of hypertension. In a review of previous studies related to nuts and hypertension, Casas-Agustench et al. [8] reported that limited evidence from prospective studies and clinical trials suggests that nut consumption exerts a beneficial effect on blood pressure. A few previous investigations have explored the associations between nut consumption and hypertension in population-based cohorts. Moreover, there is scarce information from previous studies on the possibility of preventing hypertension as a result of consumption of minerals from nuts, such as Ca, Mg, and K.

The purpose of this study was to investigate the association between the intake of nuts, focusing on their minerals and the prevalence of hypertension in a representative sample of community-dwelling adults fed self-selected diets.

Materials and Methods

Study Population

This study used Korea National Health and Nutrition Examination Survey (KNHANES) raw data acquired by the Korean Center for Disease Control. KNHANES is a national survey conducted using a stratified, multistage clustered probability-sampling design and consists of three survey types: examinations, health interviews, and nutrition surveys [9]. In this study, we used raw data from the KNHANES 2016–2019 database. Of the 16,574 subjects aged 19–64 years, we excluded one subject with missing nutritional survey data, 876 subjects who reported deficient or excessive energy intake (605 men and 271 women) (<800 kcal/day or >4500 kcal/day for men, <500 kcal/day or >3500 kcal/day for women) [10], and 943 subjects (496 men and 447 women) without blood pressure values, one of the main variables in this study. Additionally, 2060 persons (948 men and 1112 women) with diseases and metabolic abnormalities associated with hypertension, such as dyslipidemia, stroke, myocardial infarction, diabetes, and angina pectoris, and 581 persons (267 men and 314 women) with missing data on body mass index (BMI) and other socioeconomic variables were excluded, resulting in a final study population of 12,113 persons (4762 men and 7351 women).

KNHANES is a research endeavor conducted by the government for public welfare in accordance with paragraph (1) of Article 2 of the Bioethics and Safety Act and Article 2 (2) 1 of the Enforcement Rule of the same act; and therefore, it is deemed exempt from review by the Institutional Review Board (IRB), and KNHANES 2016–2017 was conducted without it. However, since KNHANES 2018, IRB approval after review has been obtained as KNHANES collects human-derived material, and the KNHANES raw data are available to third-party users (2018-01-03-P-A, 2018-01-03-C-A). All the subjects signed a consent form before participating in the survey.

Demographic Factors

The demographic factors of the subjects were evaluated through health interviews and examinations. Data on age, sex, household income, education level, residential areas, alcohol intake, smoking status, aerobic exercise, and marital status were obtained from health interviews. Data on BMI, SBP, and DBP were collected from examination. According to the World Health Organization's Asia-Pacific guidelines [11], the degree of obesity was classified using BMI (normal: <23 kg/m^2, overweight: ≥23 and <25 kg/m^2, obesity group: ≥25 kg/m^2). Hypertension was defined as SBP of 140 mmHg or greater, DBP of 90 mmHg or greater, or taking antihypertensive medication to lower blood pressure.

Dietary Intake Survey for Nut and Mineral Intake Assessment

Dietary intake data were assessed using the 24-h recall method for 1 day. Trained survey staff conducted face-to-face interviews with subjects to record the types and amounts of foods and beverages and to estimate the types and amounts of ingredients for each food consumed 1 day before the survey [9]. To improve the overall estimation accuracy of portion size, measuring aids such as two-dimensional food containers and food models, measuring cups and spoons, thickness sticks, 30-cm rulers, and tape measures were provided.

Dietary intake data obtained were used for analysis of daily energy intake and nut intake in the subjects. Additionally, nuts were grouped together with foods with the same raw material and classified into 20 categories. Twenty different nut types, including hazelnuts, perilla seeds, peanuts, macadamia nuts, chestnuts, Brazil nuts, hemp seeds, almonds, ginkgo nuts, pine nuts, sesame seeds, cashew nuts, coconuts, pistachio nuts, pecans, sunflower seeds, walnuts, pumpkin seeds, flax seeds, and chia seeds, were listed to calculate the daily intake of each nut type and the total daily nut intake. Then, the intake of Ca, Fe, manganese (Mn), P, K, Na, Zn, and Cu was estimated using databases of food composition tables [12]. Some mineral contents of nuts that were not indicated in the database were calculated using those of a previous study [13] for the analysis of mineral intake from nut intake.

Statistical Analysis

All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc, Cary, NC, USA), and descriptive statistics were calculated based on the survey procedure, which incorporates sample weight, by using cluster variables using kstrata and primary sampling units. Furthermore, this study conducted a comparison and correlation analysis of variables between groups according to the median daily nut intake in male and female subjects because their nut intake was low and the intake distribution was wide and skewed. The demographic factors, nut intake, and mineral intake from nut consumption of the subjects are presented as the mean and standard error, frequency, or percentage. Student's *t*-tests and chi-square tests were used to compare the continuous variables of nut intake, age, and BMI of the subjects and categorical variables of demographic characteristics. Additionally, the confounding factor-adjusted mean values of SBP and DBP were analyzed using a multivariate regression model. The risk of hypertension induced by mineral intake from nuts and nuts themselves was analyzed through logistic regression analysis, and the results, adjusted for confounding factors, were expressed as odds ratios (ORs) and 95% confidence intervals (CIs). The significance level of all analyses was $p<0.05$.

Results

Nut Intake

Daily intake of nuts among the subjects is indicated in Table 1. The average daily nut intake was 4.34 g for females and 3.78 g males. In all subjects, chestnut intake was the highest at 0.95 g/day, followed by peanuts (0.72 g/day), almonds (0.62 g/day), sesame seeds (0.62 g/day), perilla seeds (0.33 g/day), and walnuts (0.32 g/day).

Demographic Characteristics

Table 2 shows the demographic characteristics according to nut intake of the participants. Subjects were divided into the undermedian (UM) group and the overmedian (OM) group according to daily nut intake. The average age of all participants was 40.92 years, and the age of the OM group

Table 1 Daily nut intakes of the participants

Nuts	Total (*n*=12,113)			Male (*n*=4762)			Female (*n*=7351)		
Almonds	0.624	±	0.038[1]	0.576	±	0.058	0.668	±	0.044
Brazil nuts	0.077	±	0.011	0.071	±	0.021	0.083	±	0.010
Cashew nuts	0.124	±	0.017	0.120	±	0.029	0.129	±	0.021
Chestnuts	0.945	±	0.103	0.623	±	0.096	1.240	±	0.174
Chia seeds	0.000	±	0.000	0.000	±	0.000	0.000	±	0.000
Coconuts	0.035	±	0.008	0.016	±	0.008	0.052	±	0.013
Flax seeds	0.012	±	0.003	0.004	±	0.002	0.019	±	0.005
Ginkgo nuts	0.051	±	0.009	0.031	±	0.009	0.070	±	0.015
Hazelnuts	0.005	±	0.001	0.002	±	0.001	0.008	±	0.002
Hemp seeds	0.033	±	0.008	0.014	±	0.005	0.051	±	0.014
Macadamia nuts	0.033	±	0.007	0.021	±	0.006	0.044	±	0.013
Peanuts	0.715	±	0.058	0.868	±	0.105	0.575	±	0.048
Pecans	0.016	±	0.003	0.013	±	0.004	0.019	±	0.005
Perilla seed	0.326	±	0.021	0.335	±	0.031	0.318	±	0.025
Pine nuts	0.045	±	0.005	0.043	±	0.007	0.047	±	0.007
Pistachio nuts	0.008	±	0.002	0.008	±	0.004	0.008	±	0.002
Pumpkin seeds	0.033	±	0.006	0.030	±	0.009	0.036	±	0.008
Sesame seeds	0.615	±	0.012	0.656	±	0.017	0.576	±	0.015
Sunflower seeds	0.056	±	0.009	0.057	±	0.011	0.055	±	0.012
Walnuts	0.316	±	0.020	0.288	±	0.029	0.341	±	0.025
Total	4.070	±	0.142	3.777	±	0.187	4.339	±	0.203

[1]Values are presented as mean±standard error

Unit: g/day, used the raw data from the 1998–2019 Korea National Health and Nutrition Examination Survey

Table 2 Demographic characteristics according to nut intake of the participants

	Total (n=12,113)				Male (n=4762)				Female (n=7351)			
	Total (n=12,113)	≤Median (n=5971)	>Median (n=6142)	p value	Total (n=4762)	≤Median (n=2337)	>Median (n=2425)	p value	Total (n=7351)	≤Median (n=3611)	>Median (n=3740)	p value
Age (yrs)	40.92±0.16[1]	39.00±0.26	42.84±0.21	<.0001	40.59±0.23	38.80±0.42	42.37±0.3	<.0001	41.22±0.18	39.20±0.32	43.24±0.26	<.0001
BMI (kg/m^2)	23.67±0.04	23.67±0.08	23.67±0.06	0.9792	24.57±0.06	24.59±0.12	24.55±0.08	0.7069	22.84±0.06	22.85±0.10	22.84±0.08	0.9041
Normal	5835 (46.9)	2906 (47.8)	2929 (45.9)	0.2069	1569 (33.2)	788 (34.5)	781 (31.9)	0.2154	4266 (59.5)	2100 (59.9)	2166 (59.1)	0.7305
Overweight	2555 (21.1)	1230 (20.7)	1325 (21.5)		1210 (25.2)	582 (24.5)	628 (25.8)		1345 (17.4)	640 (17.0)	705 (17.8)	
Obesity	3723 (32.0)	1835 (31.5)	1888 (32.5)		1983 (41.6)	967 (40.9)	1016 (42.3)		1740 (23.2)	871 (23.2)	869 (23.2)	
Household income												
1 (low)	1003 (8.4)	563 (9.6)	440 (7.3)	<.0001	403 (8.6)	240 (9.9)	163 (7.3)	0.0014	600 (8.2)	316 (9.0)	284 (7.5)	0.0021
2	2870 (23.4)	1486 (24.6)	1384 (22.2)		1082 (22.6)	562 (23.7)	520 (21.4)		1788 (24.2)	919 (25.4)	869 (23.0)	
3	3818 (31.8)	1880 (31.7)	1938 (31.8)		1488 (31.8)	716 (31.7)	772 (31.9)		2330 (31.7)	1164 (32)	1166 (31.5)	
4 (high)	4422 (36.4)	2042 (34.1)	2380 (38.7)		1789 (37.0)	819 (34.7)	970 (39.4)		2633 (35.8)	1212 (33.6)	1421 (38.1)	
Education level												
≤Elementary school	674 (4.5)	322 (4.4)	352 (4.7)	0.0020	208 (3.4)	108 (3.4)	100 (3.4)	0.0001	466 (5.5)	214 (5.2)	252 (5.8)	0.5023
Middle school	823 (5.9)	388 (5.6)	435 (6.1)		293 (5.3)	140 (5.0)	153 (5.6)		530 (6.4)	246 (6.2)	284 (6.7)	
High school	4500 (38.3)	2311 (40.2)	2189 (36.4)		1790 (38.7)	943 (42.0)	847 (35.3)		2710 (38.0)	1361 (38.7)	1349 (37.4)	
≥College	6116 (51.3)	2950 (49.8)	3166 (52.7)		2471 (52.6)	1146 (49.5)	1325 (55.7)		3645 (50.0)	1790 (49.9)	1855 (50.1)	
Aerobic exercise (yes)	5786 (50.1)	2839 (50.2)	2947 (50)	0.8549	2438 (53.3)	1212 (54.7)	1226 (51.9)	0.0787	3348 (47.2)	1621 (46.2)	1727 (48.3)	0.1222
Current smoking (yes)	2203 (21.4)	1174 (23.1)	1029 (19.6)	0.0001	1790 (37.8)	967 (41.7)	823 (34.0)	<.0001	413 (6.3)	229 (7.1)	184 (5.4)	0.0146
Drinking (yes)	7215 (62.3)	3611 (62.9)	3604 (61.7)	0.2119	3511 (73.3)	1712 (72.7)	1799 (73.9)	0.3880	3704 (52.3)	1898 (54.4)	1806 (50.1)	0.0010
Marital status												
Married	8476 (65.2)	3893 (59.5)	4583 (70.9)	<.0001	3103 (60.8)	1369 (53.6)	1734 (68)	<.0001	5373 (69.3)	2504 (64.9)	2869 (73.7)	<.0001
Others[2]	3637 (34.8)	2078 (40.5)	1559 (29.1)		1659 (39.2)	968 (46.4)	691 (32)		1978 (30.7)	1107 (35.1)	871 (26.3)	
Region (urban)	10300 (87.3)	5098 (87.8)	5202 (86.9)	0.2344	3993 (86.6)	1976 (87.8)	2017 (75.5)	0.0426	6307 (88.0)	3098 (87.7)	3209 (88.3)	0.5078
SBP (mmHg)	114.48±0.18	115.36±0.23	114.87±0.24	0.0777[4]	118.28±0.25	118.55±.36	118.39±.36	0.7041[5]	111.00±0.20	111.69±.28	110.63±0.27	0.0022[6]
DBP (mmHg)	76.16±0.16	76.45±0.17	75.84±0.17	0.0030[4]	79.14±0.19	78.96±0.28	78.45±0.27	0.1100[5]	73.44±0.15	73.96±0.20	73.14±0.20	0.0007[6]
Hypertension (yes)[3]	1973 (15.8)	940 (15.3)	1033 (16.3)	0.1835	1039 (20.7)	493 (20.1)	546 (21.2)	0.3749	934 (12.2)	449 (11.1)	485 (11.7)	0.4473

[1]Values are presented as mean±standard error or N (percentage)

[2]Widowed, separated, divorced, or never married

[3]Hypertension was defined as systolic BP ≥140 mmHg and/or diastolic BP ≥90 mmHg and/or taking medication of hypertension

[4]Adjusted for age, sex, household income, education level, current smoking, marital status, and energy intake

[5]Adjusted for age, household income, education level, current smoking, marital status, region, and energy intake

[6]Adjusted for age, household income, current smoking, drinking, marital status, and energy intake

Used the raw data from the 1998–2019 Korea National Health and Nutrition Examination Survey

was significantly higher than that of the UM group for both men and women ($p<0.001$). The household income, education level, current smoking status, and marital status of the subjects showed significant differences between the UM group and the OM group. When adjusted for these covariates, the blood pressure of the OM group was significantly lower than that of the UM group for SBP in women and for DBP in all subjects or women alone ($p<0.01$). However, the prevalence of hypertension between the two groups was not significantly different for either men or women.

Energy and Mineral Intake from Nuts

The median nut intake was 0.56 g/day for all subjects: 0.59 g/day for men and 0.53 g/day for women (Table 3). Table 4 shows the daily intake of energy and minerals from nuts according to the median nut intake of the subjects. The energy intake of the OM group was significantly higher than that of the UM group for both men (2386.61 kcal/day vs. 2181.61 kcal/day, $p<0.001$) and women (1787.86 kcal/day vs. 1582.41 kcal/day, $p<0.001$). The daily intake of minerals from nuts was also significantly higher in the OM group than in the UM group.

Hypertension Risk According to Mineral Intake from Nuts

Table 5 shows hypertension risk of the subjects according to nut intake and mineral intake from nuts. In men, there was no significant difference in the risk of hypertension according to nut intake. However, in women, the UM group according to nut intake had a significantly higher risk of hypertension (women: OR=1.27, 95% CI: 1.07–1.50; $p<0.01$, all subjects: OR=1.15, 95% CI: 1.02–1.30; $p<0.05$) after covariate adjustment than the OM group. Regarding the mineral intake from nuts for all subjects or women alone, the mineral-UM group had a significantly higher risk of hypertension than the mineral-OM group.

Discussion

Nuts are reported to be an effective food group that is sustainable and improves metabolic health [14], so we analyzed the association between mineral-focused nut intake and the prevalence of hypertension in the Korean population. As a main result, only in women did the subjects with high consumption of nuts and minerals from nuts, such as Ca, Fe, Mg, P, and K, have a lower risk of hypertension than the subjects with low consumption.

Nut consumption by populations has been reported to vary widely because nuts are not a common food group used in a typical meal. According to KNHANES, the daily nut consumption per capita in the Korean adult population increased from 3.1 g in 2009 to 5.7 g in 2019 [4]. In this study, which analyzed the most recently released data, the daily consumption of 20 types of nuts was 4.1 g. As the nutritional and health functions of nuts have been revealed, nut consumption by populations has been reported in many countries. In the study using the NHANES 2005–2010 data of 14,386 US adults acquired over 19 years, the nut consumption per capita was 3.3 g/day [15]. Nut intake among 12,153 Australians who participated in the 2011–2012 National Nutrition and Physical Activity Survey was reported to be 4.6 g/day [16]. In 4721 New Zealanders participating in the 2008–2009 New Zealand Adult Nutrition Survey, nut consumption was 5.2 g/day, which is far below the recommended level of 30 g/day [17]. Countries in the

Table 3 Daily intakes of nuts and minerals from nuts

	Total (n=12,113)			Male (n=4762)			Female (n=7351)		
	Median	IQR	Min–max	Median	IQR	Min–max	Median	IQR	Min–max
Nuts consumption (g/d)	0.560	2.04	0–469.30	0.590	1.93	0–337.93	0.533	2.17	0–469.30
Ca (mg/d)	3.648	9.85	0–447.14	4.090	10.14	0–447.14	3.356	9.62	0–382.05
Fe (mg/d)	0.033	0.11	0–8.31	0.036	0.11	0–5.63	0.031	0.11	0–8.31
Mg (mg/d)	1.798	5.63	0–488.70	1.957	5.66	0–318.96	1.660	5.62	0–488.70
P (mg/d)	3.730	12.12	0–1153.54	4.015	12.20	0–712.92	3.472	12.02	0–1153.54
K (mg/d)	2.688	10.54	0–2011.61	2.810	9.97	0–1393.64	2.561	11.24	0–2011.61
Na (mg/d)	0.011	0.04	0–1652.21	0.012	0.04	0–1652.21	0.010	0.04	0–485.87
Zn (mg/d)	0.027	0.09	0–6.91	0.029	0.09	0–5.58	0.025	0.09	0–6.91
Cu (mg/d)	0.006	0.02	0–2.08	0.006	0.02	0–1.62	0.006	0.02	0–2.08
Mn (mg/d)	0.008	0.04	0–23.97	0.008	0.03	0–17.63	0.007	0.04	0–23.97

IQR interquartile range

Used the raw data from the 1998–2019 Korea National Health and Nutrition Examination Survey

Table 4 Daily intakes of energy and minerals from nuts according to the median of nut intake

	Total (n=12,113)				Male (n=4762)				Female (n=7351)			
	Total (n=12,113)	≤Median (n=5971)	>Median (n=6142)	p value	Total (n=4762)	≤Median (n=2337)	>Median (n=2425)	p value	Total (n=7351)	≤Median (n=3611)	>Median (n=3740)	p value
Energy (kcal/d)	1971.73±8.87[1]	1863.66±12.79	2079.76±11.31	<.0001	2284.17±12.43	2181.61±18.51	2386.61±16.65	<.0001	1685.16±8.68	1582.41±12.16	1787.86±11.47	<.0001
Mineral intake from nuts												
Ca (mg/d)	10.117±0.216	1.197±0.022	19.032±0.359	<.0001	10.249±0.331	1.292±0.035	19.197±0.563	<.0001	9.995±0.250	1.119±0.026	18.867±0.427	<.0001
Fe (mg/d)	0.153±0.004	0.009±0.000	0.296±0.007	<.0001	0.148±0.006	0.010±0.000	0.286±0.010	<.0001	0.157±0.005	0.009±0.000	0.306±0.009	<.0001
Mg (mg/d)	8.350±0.232	0.514±0.009	16.183±0.412	<.0001	8.294±0.363	0.553±0.015	16.027±0.664	<.0001	8.401±0.257	0.480±0.011	16.319±0.461	<.0001
P (mg/d)	17.679±0.480	1.039±0.018	34.313±0.850	<.0001	17.544±0.747	1.118±0.029	33.954±1.356	<.0001	17.803±0.538	0.970±0.021	34.629±0.961	<.0001
K (mg/d)	23.020±0.762	0.722±0.012	45.309±1.408	<.0001	21.872±1.078	0.773±0.020	42.95±2.005	<.0001	24.073±1.003	0.677±0.015	47.461±1.863	<.0001
Na (mg/d)	1.477±0.305	0.003±0.000	2.951±0.609	<.0001	1.671±0.575	0.003±0.000	3.337±1.148	<.0001	1.300±0.146	0.003±0.000	2.596±0.291	<.0001
Zn (mg/d)	0.130±0.004	0.008±0.000	0.252±0.006	<.0001	0.130±0.006	0.008±0.000	0.253±0.011	<.0001	0.129±0.004	0.007±0.000	0.251±0.007	<.0001
Cu (mg/d)	0.035±0.001	0.002±0.000	0.069±0.002	<.0001	0.034±0.002	0.002±0.000	0.067±0.003	<.0001	0.036±0.001	0.002±0.000	0.071±0.002	<.0001
Mn (mg/d)	0.108±0.005	0.002±0.000	0.214±0.011	<.0001	0.092±0.006	0.002±0.000	0.182±0.011	<.0001	0.123±0.009	0.002±0.000	0.244±0.017	<.0001

[1]Values are presented as mean±standard error

Used the raw data from the 1998–2019 Korea National Health and Nutrition Examination Survey

Mediterranean region are reported to have higher consumption of nuts than other countries. The per capita consumption of nuts in Spain in 2001 was 7.9 g/day [18]. Although it is difficult to directly compare because each study differs with respect to the range of nut types, the daily nut intake of the Korean population in this study was similar to that of other countries and lower than that of the Mediterranean region.

In Korea, one serving size of nuts was set to 10 g, taking into account the mean intake, median, and intake distribution of the KNHANES data [19]. Nut consumption reported in several countries, including this study, was not higher than one portion in Korea. "Out-of-hand" nut consumption, defined as at least 7 g/day of pure nuts, not as part of other products, was reported as the level with improved nutrient intake and health risk markers [20]. Regular nut consumption of approximately 30 g/day is recommended by numerous dietary guidelines globally [17, 21, 22]. Studies on the nutritional and health effects of nuts suggest the benefits of high levels of consumption, but one of the limitations of recommending larger portions is the fact that nuts are highly calorigenic [23] due to their high nutrient density. Additionally, it has been reported that nuts can act as food allergens depending on their types or individual characteristics [24, 25]. Therefore, it may be practical and more important to establish that nut consumption levels through ordinary diets have both nutritional and health effects.

Although the nutrient composition differs according to individual nut types, overall, nuts are known as a nutrient-rich food group and especially a source of non-Na minerals, including Ca, Cu, Fe, Mg, and P. Gülfen and Özdemir [26] reported that peanuts, sunflower seeds, and pumpkin seeds are good trace element suppliers, including not only Cu but also Fe, Mn, Zn, and selenium (Se). A serving of 30 g of Brazil nuts contains up to 10 times the daily value of Se and approximately one-third of the daily value of Mg and P [27]. Pistachio nuts can provide more than 10% of the daily value for K, and pine nuts contain approximately one-third of the daily value for Zn [27]. Therefore, nuts are suggested as additional foods to supplement the dietary mineral supply when the mineral content of the ordinary diet is not sufficient. When the daily intake of 20 types of nuts was analyzed in this study, chestnut intake was the highest, followed by peanut, almond, sesame seed, and walnut intake. With respect to mineral intake from nuts, K was the highest, followed by P, Ca, and Mg. Since the average intake of nuts was as low as 4.1 g/day, the average intake of each mineral from nuts was also assessed as low. Nevertheless, some of the minerals that were abundantly found in nuts, including Ca, Mg, and K, have been reported to be insufficient in the Korean diet [4].

As mentioned previously, nuts are low in Na and contain significant amounts of minerals such as Ca, Mg, and K, as well as mono- and polyunsaturated fatty acids, fiber,

Table 5 Adjusted odd radios and 95% confidence intervals of hypertension risk by nut and mineral intake from nut

Nut and mineral intake	Total[1]				Male[2]				Female[3]			
	Crude	*p* value	Adjust	*p* value	Crude	*p* value	Adjust	*p* value	Crude	*p* value	Adjust	*p* value
≥Nut median (Ref.)	1	0.1837	1	0.0280		0.3748		0.2524		0.4475		0.0073
<Nut median	0.927 (0.828–1.037)		1.149 (1.015–1.301)		0.933 (0.801–1.087)		1.101 (0.934–1.297)		0.941 (0.804–1.101)		1.266 (1.066–1.503)	
≥Ca median (Ref.)	1	0.1861	1	0.0204		0.5445		0.1451		0.2935		0.0318
<Ca median	0.927 (0.829–1.037)		1.155 (1.023–1.305)		0.955 (0.823–1.108)		1.126 (0.960–1.321)		0.919 (0.788–1.076)		1.206 (1.016–1.430)	
≥Fe median (Ref.)	1	0.1007	1	0.0229		0.3464		0.2667		0.2461		0.0183
<Fe median	0.911 (0.814–1.018)		1.153 (1.020–1.304)		0.929 (0.798–1.083)		1.097 (0.932–1.292)		0.911 (0.779–1.066)		1.227 (1.035–1.455)	
≥Mg median (Ref.)	1	0.1097	1	0.0267		0.2315		0.4478		0.2104		0.0255
<Mg median	0.913 (0.817–1.021)		1.148 (1.016–1.298)		0.911 (0.781–1.061)		1.066 (0.904–1.256)		0.904 (0.771–1.059)		1.218 (1.024–1.447)	
≥P median (Ref.)	1	0.1130	1	0.0285		0.3110		0.2839		0.2845		0.0176
<P median	0.914 (0.817–1.022)		1.147 (1.015–1.297)		0.925 (0.794–1.076)		1.093 (0.929–1.287)		0.918 (0.784–1.074)		1.230 (1.037–1.460)	
≥K median (Ref.)	1	0.1820	1	0.0241		0.3990		0.2234		0.4784		0.0093
< K median	0.927 (0.83–1.036)		1.152 (1.019–1.303)		0.936 (0.803–1.091)		1.107 (0.940–1.305)		0.945 (0.807–1.106)		1.258 (1.058–1.496)	
≥Na median (Ref.)	1	0.2420	1	0.0323		0.3817		0.3032		0.5590		0.0058
<Na median	0.935 (0.836–1.046)		1.144 (1.011–1.293)		0.934 (0.801–1.089)		1.090 (0.925–1.284)		0.955 (0.817–1.116)		1.271 (1.072–1.507)	
≥Zn median (Ref.)	1	0.1073	1	0.0301		0.3135		0.3113		0.1406		0.0654
<Zn median	0.913 (0.817–1.020)		1.145 (1.013–1.294)		0.925 (0.795–1.076)		1.088 (0.924–1.281)		0.888 (0.759–1.040)		1.174 (0.990–1.394)	
≥Cu median (Ref.)	1	0.1504	1	0.0194		0.3603		0.2635		0.2038		0.0211
<Cu median	0.921 (0.824–1.030)		1.159 (1.024–1.311)		0.931 (0.799–1.085)		1.099 (0.932–1.296)		0.903 (0.772–1.057)		1.222 (1.031–1.449)	
≥Mn median (Ref.)	1	0.1942	1	0.0251		0.4026		0.2105		0.4228		0.0099
<Mn median	0.929 (0.831–1.038)		1.151 (1.018–1.301)		0.936 (0.802–1.093)		1.112 (0.942–1.313)		0.937 (0.800–1.098)		1.256 (1.056–1.493)	

[1] Adjusted for age, sex, household income, education level, current smoking, marital status, and energy intake

[2] Adjusted for age, household income, education level, current smoking, marital status, region, and energy intake

[3] Adjusted for age, household income, current smoking, drinking, marital status, and energy intake

Hypertension was defined as systolic BP ≥140 mmHg and/or diastolic BP ≥90 mmHg and/or taking medication of hypertension

Ca, calcium; *Fe*, iron; *Mg*, magnesium; *P*, phosphorus; *K*, potassium; *Na*, sodium; *Zn*, zinc; *Cu*, copper; *Mn*, manganese

Used the raw data from the 1998–2019 Korea National Health and Nutrition Examination Survey

antioxidants, and vitamins. These compositional properties confer nuts with the potential to beneficially influence blood pressure [8]. Similar to our results, two prospective studies by Djoussé et al. [6] and Martinez-Lapiscina et al. [7] reported that nuts are potentially protective against hypertension because of their complex compositional characteristics. In addition, we further investigated the antihypertensive effects of mineral intake through nuts. Although the mean intake of each mineral from nuts was low and exhibited wide variation, the UM group of all 9 minerals, including Ca, Mg, and K, showed higher odds of having hypertension than the OM group. When men and women were separated, these results were particularly significant in women. We also tested the interaction between sex and nuts or minerals from nut intake on hypertension and found no significant interaction between them in any variables (data not shown). This confirmed that the association of nut intake with the risk of hypertension was different in men and women independently. Although there is a limit to exactly interpreting such a sex difference in our cross-sectional study, the average age of middle-aged adults with a significant change in blood pressure and higher nut intake in women may be considered. However, future systematic research is needed to explain this relationship.

Minerals have been suggested as components of nuts that may modulate blood pressure. For example, Ca inhibits parathyroid hormone, which induces hypertension by increasing intracellular Ca levels [28]. Mg stimulates the production of nitrous oxide and vasodilator prostacyclins and blocks Ca channels, inducing vasodilation [29]. K may decrease blood pressure by reducing extracellular fluid volume, reducing the angiotensin effects of the renin-angiotensin system, relaxing vascular smooth muscle, and reducing peripheral vascular resistance [30]. Due to the beneficial effects on blood pressure caused by these minerals, it has been continuously reported that mineral intake through the total diet, including nuts, exerts a protective effect against high blood pressure. Larsson et al. [31], Lee et al. [32], and Cunha et al. [33] reported that intake of Ca, Mg, and K exhibits a negative correlation with blood pressure. Epidemiological studies have reported that decreased serum trace minerals such as Zn and Cu are associated with the incidence of coronary artery disease [34–36]. In the authors' previous study among Korean adults, after adjusting for age, sex, BMI, and energy intake, Mg intake had a negative correlation with SBP, and Cu intake had a negative correlation with SBP and DBP. Additionally, Mn intake was negatively correlated with DBP [37].

In the present study, we found an inverse association between mineral consumption from nuts and hypertension prevalence. These results highlight the potential possibility that minerals from nuts can have protective effects on hypertension even through low intake. As mentioned, previous studies [31–33] indicating that Ca, Mg, and K play preventive roles in high blood pressure are in line with the results of this study. Moreover, Na intake, known as a dietary risk factor for hypertension, also corresponded with a significantly higher risk of hypertension in the Na-UM group after adjusting for confounding factors. This result may be possibly interpreted as the fact that the amount of Na intake from nuts is very low and that complex effects caused by other preventive minerals modulate hypertension. However, there is insufficient evidence to support this interpretation of the results because previous studies on the relationship between Na intake through nuts and hypertension are very limited. Follow-up studies including intervention trials to support this possibility should be conducted.

Our study is not without limitations. First, the cross-sectional nature of this study does not allow us to determine causal relationships between nut consumption and hypertension. Second, dietary intake data from the KNHANSE estimated based on a single-day 24-h recall may not capture the long-term nut intake patterns. However, to our knowledge, this is the first study to explore the association between nut intake, including nuts themselves and various minerals contained in nuts, and hypertension in Korean adults using nationally representative data with a large sample size. The findings and lessons learned from this study can shed light on how beneficial effects of nuts previously identified in hypertension studies, mostly conducted in Western countries, play roles in preventing hypertension in Eastern/Asian countries. Additionally, in our study, nut intake was measured as the sum of consumption of 20 kinds of nuts, and intake of 9 minerals from nuts was measured. This approach makes it possible to produce guidelines that can recommend the appropriate consumption of nuts for the prevention and management of cardiovascular diseases such as high blood pressure without specifying the type of nuts in the practical application of the results. Additionally, by analyzing mineral intake from nuts and examining the relationship with blood pressure, the benefits of mineral intake through nuts can be suggested. More longitudinal and intervention studies are needed to clarify the possible effects of nutrient consumption or mineral consumption from nuts on hypertension.

Conclusion

After adjustment for potential confounders, an inverse association was observed between nut consumption, including the presence of minerals, and hypertension prevalence in Korean women. Based on our results, it is suggested that incorporation of nuts into a usual diet may produce beneficial effects and lower the risk of hypertension in Korean adults, especially in women.

Availability of Data and Material Data used in this study are from the Korean CDC (https://knhanes.kdca.go.kr/knhanes/main.do). After creating an account at this site, interested readers can access the raw data from the 1998–2019 Korea National Health and Nutrition Examination Survey. The dataset file is available from Korean CDC at https://knhanes.kdca.go.kr/knhanes/main.do.

Code Availability Not applicable.

Author Contribution **Mi-Kyeong Choi:** conceptualization, funding acquisition, validation, supervision, writing - review and editing.
Yun-Jung Bae: methodology, data curation, formal analysis, software, visualization.
Mi-Hyun Kim: writing - original draft.

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Declarations

IRB approval after review has been obtained as KNHANES collects human-derived material (2018-01-03-P-A, 2018-01-03-C-A), and all participants provided their written informed consent.

Consent for Publication All the authors have consent to submit the manuscript for publication in Biological Trace Element Research.

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