19. Nurminen J, Puustinen J, Piirtola M, Vahlberg T, Kivelä S-L. Psychotropic drugs and the risk of fractures in old age: a prospective population-based study. BMC Public Health 2010; 10: 396.
20. Ray WA. Psychotropic drugs and injuries among the elderly: a review. J Clin Psychopharmacol 1992; 12: 386–96.
21. Diem SJ, Blackwell TL, Stone KL *et al*. Use of antidepressants and rates of hip bone loss in older women: the study of osteoporotic fractures. Arch Intern Med 2007; 167: 1240–5.
22. Bhangu J, King-Kallimanis B, Cunningham C, Kenny RA. Prevalence of syncope in older adults with depression: a population based study. Age Ageing 2013; 42(Suppl. 2): ii20–2.
23. Pacher P, Ungvari Z. Selective serotonin-reuptake inhibitor antidepressants increase the risk of falls and hip fractures in elderly people by inhibiting cardiovascular ion channels. Med Hypotheses 2001; 57: 469–71.
24. French DDD, Chirikos TN, Spehar A, Campbell R, Means H, Bulat T. Effect of concomitant use of benzodiazepines and other drugs on the risk of injury in a Veterans population. Drug Saf 2005; 28: 1141–50.
25. Zint K, Haefeli WE, Glynn RJ, Mogun H, Avorn J, Stürmer T. Impact of drug interactions, dosage, and duration of therapy on the risk of hip fracture associated with benzodiazepine use in older adults. Pharmacoepidemiol Drug Saf 2010; 19: 1248–55.
26. Schneeweiss S, Maclure M. Use of comorbidity scores for control of confounding in studies using administrative databases. Int J Epidemiol 2000; 29: 891–8.
27. Richardson K, Kenny RA, Peklar J, Bennett K. Agreement between patient interview data on prescription medication use and pharmacy records in the over 50s varied by therapeutic group and reporting of indicated health condition. J Clin Epidemiol 2013; 66: 1308–16.
28. Ganz DA, Higashi T, Rubenstein LZ. Monitoring falls in cohort studies of community-dwelling older people: effect of the recall interval. J Am Geriatr Soc 2005; 53: 2190–4.
29. Chu LW, Chi I, Chiu AYY. Incidence and predictors of falls in the Chinese elderly. Ann Acad Med Singapore 2005; 34: 60–72.
30. Van der Velde N, Stricker BHC, Pols HAP, van der Cammen TJM. Withdrawal of fall-risk-increasing drugs in older persons: effect on mobility test outcomes. Drugs Aging 2007; 24: 691–9.

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Association of vegetables and fruits consumption with sarcopenia in older adults: the Fourth Korea National Health and Nutrition Examination Survey

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Abstract

Background: several studies have found nutrients, including antioxidants, to be associated with sarcopenia. However, whether specific foods, such as vegetables and fruits, are associated with sarcopenia has not been studied.
Objective: to examine the association of the frequency of vegetables and fruits consumption with sarcopenia in older people.
Methods: this study used cross-sectional data from the Fourth Korea National Health and Nutrition Examination Survey in 2008–09. Subjects were community-dwelling 823 men and 1,089 women aged ≥65 years. Frequency of food group

consumption was obtained by using the food frequency questionnaire. Body composition was measured with the dual-energy X-ray absorptiometry and sarcopenia was defined as appendicular lean mass adjusted for height and fat mass. Logistic regression was used to assess the association of the frequency of food group consumption with sarcopenia, controlling for sociodemographics and health-related variables.

Results: dietary intake of vegetables, fruits and both vegetables and fruits was associated with a significantly reduced risk of sarcopenia after controlling for covariates in men ($P = 0.026$ for trend, $P = 0.012$ for trend, $P = 0.003$ for trend, respectively). Men in the highest quintile, compared with those in the lowest quintile, of vegetables [odds ratio (OR) = 0.48; 95% confidence interval (CI): 0.24–0.95], fruits (OR = 0.30; 95% CI: 0.13–0.70) and vegetables and fruits consumption (OR = 0.32; 95% CI: 0.16–0.67) demonstrated a lower risk of sarcopenia. In women, high consumption of fruits demonstrated a lower risk of sarcopenia (OR = 0.39; 95% CI: 0.18–0.83).

Conclusion: frequent vegetables and fruits consumption was inversely associated with sarcopenia in older adults.

Keywords: *vegetables, fruits, sarcopenia, diet, aged, older people*

Introduction

Sarcopenia is characterised by the age-related loss of muscle mass and function [1] and is associated with frailty, impaired physical performance, greater risk of falls and functional disability in older adults [2]. With the rapid ageing of the world's population, sarcopenia is increasingly recognised as a major health problem.

A literature review identified diet as one important contributing factor in the complex aetiology of sarcopenia [3]. Various nutrients such as protein, vitamin D and antioxidants have been examined for their association with sarcopenia [4–11]. Among them antioxidants have been considered as possible mediators of sarcopenia against oxidative stress on skeletal muscle [12]. Reduced muscle strength has been found to be associated with low plasma levels of vitamin E and carotenoids [9, 10] and low dietary intakes of vitamin C and β-carotene [9]. Antioxidants are found in plenty of foods, mainly in vegetables and fruits [13]. However, there is a paucity of studies that have investigated the association of vegetables and fruits consumption with sarcopenia. In the Hertfordshire cohort study, a positive relationship between fruit, fruit and vegetables consumption and muscle function was reported in older men and women [14].

There have been no reported studies on the relationship between vegetables and fruits consumption and sarcopenia in a nationally representative sample of older people. The objective of this study was to examine the association of the frequency of vegetables and fruits consumption with sarcopenia in older Korean adults living in the community.

Methods

Study population

Data are from the cross-sectional survey of the second and third year (2008–09) of the Fourth Korea National Health and Nutrition Examination Survey (KNHANES IV), conducted by the Korea Centers for Disease Control and Prevention (KCDC). Detailed information of the survey design is provided elsewhere [15] (Supplementary data are available in *Age and Ageing* online, Appendix Table S1). KNHANES IV employs a multistage stratified cluster sampling for the selection of household units among non-institutionalised residents in the Republic of Korea. The protocols for the KNHANES IV were approved by the Institutional Review Board of the KCDC. Prior to the survey, all participants signed the informed consent forms.

KNHANES IV is composed of three surveys: the Health Interview Survey, Nutrition Survey and Health Examination Survey. Among the participants, 2,328 (946 men and 1,382 women) aged ≥65 years participated in three surveys. We excluded those with missing values on food group consumption (41 men and 73 women), appendicular skeletal muscle (53 men and 125 women), height and fat mass (2 men and 2 women), education level (8 men and 9 women), smoking (2 men and 4 women), alcohol drinking (1 woman), physical activity (1 man and 2 women), supplementary nutrient intake (16 men and 19 women), age at menarche (53 women), oral contraceptive use (1 woman) and hormone use (4 women). The final sample for the analysis comprises 1,912 (823 men and 1,089 women).

Dietary assessment

An interviewer-administered, food frequency questionnaire (FFQ) was used to assess the usual dietary intake over the preceding year. The FFQ consisted of 63 items composed from the 24 h recall of food sources for energy and major nutrients, the most frequently consumed foods, and seasonal food intake [16]. The FFQ consisted of 63 items of which 62 were derived from the 2001 KNHANES on information about the most frequently consumed foods stratified by gender and age, and from the 2002 Seasonal Nutrition Survey on seasonal food intake. Additionally, one item on fried food consumption frequency was included, based on the Dietary Behaviours Survey [17]. Responses to the frequency of intake consisted of 10 categories ranging from rarely to three times a day.

Six foods from the FFQ [beer, soju (Korean distilled spirits), makgeolli (raw rice wine), hamburger, pizza and fried food] that showed low frequency of intake, defined as

consuming less than once per month were excluded. Food groups consisted of 12 vegetables (Chinese cabbage, radish, dried radish leaves, bean sprout, spinach, cucumber, hot pepper, carrots, pumpkin, cabbage, tomato and mushrooms), 11 fruits (mandarin, persimmon and dried persimmon, pears, watermelon, oriental melon, strawberries, grapes, peaches, apples, banana and orange), cereals, legumes/potatoes and starches, meats/eggs, fish, seaweeds, milk and milk products and beverages (Supplementary data are available in *Age and Ageing* online, Appendix Table S2). Frequency of food group consumption was summed for each food based on daily consumption and divided into quintiles by gender.

Definition of sarcopenia

To measure the body composition of the participants, dual-energy X-ray absorptiometry (Discovery-W, Hologic, Inc., MA, USA) was used. Appendicular lean mass (aLM) was defined as the sum of lean mass in arms and legs.

Participants were classified as sarcopenia, according to the definition proposed by Newman *et al.* [18]. Relative lean mass was calculated as height and fat mass-adjusted lean mass. The association between aLM on height (m) and fat mass (kg) separately by gender was modelled using linear regression. Sarcopenia was defined as the lowest quintile of the residuals.

Covariates

Sociodemographics included age (65–74, ≥75 years), education (elementary school or lower versus more than elementary school), Health status included physician-diagnosed chronic conditions (hypertension, hyperlipidaemia, stroke, myocardial infarction or angina, arthritis, asthma, chronic obstructive pulmonary disease, diabetes mellitus, cancer, depression and renal failure) and body mass index (BMI). BMI was derived by dividing measured weight (kg) by height squared (m^2). Health behaviours included self-reported smoking (none, past or current), alcohol drinking and physical activity. Drinking of alcoholic beverages was classified as none, moderate and heavy (>7 drinks/week or >3 drinks/day) [19]. Physical activity was categorised as sedentary, low (below the recommended level) and recommended (≥150 min/week of moderate-intensity and/or ≥75 min/week of vigorous-intensity aerobic physical activity) [20]. Supplementary nutrient intake was defined as any intake in the past year of vitamins and minerals for >2 weeks. For women, age at menarche (<14, 14–16, ≥17 years), oral contraceptive use and hormone use were recorded.

Statistical analysis

The characteristics of the participants were presented as percentages and medians. To analyse differences among the quintiles of vegetables, fruits and vegetables and fruits consumption group χ^2 tests were employed. Logistic regression was used to derive odds ratios (OR) with 95% confidence intervals (CI) of sarcopenia, with the reference category being the lowest quintile of the frequency of vegetables, fruits and a combined vegetables and fruits consumption, after adjustment for all covariates and other food group consumption. For tests of linear trend across the frequency of vegetables, fruits and vegetables and fruits consumption, we used the median value in each category as a continuous variable in the logistic regression model. Significance was defined as two-sided *P*-value of <0.05. All analyses were performed separately by gender. The IBM SPSS Statistics 19.0 (2010, International Business Machines Corp., Armonk, NY, USA) was used for statistical tests. Because of the complex sampling design sampling weights were applied in analysing and comparing the sample characteristics.

Results

Women were older than men, with a higher percentage aged 75 years and older among women (35.4%) than men (28.9%). More men than women were educated (49.2 versus 13.7%). The percentage of those with chronic conditions diagnosed by a physician was higher in women (79.1%) than men (67.8%). Supplementary nutrient intake was higher in women (21.8%) than in men (15.2%). In women, 93.4% reported age at menarche of ≥14 years, with 19.5% reporting oral contraceptive use and 6.7%, hormone use. Men tended to consume vegetables (4.5 times/day) and a combination of vegetables and fruits (5.2 times/day) more frequently than did women (4.0 and 4.7 times/day, respectively) (Supplementary data are available in *Age and Ageing* online, Appendix Table S3).

According to quintiles of vegetables consumption, there were significant associations with population characteristics (Table 1). In men, compared with the low vegetables consumption group, the high vegetables consumption group had higher levels of education, physical activity and consumption of other food groups. In women, high vegetables consumption was significantly associated with being younger, higher education, lower percentage of smoking, lower age at menarche, higher oral contraceptive use and hormone use and consumption of higher levels of other food groups.

According to quintiles of fruits consumption, compared with the low fruits consumption group, the high fruits consumption group was younger, had higher education and consumed higher levels of other food groups for both genders (Table 2). In addition, higher BMI in men and lower percentage of alcohol drinking, higher supplementary nutrient intake, lower age at menarche, higher oral contraceptive use and hormone use in women were significantly associated with a high frequency of fruits consumption.

Frequency of vegetables and fruits consumption was significantly associated with education, physical activity, supplementary nutrient intake and consumption of other food groups in men. In women, age, education, smoking, age at menarche, oral contraceptive use, hormone use and consumption of other food groups were found to be significant (Supplementary data are available in *Age and Ageing* online, Appendix Table S4).

Table 1. Characteristics according to quintiles (Q) of vegetables consumption

	Men (n = 823)				Women (n = 1,089)			
	Q1	Q3	Q5	*P*-value*	Q1	Q3	Q5	*P*-value*
Age (≥75 years)	33.1	28.0	23.6	0.368	45.6	33.5	29.2	0.011
>Elementary school	37.1	51.6	55.4	0.012	9.5	16.0	22.6	0.003
Number of chronic conditions (≥3)	7.7	9.6	6.5	0.289	22.4	19.1	18.4	0.340
Body mass index (kg/m^2) (≥25.0)	23.6	25.0	19.8	0.308	40.9	39.3	39.6	0.356
Current smoker	31.6	21.3	21.8	0.239	5.9	4.4	5.4	0.006
Heavy drinker[a]	43.7	37.5	41.9	0.185	6.8	7.5	6.9	0.938
Recommended level[b]	24.7	39.0	31.3	0.008	28.2	25.2	31.8	0.424
Supplementary nutrient intake (yes)	11.9	16.4	16.5	0.141	21.3	20.1	26.2	0.734
Age at menarche (≥17 years)				NR	42.9	45.8	35.8	<0.001
Oral contraceptive use (yes)				NR	15.5	19.5	22.7	<0.001
Hormone use (yes)				NR	5.7	3.4	14.2	<0.001
Highest quintiles of food group consumption								
Cereals	15.1	20.5	28.0	0.001	10.2	19.7	34.1	<0.001
Legumes/potatoes and starches	13.3	20.9	35.2	<0.001	10.2	17.8	40.2	<0.001
Meats/eggs	17.5	16.2	34.3	<0.001	8.3	19.0	40.4	<0.001
Fish	9.8	17.3	37.5	<0.001	8.5	13.9	43.8	<0.001
Seaweeds	8.9	19.1	34.9	<0.001	6.4	17.2	41.3	<0.001
Fruits	7.0	20.5	36.7	<0.001	7.7	15.3	46.5	<0.001
Milk and milk products	16.3	15.5	25.8	0.107	16.4	16.1	32.3	0.006
Beverages	13.6	17.9	30.8	0.021	13.9	23.9	30.0	0.064

Values are percentage.
NR, not relevant.
*P value from χ^2 test.
[a]>7 drinks/week or >3 drinks/day [19].
[b]≥150 min/week of moderate-intensity and/or ≥75 min/week of vigorous-intensity aerobic physical activity [20].

Table 2. Characteristics according to quintiles (Q) of fruits consumption

	Men (n = 823)				Women (n = 1,089)			
	Q1	Q3	Q5	*P*-value*	Q1	Q3	Q5	*P*-value*
Age (≥75 years)	39.8	31.4	19.1	0.007	45.8	40.4	23.6	0.002
>Elementary school	27.6	48.7	66.3	<0.001	0.7	17.0	27.8	<0.001
Number of chronic conditions (≥3)	7.6	12.5	9.5	0.255	21.3	16.5	27.7	0.584
Body mass index (kg/m^2) (≥25.0)	15.4	29.8	31.0	0.016	34.8	39.8	46.2	0.326
Current smoker	38.6	25.7	19.5	0.068	8.1	5.0	3.5	0.081
Heavy drinker[a]	38.2	47.4	35.5	0.402	8.1	6.6	4.8	0.001
Recommended level[b]	25.0	40.4	32.7	0.064	23.6	24.6	29.2	0.673
Supplementary nutrient intake (yes)	11.6	14.1	19.5	0.522	11.1	27.6	33.7	<0.001
Age at menarche (≥17 years)				NR	54.1	39.9	37.5	<0.001
Oral contraceptive use (yes)				NR	15.7	21.0	22.5	<0.001
Hormone use (yes)				NR	2.8	5.3	14.7	<0.001
Highest quintiles of food group consumption								
Cereals	13.2	16.2	28.0	<0.001	8.9	18.2	32.6	<0.001
Legumes/potatoes and starches	9.2	11.9	32.6	<0.001	9.0	16.7	40.2	<0.001
Meats/eggs	10.3	20.3	35.4	<0.001	5.6	21.1	42.9	<0.001
Fish	9.3	17.1	40.5	<0.001	3.4	16.8	39.0	<0.001
Vegetables	10.2	14.0	37.1	<0.001	4.9	15.5	47.7	<0.001
Seaweeds	7.9	17.7	36.0	<0.001	5.5	15.1	45.1	<0.001
Milk and milk products	11.8	21.8	34.4	<0.001	9.0	15.0	39.4	<0.001
Beverages	17.0	20.0	26.3	0.010	13.4	21.8	22.6	0.058

Values are percentage.
NR, not relevant.
*P-value from χ^2 test.
[a]>7 drinks/week or >3 drinks/day [19].
[b]≥150 min/week of moderate-intensity and/or ≥75 min/week of vigorous-intensity aerobic physical activity [20].

Table 3. OR and 95% CI of sarcopenia by quintiles (Q) of vegetables, fruits and vegetables and fruits consumption in logistic regression analysis

	Men (n = 823)					
	Q1	Q2	Q3	Q4	Q5	P for trend
Vegetables						
Median (times/day)	2.2	3.7	4.5	5.3	6.6	
Crude OR	1.00	0.61 (0.33–1.14)	0.53 (0.29–0.99)	0.44 (0.24–0.78)	0.41 (0.21–0.80)	0.002
Adjusted OR[a]	1.00	0.61 (0.32–1.19)	0.57 (0.28–1.16)	0.58 (0.30–1.11)	0.48 (0.24–0.95)	0.026
Fruits						
Median (times/day)	0.2	0.4	0.7	1.1	1.9	
Crude OR	1.00	0.60 (0.36–1.00)	0.50 (0.29–0.86)	0.48 (0.25–0.90)	0.28 (0.15–0.53)	<0.001
Adjusted OR[a]	1.00	0.61 (0.31–1.23)	0.50 (0.23–1.11)	0.55 (0.25–1.23)	0.30 (0.13–0.70)	0.012
Vegetables and fruits						
Median (times/day)	2.8	4.3	5.2	6.3	7.9	
Crude OR	1.00	0.47 (0.25–0.89)	0.49 (0.25–0.97)	0.37 (0.21–0.66)	0.32 (0.17–0.62)	<0.001
Adjusted OR[a]	1.00	0.44 (0.22–0.88)	0.53 (0.26–1.07)	0.41 (0.21–0.77)	0.32 (0.16–0.67)	0.003
	Women (n = 1,089)					
	Q1	Q2	Q3	Q4	Q5	P for trend
Vegetables						
Median (times/day)	1.3	3.2	4.0	4.9	6.4	
Crude OR	1.00	1.68 (0.97–2.91)	1.00 (0.57–1.76)	0.73 (0.39–1.34)	0.82 (0.47–1.43)	0.125
Adjusted OR[b]	1.00	1.87 (1.05–3.32)	1.07 (0.57–2.01)	0.74 (0.38–1.44)	0.98 (0.48–2.01)	0.560
Fruits						
Median (times/day)	0.1	0.3	0.6	1.1	1.9	
Crude OR	1.00	0.63 (0.35–1.11)	0.80 (0.46–1.41)	0.77 (0.44–1.33)	0.47 (0.26–0.86)	0.030
Adjusted OR[b]	1.00	0.67 (0.35–1.28)	0.77 (0.40–1.52)	0.78 (0.39–1.56)	0.39 (0.18–0.83)	0.023
Vegetables and fruits						
Median (times/day)	1.8	3.7	4.7	5.8	7.9	
Crude OR	1.00	1.45 (0.85–2.48)	1.08 (0.62–1.88)	0.57 (0.31–1.03)	0.88 (0.50–1.55)	0.136
Adjusted OR[b]	1.00	1.45 (0.81–2.60)	0.97 (0.50–1.89)	0.55 (0.28–1.09)	0.80 (0.38–1.66)	0.205

[a]Adjusted for age, education level, number of physician diagnosed chronic conditions, body mass index, smoking, alcohol drinking, physical activity, supplementary nutrient intake and quintiles of other food group consumptions.
[b]Adjusted for age, education level, number of physician diagnosed chronic conditions, body mass index, smoking, alcohol drinking, physical activity, supplementary nutrient intake, age at menarche, oral contraceptive use, hormone use and quintiles of other food group consumptions.

In men, there were significant associations of the frequency of vegetables, fruits and combined vegetables and fruits consumption with sarcopenia (Table 3). Even after adjusting for all covariates, compared with the lowest quintile of vegetables, fruits and vegetables and fruits consumption, the highest quintile of vegetables (OR = 0.48, 95% CI: 0.24–0.95, P = 0.026 for trend), fruits (OR = 0.30, 95% CI: 0.13–0.70, P = 0.012 for trend) and vegetables and fruits (OR = 0.32, 95% CI: 0.16–0.67, P = 0.003 for trend) consumption showed a significantly lower likelihood of sarcopenia.

In women, after adjusting for covariates, compared with the lowest quintile of fruits consumption, the highest quintile of fruits consumption showed an inversely significant association with sarcopenia (OR = 0.39, 95% CI: 0.18–0.83, P = 0.023 for trend). The association of vegetables or vegetables and fruits consumption with sarcopenia was not significant.

Discussion

In this study, dietary vegetables, fruits and combined vegetables and fruits consumption in older men was associated with a significantly reduced risk of sarcopenia, even after adjusting for covariates. A significant linear trend was observed across the quintiles of vegetables, fruits and vegetables and fruits consumption. Compared with men in the lowest quintile of vegetables, fruits and vegetables and fruits consumption, those in the highest quintile of vegetables, fruits and vegetables and fruits consumption had a 52, 70 and 68% lower risk of sarcopenia.

Several studies reported a positive association of muscle strength with carotenoids, vitamin C and vitamin E [9, 10]. Dietary intakes of vitamin C and β-carotene and plasma levels of vitamin E were positively associated with knee extension strength in Italian elderly in the Invecchiare in Chianti study [9]. Also, low plasma carotenoids levels, a marker of poor vegetables and fruits intake, were positively associated with a decline in skeletal muscle strength [10]. The effect of antioxidant supplement on sarcopenia is, however, controversial [11]. There is scant research on the association between food and sarcopenia. In the Hertfordshire cohort study, higher fruit consumption was associated with higher grip strength in older men, and higher consumption of vegetables and fruits was associated with higher grip strength in older women in univariate analyses [14]. In multivariable analyses, vegetable consumption was positively correlated with grip

strength in older women (regression coefficient = 0.03, 95% CI = 0.00–0.06 kg per portion vegetables consumed per week, $P = 0.03$). In our study, the association was more prominent in men than in women. The discrepancy in the findings may be due to differences in the definition of sarcopenia and dietary patterns between the two studies. In the Hertfordshire cohort study, grip strength was measured, while in our study, muscle mass was used in defining sarcopenia. Also, in the Hertfordshire study, women showed higher intakes of fruits and vegetables than those of men, whereas it was the reverse in the current study (data not shown).

It is biologically conceivable that vegetables and fruits consumption may lower the risk of sarcopenia. Vegetables and fruits, the primary source of antioxidants such as carotenoids and vitamin C [13], may decrease the risk of sarcopenia, given the catabolic effects of oxidative stress on skeletal muscle [12]. Dietary carotenoids, such as lutein, lycopene, α-carotene, β-carotene, β-cryptoxanthin and zeaxanthin protect against oxidative stress through their ability to quench singlet oxygen, scavenge free radicals, inhibit lipid peroxidation and modulate redox-sensitive transcription factors involved in the up-regulation of pro-inflammatory cytokines [21, 22]. Ascorbic acid directly protects cell membranes and lipoproteins from reactive oxygen species by interacting with free radicals and singlet oxygen [23–25] and indirectly protects them by regenerating of α-tocopherol from the tocopherol radical [26]. Moreover, ascorbic acid concentrations are inversely correlated with isoprostanes, a marker of lipid peroxidation [27].

Alternatively, high levels of vegetables and fruits consumption may reflect dietary patterns that are conducive to protection against sarcopenia. However, in the current sample of older Korean adults, we did not find significant differences in the consumption pattern of other food groups between those with and without sarcopenia (data not shown). Further study is needed to clarify the association between different dietary patterns and sarcopenia. Given that the contribution of other antioxidant nutrients in the Korean diet did not differ between the two groups, the antioxidant effects of vegetables and fruits may be limited.

In women, consumption of fruits was significantly associated with a lower odds of sarcopenia. As above mentioned, fruits may decrease the risk of sarcopenia, given the catabolic effects of oxidative stress on skeletal muscle [12]. However, consumption of vegetables, and combined vegetables and fruits was not significantly associated with sarcopenia. It is uncertain why there was less prominent relationship between food group consumption and sarcopenia in women. It may be that insufficient control for other unknown or known confounders may have affected the results. Alternatively, in women, diet may play a lesser role on sarcopenia than in men.

The strength of this study is that the sample came from a nationally representative older population, adding credence to the generalisability of the findings. The significance of the results obtained after adjustment for various demographic and health-related variables attest to the robustness of the findings.

Several limitations, however, need to be taken into account in interpreting the results. First, we used the definition of sarcopenia proposed by Newman *et al.* [18], calculated as the lowest quintile of the residual of muscle mass, adjusted for body fat mass and height. Although, there is still no universal operative definition of sarcopenia, recent consensus definition provided by international groups of experts included muscle mass, muscle strength and physical performance as components of sarcopenia [1]. Thus, our results may explain partly the association of vegetables and fruits consumption with sarcopenia in one definition. Second, although the FFQ used in this study was based on frequent food sources of energy and major nutrients, it has not been formally validated. Third, the association between vegetables, fruits and vegetables and fruits consumption and sarcopenia could be due to residual confounding. Men who frequently consumed vegetables, fruits and vegetables and fruits had a healthier lifestyle and consumed other food groups more frequently as well. Adjusting for non-dietary factors and dietary factors to examine the independent effects of vegetables and fruits consumption on sarcopenia, however, did not alter our findings. Finally, any causal inference of the association between food group consumption and sarcopenia is not warranted due to the cross-sectional study design. Longitudinal studies are needed to examine any causal relationships.

In conclusion, this study revealed that frequent vegetables and fruits consumption was inversely associated with sarcopenia in older adults. The findings suggest that in protecting against sarcopenia there may be a potential benefit of a food-based or diet approach that can promote the consumption of healthy nutrients. Health experts may need to consider encouragement of frequent consumption of vegetables and fruits for older adults during nutritional consultation and education. Future prospective and intervention studies may help shed more light on the potential beneficial effects of vegetables and fruits consumption on the prevention of sarcopenia.

Key points

- Frequent fruits consumption was inversely associated with sarcopenia in older adults.
- The association between vegetables consumption and sarcopenia was significant in men but not in women.
- Frequent combined vegetables and fruits consumption was associated with a 68% reduced risk of sarcopenia in older men.

Conflicts of interest

None declared.

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Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

References

1. Cruz-Jentoft AJ, Baeyens JP, Bauer JM *et al*. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010; 39: 412–23.
2. Roubenoff R. Sarcopenia and its implications for the elderly. Eur J Clin Nutr 2000; 54(Suppl. 3): S40–7.
3. Volkert D. The role of nutrition in the prevention of sarcopenia. Wien Med Wochenschr 2011; 161: 409–15.
4. Houston DK, Nicklas BJ, Ding J *et al*. Dietary protein intake is associated with lean mass change in older, community-dwelling adults: the Health, Aging, and Body Composition (Health ABC) Study. Am J Clin Nutr 2008; 87: 150–5.
5. Børsheim E, Bui QU, Tissier S, Kobayashi H, Ferrando AA, Wolfe RR. Effect of amino acid supplementation on muscle mass, strength and physical function in elderly. Clin Nutr 2008; 27: 189–95.
6. Paddon-Jones D, Rasmussen BB. Dietary protein recommendations and the prevention of sarcopenia. Curr Opin Clin Nutr Metab Care 2009; 12: 86–90.
7. Annweiler C, Schott AM, Berrut G, Fantino B, Beauchet O. Vitamin D-related changes in physical performance: a systematic review. J Nutr Health Aging 2009; 13: 893–8.
8. Ceglia L. Vitamin D and its role in skeletal muscle. Curr Opin Clin Nutr Metab Care 2009; 12: 628–33.
9. Cesari M, Pahor M, Bartali B *et al*. Antioxidants and physical performance in elderly persons: the Invecchiare in Chianti (InCHIANTI) study. Am J Clin Nutr 2004; 79: 289–94.
10. Lauretani F, Semba RD, Bandinelli S *et al*. Low plasma carotenoids and skeletal muscle strength decline over 6 years. J Gerontol A Biol Sci Med Sci 2008; 63: 376–83.
11. Cerullo F, Gambassi G, Cesari M. Rationale for antioxidant supplementation in sarcopenia. J Aging Res 2012; 2012: 316943.
12. Doria E, Buonocore D, Focarelli A, Marzatico F. Relationship between human aging muscle and oxidative system pathway. Oxid Med Cell Longev 2012; 2012: 830257.
13. Wu X, Beecher GR, Holden JM, Haytowitz DB, Gebhardt SE, Prior RL. Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. J Agric Food Chem 2004; 52: 4026–37.
14. Robinson SM, Jameson KA, Batelaan SF *et al*. Diet and its relationship with grip strength in community-dwelling older men and women: the Hertfordshire cohort study. J Am Geriatr Soc 2008; 56: 84–90.
15. Ministry of Health & Welfare, Korea Centers for Disease Control & Prevention. Korea Health Statistics 2009: Korea National Health and Nutrition Examination Survey (KNHANES IV-3). Seoul: Ministry of Health & Welfare, Korea Centers for Disease Control & Prevention, 2010.
16. Korea Centers for Disease Control & Preventive, Korea Health Industry Development Institute. In-depth Analysis of the 3rd (2005) Korea Health and Nutrition Examination Survey: Nutrition Survey. Seoul: Korea Centers for Disease Control & Preventive, Korea Health Industry Development Institute, 2007.
17. Ministry of Health & Welfare, Korea Health Industry Development Institute. The Third Korea National Health & Nutrition Examination Survey (KNHANES III), 2005—Nutrition Survey (I). Seoul: Ministry of Health & Welfare, Korea Health Industry Development Institute, 2006.
18. Newman AB, Kupelian V, Visser M *et al*. Sarcopenia: alternative definitions and associations with lower extremity function. J Am Geriatr Soc 2003; 51: 1602–9.
19. National Institute on Alcohol Abuse and Alcoholism. Helping Patients who Drink too Much. Besthesda, MD: National Institutes of Health, 2005.
20. World Health Organization. Global Recommendations on Physical Activity for Health. Geneva: World Health Organization Press, 2010.
21. Young AJ, Phillip DM, Lowe GM. Carotenoid antioxidant activity. In: Krinsky NI, Mayne ST, Sies H (eds). Carotenoids in Health and Disease. New York: Marcel Dekker, 2004, 105–26.
22. Hu P, Reuben DB, Crimmins EM, Harris TB, Huang MH, Seeman TE. The effects of serum beta-carotene concentration and burden of inflammation on all-cause mortality risk in high-functioning older persons: MacArthur studies of successful aging. J Gerontol A Biol Sci Med Sci 2004; 59: 849–54.
23. Frei B, England L, Ames BN. Ascorbate is an outstanding antioxidant in human blood plasma. Proc Natl Acad Sci USA 1989; 86: 6377–81.
24. Niki E, Yamamoto Y, Takahashi M *et al*. Free radical-mediated damage of blood and its inhibition by antioxidants. J Nutr Sci Vitaminol (Tokyo) 1988; 34: 507–12.
25. Rose RC, Bode AM. Biology of free radical scavengers: an evaluation of ascorbate. FASEB J 1993; 7: 1135–42.
26. Beyer RE. The role of ascorbate in antioxidant protection of biomembranes: interaction with vitamin E and coenzyme Q. J Bioenerg Biomembr 1994; 26: 349–58.
27. Block G, Dietrich M, Norkus EP *et al*. Factors associated with oxidative stress in human populations. Am J Epidemiol 2002; 156: 274–85.

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