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Association between nut consumption and low muscle strength among Korean adults

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Abstract

Nuts are an important component of a healthy diet, but little has been known about their effects on muscle health. Therefore, this study examined the association between nut consumption and low muscle strength among Korean adults. This cross-sectional analysis was conducted using single 24-h recall and handgrip strength data from 3962 younger adults 19–39 years, 6921 middle-aged adults 40–64 years and 3961 older adults ≥65 years participated in the seventh cycle (2016–2018) of the Korea National Health and Nutrition Examination Survey. Low muscle strength was defined as handgrip strength <28 kg for men and <18 kg for women. Sex-specific OR were obtained for younger, middle-aged and older adults using multivariable logistic regression analyses. About one in four Korean adults were consuming nuts (using a culinary definition) with peanut being the most frequently consumed type. After adjustment for age, BMI, total energy intake, household income, alcohol consumption, smoking, resistance exercise, medical history and dietary protein intake, nut consumption was associated with the lower risk of low muscle strength among older adults ≥65 years (men: OR 0·55, 95 % CI (0·38, 0·79); women: OR 0·69, 95 % CI (0·51, 0·93)); however, this association was not observed among younger adults 19–39 years or middle-aged adults 40–64 years. Our results suggest that consuming nuts might be beneficial in lowering the risk of low muscle strength among Korean older adults.

Keywords: **Nuts: Sarcopenia: Handgrip strength: Muscle strength: National Health and Nutrition Examination Survey**

Sarcopenia, which has been recently established as a muscle disease[1], is a condition of age-related loss of skeletal muscle mass, low muscle strength and/or low physical performance[2]. For use in community-based health care and screening, the Asian Working Group for Sarcopenia 2019 consensus has introduced a concept of 'possible sarcopenia' defined as low muscle strength with or without low muscle mass[2]. Low muscle strength was defined as handgrip strength <28 kg for Asian older men and <18 kg for Asian older women[2].

Since sarcopenia increases the risk of multiple chronic diseases, such as type 2 diabetes, CVD, non-alcoholic fatty liver disease and osteoporosis as well as impaired ability and frailty to perform daily activities[3–7], it is very important to manage muscle health with advancing age. Although having regular resistance training and higher dietary protein intake are major preventive factors for maintaining optimal muscle mass, strength and function[8,9], emerging evidence suggests that adequate intakes of other nutrients, including dietary fibres, n-3 PUFA and micronutrients, play important roles in preventing muscle strength decline[10–13].

Nuts are rich in plant-based protein, dietary fibre, PUFA, MUFA, phytosterols and phytochemicals and are low in SFA and carbohydrates[14], and thus, they have been associated with numerous health outcomes including cardiometabolic diseases[15]. Given their nutrient profiles, nuts also have the potential to prevent muscle strength decline through an influence on various mechanisms influencing oxidative stress, inflammation and insulin resistance[16]. However, little is known whether consumption of nuts exerts beneficial effects on muscle strength. Therefore, this study aimed to examine an association between nut consumption and low muscle strength among a representative sample of Korean adults.

Methods

Data source and subjects

The Korea National Health and Nutrition Examination Survey (KNHANES) is a cross-sectional survey of a nationally representative sample of the Korean population ≥1 year[17,18]. We

Abbreviation: KNHANES, Korea National Health and Nutrition Examination Survey.

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used data from the KNHANES VII (2016–2018). Among 24 269 participants of the KNHANES VII, children <18 years (*n* 4880), those who did not complete a 24-h dietary recall (*n* 2535), those missing hand grip strength information (*n* 1455) and those with implausible energy intake (<500 kcal/d or >4000 kcal/d, *n* 555) were subsequently excluded. A final sample of 14 844 participants was stratified by sex and age to adjust for possible biological differences[19]: younger men aged 19–39 years (*n* 1620), younger women aged 19–39 years (*n* 2342), middle-aged men aged 40–64 years (*n* 2799), middle-aged women aged 40–64 years (*n* 4122), older men ≥65 years (*n* 1760) and older women ≥65 years (*n* 2201).

This study was conducted according to the guidelines laid down in the Declaration of Helsinki. The KNHANES data collection procedure was approved by the Institutional Review Board of the Korea Centers for Diseases Control and Prevention (IRB No. 2018-01-03-P-A), and written informed consent was obtained from all participants. Ethical review and approval were waived for the secondary analyses of the KNHANES data by the Institutional Review Board of the Seoul Women's University (SWU IRB-2023A-02).

Dietary intake measures

Dietary intake data were collected by an in-person 24-h dietary recall by trained staff. Daily intakes of individual foods and nutrients and total energy were calculated using the KNHANES recipe and food composition databases.

We used a culinary definition of nuts including both tree nuts (hazelnuts, acorns, macadamia nuts, chestnuts, Brazil nuts, almonds, gingko nuts, pine nuts, cashew nuts, pecans, walnuts and pistachio nuts) and peanuts. Although peanuts are botanically categorised as legume, their nutrient profiles and culinary use are similar to tree nuts[20–24]. To assess if peanuts have distinct effects on muscle strength, we also reported the association of peanut consumption with low muscle strength separately. In addition, to examine whether nuts particularly rich in MUFA or PUFA (all but chestnut and gingko nut) exert distinguishable effects on muscle strength, we analysed the association of MUFA or PUFA rich nut consumption with low muscle health. Participants were categorised as participants into consumers and non-consumers.

Handgrip strength measures

Handgrip strength was measured in an upright position with the elbow fully extended using the Digital Grip Strength Dynamometer (T.K.K.5401). We used the maximum value of three trials of the dominant hand, expressed in kg. Participants self-determined their eligibility based on a priori criteria (e.g. no acute injury or operation and no amputation or paralysis) from 2016. Low muscle strength was defined as hand grip strength <28 kg for men and <18 kg for women based on the Asian Working Group for Sarcopenia 2019 consensus[2].

Covariate measures

Information on demographic and socio-economic factors, lifestyle factors and medical history was collected during an in-person health interview using a structured questionnaire. Household income was categorised into quartiles: low (Q1), middle-low (Q2), middle-high (Q3) and high (Q4). Current alcohol consumer was defined as those who drank more than once a month during the year before the interview. Current smoker was defined as those who smoked >100 cigarettes in their lifetime and were still smoking. Regular resistance exercise was defined as performing strength exercise (e.g. push-ups, sit-ups, deadlifts and chin-ups) more than twice a week. Medical history was operationalised as any history of type 2 diabetes, stroke, arthritis, osteoporosis, cancer, kidney disease, myocardial infarction or angina, which may affect dietary intake and muscle health.

Body weight and height were measured during the health examination. BMI was calculated as weight in kg divided by the square of height in metre.

Statistical analyses

All statistical analyses were conducted using the SAS software (Version 9.4, SAS Institute) adjusting for survey design effects. A two-sided *P*-value < 0·05 was considered statistically significant with the exact *P*-values presented to enhance interpretation.

General characteristics were described by nut consumption using the means or percentages ± standard errors. Differences in general characteristics between nut consumers and non-consumers were determined using the Rao–Scott χ^2 tests for categorical variables and *t*-tests for continuous variables. The associations between nut consumption and low muscle strength were analysed using multivariate logistic regression models with the non-consumer group set as the reference group. Unadjusted model estimated crude OR and 95 % CI. Model 1 was adjusted for age, BMI and total energy intake. Model 2 was additionally adjusted for household income, current alcohol consumption, current smoking, regular resistant exercise and medical history. Model 3 added protein intake, an established preventive factor for low muscle mass[25].

Results

One in four (24·5 %) Korean adults were consuming nuts: 16·8 % in younger men 19–39 years, 19·8 % in younger women 19–39 years, 26·6 % in middle-aged men 40–64 years, 31·4 % in middle-aged women 40–64 years, 26·2 % in older men ≥65 years and 23·3 % in older women ≥65 years (Fig. 1). The most frequently consumed type was peanut.

General characteristics of nut consumers and non-consumers are presented by sex and age in online Supplementary Table 1–3. Among younger men and women 19–39 years, nut consumers were older, were more likely to have a higher household income and had a higher protein intake. Among younger men, nut consumers were less likely to be current smokers and had a lower BMI. Among younger women, nut consumers were less likely to be current alcohol consumers and more likely to do regular resistance exercise. No differences in maximal handgrip strength were observed between consumers and non-consumers. Daily mean intakes of nuts among

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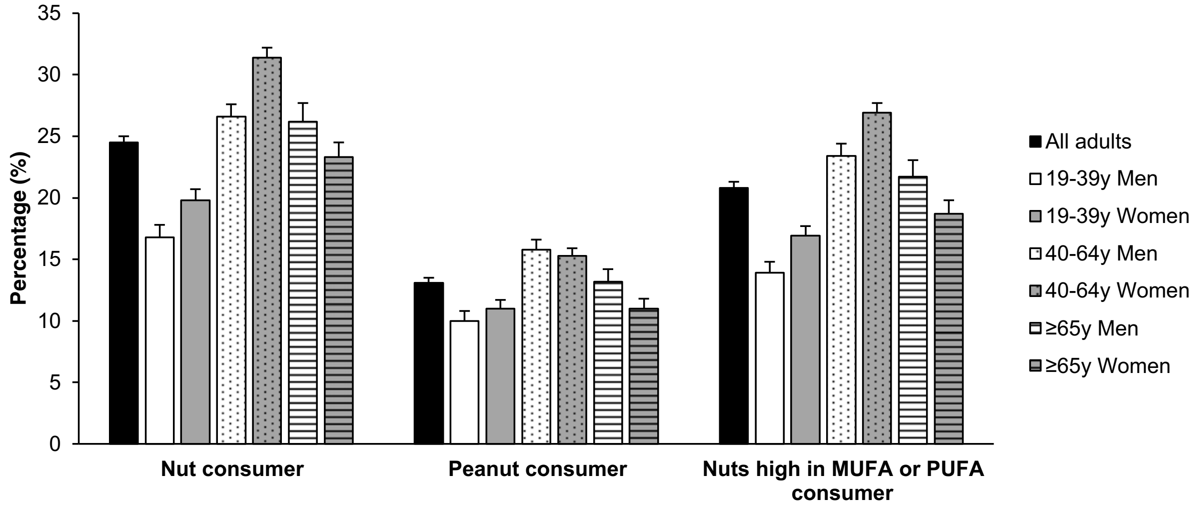

Fig. 1. Proportion of nut consumers by age and sex. Nut includes tree nuts (hazelnuts, acorns, macadamia nuts, chestnuts, Brazil nuts, almonds, gingko nuts, pine nuts, cashew nuts, pecans, walnuts and pistachio nuts) and peanuts. Nuts high in MUFA or PUFA include all but chestnuts and gingko nuts.

consumers were 8·7 and 9·5 g for younger men and women, respectively (online Supplementary Table 1).

Among middle-aged men and women 40–64 years, nut consumers were older, were more likely to have a higher household income and do regular resistance exercise, less likely to be current smokers and had higher intakes of energy and protein. Among middle-aged women, nut consumers less likely to be current alcohol consumers and had a lower BMI. No statistical differences in maximal handgrip strength were noted between consumers and non-consumers. Daily mean intakes of nuts among consumers were 14·6 and 14·4 g for middle-aged men and women, respectively (online Supplementary Table 2).

Among older men and women ≥65 years, nut consumers were younger, were more likely to have a higher household income, do regular resistance exercise, had higher intakes of total energy and protein and had a higher maximal handgrip strength. No significant differences were observed for current alcohol consumption, medical history (any history of type 2 diabetes, stroke, arthritis, osteoporosis, cancer, kidney disease, myocardial infarction or angina) or BMI (both men and women) or current smoking (women). Nut consumers were less likely be currently smoking than non-consumers only among older men. Daily mean intakes of nuts among consumers were 16·8 and 20·1 g for older men and women, respectively (online Supplementary Table 3).

The associations between nut consumption and low muscle strength differed by age (Table 1). Among younger or middle-aged men and women, there was no significant association between nut consumption and low muscle strength. However, among older men and women, nut consumption was associated with a substantially lower risk of low muscle strength. In the multivariate model 3 that included a range of demographic, socio-economic, lifestyle and dietary factors, older male nut consumers had 45 % reduced risk (OR 0·55; 95 % CI (0·38, 0·79)) and older female nut consumers had 31 % reduced risk (OR 0·69; 95 % CI (0·51, 0·93)) compared with non-consumers. Similar patterns were observed for peanuts alone (Table 2) and for nuts high in MUFA or PUFA (all but chestnut and gingko nut) (Table 3) with the exception that the higher consumption of nuts high in MUFA or PUFA was associated with the higher risk of low muscle strength among younger women 19–39 years.

Discussion

Nuts are known as a healthy food group for cardiometabolic health[15], but it is not clear if the beneficial effect of nuts extends to muscle health despite close relationship between metabolic health and muscle health[26]. Therefore, this study investigated the cross-sectional association between nut consumption and low muscle strength among Korean adults by sex and age.

Our analysis of the KNHANES VII (2016–2018) data found that one in four Korean adults were consuming nuts with less than 20 % of younger adults consuming nuts. Among nut consumers, the daily mean intake amounts of nuts among consumers increased by age, but the average nut intakes ranged from 8·7 g (younger men 19–39 years) to 20·1 g (older women ≥65 years). Although the amount of nut consumption is far below than the recommended amounts from multiple dietary guidelines (approximately 30 g/d)[27,28], older men and women ≥65 years who consumed nuts had substantially lower risks of low muscle strength, after adjusting for confounding factors, compared with those who did not consume nuts. Null or rather disadvantageous associations of nut consumption with low muscle strength among younger adults observed in this study call for further studies using longitudinal data to examine how those associations change across life course or future studies using different cut-offs for low muscle strength because the current cut-offs were derived from older adult data[2].

Our findings about beneficial effects of nuts on low muscle strength among older adults were consistent with the findings from a prospective study in Spain on a dose–response association of nut consumption with a lower risk of impaired agility and mobility in men and a lower risk of impaired overall physical function in women[29]. Other studies that examined nuts

Table 1. Association between nut consumption and low muscle strength by age and sex (Numbers; odds ratios and 95 % confidence intervals)

	Unadjusted			Model 1*			Model 2†			Model 3‡		
Nut consumption	*n*§	OR	95 % CI	*n*	OR	95 % CI	*n*	OR	95 % CI	*n*	OR	95 % CI
19–39 years												
Men												
Non-consumer	1340	1	Ref	1336	1	Ref	1330	1	Ref	1330	1	Ref
Consumer	280	1·07	0·40, 2·85	279	1·17	0·44, 3·11	278	1·30	0·46, 3·67	278	1·42	0·50, 4·03
Women												
Non-consumer	1865	1	Ref	1863	1	Ref	1847	1	Ref	1847	1	Ref
Consumer	477	1·34	0·88, 2·04	477	1·45	0·94, 2·24	476	1·53	0·99, 2·37	476	1·55	0·99, 2·40
40–64 years												
Men												
Non-consumer	2065	1	Ref	2065	1	Ref	2043	1	Ref	2043	1	Ref
Consumer	734	1·09	0·61, 1·94	732	1·13	0·63, 2·04	730	1·48	0·76, 2·88	730	1·48	0·75, 2·89
Women												
Non-consumer	2856	1	Ref	2855	1	Ref	2838	1	Ref	2838	1	Ref
Consumer	1266	0·80	0·58, 1·09	1265	0·79	0·57, 1·09	1253	0·83	0·60, 1·15	1253	0·84	0·60, 1·17
≥65 years												
Men												
Non-consumer	1321	1	Ref	1312	1	Ref	1284	1	Ref	1284	1	Ref
Consumer	439	0·41	0·30, 0·56	438	0·54	0·38, 0·75	431	0·56	0·39, 0·80	431	0·55	0·38, 0·79
Women												
Non-consumer	1726	1	Ref	1706	1	Ref	1670	1	Ref	1670	1	Ref
Consumer	475	0·48	0·37, 0·64	473	0·64	0·48, 0·85	467	0·66	0·49, 0·89	467	0·69	0·51, 0·93

* Model 1: adjusted for age, BMI and total energy intake.
† Model 2: adjusted for all covariates included in model 1 plus household income, alcohol consumption, smoking, resistance exercise and medical history.
‡ Model 3: adjusted for all covariates included in model 2 plus protein intake.
§ Unweighted *n*.
Nut includes tree nuts (hazelnuts, acorns, macadamia nuts, chestnuts, Brazil nuts, almonds, gingko nuts, pine nuts, cashew nuts, pecans, walnuts and pistachio nuts) and peanuts.

Table 2. Association between peanut consumption and low muscle strength by age and sex (Numbers; odds ratios and 95 % confidence intervals)

	Unadjusted			Model 1*			Model 2†			Model 3‡		
Nut consumption	*n*§	OR	95 % CI	*n*	OR	95 % CI	*n*	OR	95 % CI	*n*	OR	95 % CI
19–39 years												
Men												
Non-consumer	1449	1	Ref	1444	1	Ref	1437	1	Ref	1437	1	Ref
Consumer	171	1·34	0·50, 3·59	171	0·83	0·19, 3·66	171	0·76	0·16, 3·52	171	0·82	0·17, 3·88
Women												
Non-consumer	2081	1	Ref	2079	1	Ref	2062	1	Ref	2062	1	Ref
Consumer	261	1·45	0·94, 2·25	261	1·41	0·84, 2·38	261	1·46	0·87, 2·46	261	1·47	0·87, 2·48
40–64 years												
Men												
Non-consumer	2374	1	Ref	2372	1	Ref	2349	1	Ref	2349	1	Ref
Consumer	425	1·06	0·58, 1·94	425	1·06	0·48, 2·34	424	1·41	0·62, 3·23	424	1·41	0·62, 3·22
Women												
Non-consumer	3483	1	Ref	3482	1	Ref	3457	1	Ref	3457	1	Ref
Consumer	639	0·74	0·53, 1·03	638	0·89	0·58, 1·37	634	0·92	0·60, 1·42	634	0·93	0·60, 1·44
≥65 years												
Men												
Non-consumer	1540	1	Ref	1531	1	Ref	1500	1	Ref	1500	1	Ref
Consumer	220	0·40	0·28, 0·56	219	0·54	0·37, 0·80	215	0·60	0·40, 0·91	215	0·60	0·40, 0·91
Women												
Non-consumer	1977	1	Ref	1957	1	Ref	1919	1	Ref	1919	1	Ref
Consumer	224	0·42	0·31, 0·57	222	0·57	0·39, 0·84	218	0·60	0·40, 0·88	218	0·62	0·42, 0·92

* Model 1: adjusted for age, BMI and total energy intake.
† Model 2: adjusted for all covariates included in model 1 plus household income, alcohol consumption, smoking, resistance exercise and medical history.
‡ Model 3: adjusted for all covariates included in model 2 plus protein intake.
§ Unweighted *n*.

as a component of dietary quality indices also suggested that nuts within a diet are associated with a reduced risk of falling[30] and lower odds of sarcopenia[31] and low gait speed[32], although it is difficult to disentangle the effect of nuts from those of other food components.

To rule out the possibility that the observed beneficial associations between nuts and low muscle strength are driven by protein intake, a well-established preventive dietary factor for low muscle strength[25], we included total protein intake variable in the multivariate logistic regression model (i.e., model 3). The

Table 3. Association between nuts high in MUFA or PUFA consumption and low muscle strength by age and sex (Numbers; odds ratios and 95 % confidence intervals)

	Unadjusted			Model 1*			Model 2†			Model 3‡		
Nut consumption	*n*§	OR	95 % CI	*n*	OR	95 % CI	*n*	OR	95 % CI	*n*	OR	95 % CI
19–39 years												
Men												
Non-consumer	1385	1	Ref	1381	1	Ref	1375	1	Ref	1375	1	Ref
Consumer	235	1·34	0·50, 3·59	234	1·51	0·57, 3·98	233	1·52	0·54, 4·28	233	1·66	0·58, 4·73
Women												
Non-consumer	1937	1	Ref	1935	1	Ref	1918	1	Ref	1918	1	Ref
Consumer	405	1·45	0·94, 2·25	405	1·54	0·99, 2·41	405	1·64	1·04, 2·57	405	1·65	1·05, 2·60
40–64 years												
Men												
Non-consumer	2158	1	Ref	2157	1	Ref	2134	1	Ref	2134	1	Ref
Consumer	641	1·06	0·58, 1·94	640	1·10	0·59, 2·06	639	1·47	0·72, 3·01	639	1·47	0·72, 3·01
Women												
Non-consumer	3033	1	Ref	3032	1	Ref	3010	1	Ref	3010	1	Ref
Consumer	1089	0·74	0·53, 1·03	1088	0·74	0·52, 1·03	1081	0·76	0·54, 1·08	1081	0·77	0·55, 1·09
≥65 years												
Men												
Non-consumer	1399	1	Ref	1390	1	Ref	1361	1	Ref	1361	1	Ref
Consumer	361	0·40	0·28, 0·56	360	0·54	0·37, 0·79	354	0·61	0·41, 0·90	354	0·61	0·41, 0·89
Women												
Non-consumer	1821	1	Ref	1801	1	Ref	1764	1	Ref	1764	1	Ref
Consumer	380	0·42	0·31, 0·56	378	0·56	0·41, 0·76	373	0·58	0·42, 0·78	373	0·60	0·43, 0·81

* Model 1: adjusted for age, BMI and total energy intake.
† Model 2: adjusted for all covariates included in model 1 plus household income, alcohol consumption, smoking, resistance exercise and medical history.
‡ Model 3: adjusted for all covariates included in model 2 plus protein intake.
§ Unweighted *n*.
Nuts high in MUFA or PUFA include all but chestnuts and gingko nuts.

adjustment for protein intake led to considerable attenuation in older women as expected, but not in men, and the associations between nuts and low muscle strength were still significant in both older women and men. These results suggest that nut consumption has unique benefits beyond total protein intake, which may be partially attributable to protein quality, dietary fibre, MUFA and PUFA, minerals and phytochemicals contributed by nuts[16].

In particular, nuts are very good sources of MUFA and PUFA, contributing about 16 % of MUFA and 17 % of PUFA but only 8 % of SFA among nut-consuming older adults. Higher intakes of MUFA and PUFA were associated with a lower risk of muscle weakness operationalised as lowest quintile of handgrip strength, whereas higher intake of SFA intake was associated with an increased risk of lower-extremity functional impairment among older adults[33]. Several fish oil or n-3 supplementation trials supported beneficial effect of PUFA on muscle mass and function among older adults[34–36]. MUFA is known to improve metabolic fitness[37,38] by increasing fatty acid oxidation and decreasing inflammation in both skeletal muscle and adipose tissue[39–41]. The high ratio of MUFA or PUFA to SFA in nuts might help to prevent sarcopenia partially through anti-inflammatory pathways considering that the decline of muscle strength and function can be caused by adipose inflammation[42] and through stimulation of anabolic signalling in myocytes[43].

The major strengths of this study include the use of a large nationally representative data collected using validated methods, but several limitations should be considered when interpreting the results. First, there remains a possibility of residual confounding and reverse causation coming from the cross-sectional nature of the KNHANES. Second, the KNHANES VII did not include measurements of muscle mass and physical performance, so we could not formally diagnose sarcopenia. However, handgrip strength is a practical indicator of whole muscle strength and physical function[44], and we were able to define low muscle strength based on handgrip strength cut-offs recommended by the Asian Working Group for Sarcopenia 2019 consensus[2]. Nonetheless, the applicability of these cut-offs derived from older adult data is yet to be confirmed. Indeed, the prevalence of low muscle strength was less than 3 % among younger and middle-aged men and less than 10 % among younger and middle-aged women, which may be one of the reasons for null associations among younger and middle-aged adults. Lastly, nut intake measured via single 24-h recall may not fully reflect usual nut intake.

In summary, this study observed an inverse association between nut consumption and low muscle strength among Korean older adults. Our findings suggest that consuming nuts may be beneficial in lowering the risk of low muscle strength among older adults, although longitudinal and intervention studies are warranted to confirm the true effect of nuts on muscle strength as well as to reveal underlying biological mechanisms.

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Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114523002386

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