Association Between Healthy Diet and Exercise and Greater Muscle Mass in Older Adults

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OBJECTIVES: To examine the association between healthy diet and exercise, individually and combined, and low muscle mass in older Korean adults.

DESIGN: Population-based cross-sectional study from the Fourth and Fifth Korea National Health and Nutrition Examination Surveys from 2008 to 2011.

SETTING: Community.

PARTICIPANTS: Nationally representative sample aged 65 and older (1,486 men, 1,799 women) in the Republic of Korea.

MEASUREMENTS: A food frequency questionnaire was used to determine frequency of food group consumption (meat, fish, eggs, legumes; vegetables; fruits). Participation in exercise (aerobic and resistance) was based on self-report. Combined healthy lifestyle factors were calculated as the number of recommendations met regarding consumption of food groups and exercise performed. Appendicular skeletal muscle mass (ASM) was measured using dual-energy X-ray absorptiometry, and low muscle mass was defined using the variable of ASM adjusted for weight. Logistic regression analysis was performed to examine the association between healthy lifestyle factors and low muscle mass, adjusting for sociodemographic characteristics and health-related variables.

RESULTS: In women, after controlling for covariates, vegetable consumption (odds ratio (OR) = 0.52, 95% confidence interval (CI) = 0.30–0.89) and aerobic exercise (OR = 0.62, 95% CI = 0.39–1.00) were inversely associated with low muscle mass. Also, the odds of low muscle mass was lower in women with three or more healthy lifestyle factors versus none (OR = 0.45, 95% CI = 0.23–0.87). In men, there were no associations between food group consumption and exercise and low muscle mass.

CONCLUSION: Older women who exercise and consume a healthy diet have lower odds of low muscle mass. Engaging in multiple healthy behaviors may be important in preventing low muscle mass in late life. **J Am Geriatr Soc 63:886–892, 2015.**

Key words: diet; vegetables; exercise; muscles; sarcopenia

Low muscle mass is a hallmark of sarcopenia[1] and increases the risk of frailty, functional limitations, falls, and physical disability in older people.[2] The healthcare costs of sarcopenia have been estimated to be $18.5 billion in the United States.[3] Because the prevalence of sarcopenia increases with age,[4] low muscle mass is increasingly recognized as a major health concern with the aging of the population.

A literature review identified lifestyle factors including diet and exercise as important factors in the complex etiology of sarcopenia.[5] Previous studies have mostly examined the relationship between protein (total, animal, vegetable) intake, considered to be an important factor for muscle protein synthesis, and loss of skeletal muscle mass.[6–9] More recently, there has been increasing interest in the potential role that vegetables and fruits may play in preventing loss of muscle mass by combating oxidative stress and neutralizing mild metabolic acidosis,[10–16] but few studies have examined the association between vegetable and fruit consumption and outcomes related to the functional capacity of muscles.[17–19] The Korean diet contains a high proportion of vegetables but a low amount of animal-derived foods,[20] which might modulate the loss of muscle mass and development of sarcopenia. In addition, resistance exercise has been reported to induce muscle hypertrophy and increase strength in older adults[21] and was found to be related to gains in lean body mass in older adults in a recent meta-analysis,[22] but few studies

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have investigated the effects of aerobic exercise on muscle mass or strength.[23–25]

Moreover, previous studies have examined the influence of individual lifestyle factors, but because lifestyle factors tend to cluster,[26] it is important to assess the association between combined, multiple lifestyle factors and health outcomes.[27,28] The aim of this study was to examine the association between individual and combined diet and exercise patterns and muscle mass in a nationally representative sample of community-dwelling older Korean adults.

METHODS

Study Population

Data used in this study were from the Fourth and Fifth Korea National Health and Nutrition Examination Surveys (KNHANES IV-V) from 2008 to 2011, a series of cross-sectional surveys that the Korea Centers for Disease Control and Prevention (KCDC) conducts. Details of the survey design are provided elsewhere.[20,29] KNHANES IV-V is based on multistage stratified cluster sampling of households of community-dwelling people in the Republic of Korea. The institutional review board of the KCDC approved the protocols for the KNHANES IV-V. Informed consent was obtained from each participant.

KNHANES IV-V includes three surveys (Health Interview Survey, Nutrition Survey, and Health Examination Survey); 4,223 individuals (1,782 men, 2,441 women) aged 65 and older participated in the three surveys. When missing values were excluded, 3,285 individuals (1,486 men, 1,799 women) were included in the final analysis.

Lifestyle Factors

Lifestyle factors were selected from dietary guidelines for older Korean adults.[30] The guidelines consisted of five critical recommendations: consume major food groups daily (meat, fish, eggs, legumes; vegetables; milk, milk products, soy milk; fruits), refrain from eating salty foods and cook using less salt, eat regular and safe meals, drink an adequate amount of water and refrain from excess alcohol consumption, and increase physical activity to the recommended level and maintain healthy body weight by aerobic and resistance exercise.[30] Specific recommendations on diet and exercise relevant to enhancing muscle mass and capacity were selected from among these recommendations. Meat, fish, eggs, and legumes are rich in protein, and vegetables and fruits contain a wide range of antioxidants.[31] Their potential benefits with regard to muscle mass and outcomes related to muscle capacity have been previously reported.[6–9,17–19] Aerobic and resistance exercise have also been reported to have positive effects on muscle mass and strength.[21–25]

To measure the frequency of food group consumption, a food frequency questionnaire (FFQ) was used to assess the usual dietary intake over the preceding year. The FFQ comprises 63 items based on the 24-hour recall of food sources for energy and major nutrients, the most frequently consumed foods, and seasonal food intake.[32] The 63-item FFQ was taken from a 109-item FFQ that has been tested for validity and reliability.[33] Frequency of intake was recorded on a 10-point response scale, ranging from rarely to three times a day.

Thirty-eight foods from the FFQ were selected for analysis and classified into food groups consisting of 15 meats, fish, eggs, and legumes (beef; chicken; pork; ham, bacon, sausage; mackerel; tuna; croaker; pollock; anchovy; fish paste; cuttlefish; shellfish; eggs; tofu; beans), 12 vegetables (Chinese cabbage, radish, dried radish leaves, bean sprouts, spinach, cucumber, hot peppers, carrots, pumpkin, cabbage, tomatoes, mushrooms), and 11 fruits (mandarin oranges, persimmons and dried persimmons, pears, watermelon, oriental melon, strawberries, grapes, peaches, apples, bananas, oranges). For each food, the frequency of daily food group consumption was summed. Recommended levels of food group consumption were based on the dietary reference intakes for Koreans (KDRIs).[34] The recommended daily intake for adults aged 65 and older in the KDRIs included four or more meat, fish, eggs, and legumes for men and 2.5 or more for women, seven or more vegetables for men and five or more for women, and one or more fruits for both sexes.

Exercise was assessed using a self-reported questionnaire for physical activity. Participants reported frequency and amount of moderate- (e.g., swimming, carrying light objects) or vigorous- (e.g., running, carrying heavy objects) intensity aerobic physical activity in the past week based on the Korean version of the International Physical Activity Questionnaire (IPAQ) short form.[35] Spearman rho coefficients of test–retest reliability were 0.43 to 0.65 (median 0.54) and kappa values were 0.37 to 0.62 (median 0.47).[35] Participants reported taking part in physical activity for at least 10 minutes at a time during the past week. Participants also recorded the frequency of resistance exercises such as push-ups, sit-ups, or training using dumbbells, weights, or a horizontal bar in the past week. Recommended levels of exercise were based on guidelines from the World Health Organization[36] ($\geq$150 min/wk of moderate-intensity or $\geq$75 min/wk of vigorous-intensity aerobic exercise, $\geq$2 times/wk of resistance exercise).

Combined lifestyle factors were defined as the sum of the number of food groups with recommended levels of consumption and the number of types of exercise practiced to the recommended level. Because few participants (4.1% of men, 5.2% of women) practiced four or five healthy lifestyle factors, those with three or more healthy lifestyle factors were combined into one category.

Measurement of Muscle Mass

Body composition was measured using dual-energy X-ray absorptiometry (Discovery-W, Hologic Inc., Waltham, MA) in mobile examination centers. Appendicular skeletal muscle mass (ASM) was quantified as the sum of lean soft tissue in the upper and lower extremities by assuming that all nonfat and nonbone tissue was skeletal muscle.[37] To establish the cutoff value of low muscle mass, the sex-specific mean and standard deviation (SD) of the ASM/weight $\times$ 100 of a young Korean reference group were used. Low muscle mass was calculated as weight-adjusted ASM more than 2 SDs below the sex-specific mean of the reference group.[38] The healthy reference group consisted

of 8,162 Koreans aged 20 to 39, excluding those with a history of specific diseases such as diabetes mellitus, stroke, coronary artery diseases, thyroid disease, arthritis, tuberculosis, asthma, liver cirrhosis, and cancer.

Covariates

Sociodemographic characteristics included age (65–74 and ≥75), education (≤elementary school vs >elementary school), and equivalent household income (monthly household income divided by the square root of the number of household members according to sex and 5-year age group). Health status included number of self-reported physician-diagnosed chronic conditions (arthritis, hypertension, hyperlipidemia, stroke, myocardial infarction or angina pectoris, diabetes mellitus, asthma, chronic obstructive pulmonary disease, cancer, depression, renal failure; 0, 1, and ≥2), antihypertensive medication use, and body mass index (BMI; weight (kg) divided by height squared (m^2): normal (<25.0 kg/m^2) vs overweight (≥25.0 kg/m^2)). Health behaviors included smoking (none, past, current), alcohol consumption (≤1 vs >1 drink/d). For women, time since menopause (<20, 20–29, ≥30 years), oral contraceptive use, and hormone use were reported.

Statistical Analysis

Differences in sample characteristics according to muscle mass were analyzed using the chi-square test. Odds ratios (ORs) with 95% confidence intervals (CIs) of low muscle mass were derived using logistic regression, with the reference group as those not meeting the recommended levels of meat, fish, egg, legume; vegetable; and fruit consumption and aerobic and resistance exercise after adjustment for covariates and each of the other individual healthy lifestyle factors. The association between the number of healthy lifestyle factors and low muscle mass was also analyzed. Significance was determined based on a two-sided *P*-value <.05. Sex-specific analyses were conducted using IBM SPSS Statistics 19.0 (IBM Corp., Armonk, NY). All analyses were performed using the complex design sampling weights.

RESULTS

Women tended to be older and less educated than men (Table 1) and more likely to have chronic conditions (81.8% vs 66.0%). Thirty-two percent of women reported time since menopause of <20 years, 44.3% of 20 to 29 years, and 24.0% of 30 years or more; 22.0% reported ever using oral contraceptive uses and 7.6% hormones. More women than men tended to consume the recommended levels of the selected food groups. More men than women engaged in the recommended levels of aerobic (32.3% vs 25.9%) and resistance (22.2% vs 6.1%) exercise. A higher proportion of women (18.2%) than men (11.4%) participated in three or more healthy lifestyle factors. The prevalence of low muscle mass was 9.3% in men and 10.1% in women.

Men with low muscle mass were older; more likely to have chronic conditions, to use antihypertensive medication, and to be overweight; and less likely to be current smokers than those with normal muscle mass (Table 2). Women with low muscle mass were more likely than those with normal muscle mass to have chronic conditions, use antihypertensive medications and hormones, and be overweight and to have had a longer time since menopause and less likely to have used oral contraceptives.

In the men, individual and combined healthy lifestyle factors were inversely associated with low muscle mass, but the associations were not significant (Tables 3

Table 1. Characteristics of Study Subjects: Korea National Health and Nutrition Examination Survey 2008–2011

Characteristic	Men (%), n = 1,486	Women (%), n = 1,799
Age		
65–74	71.6	67.0
≥75	28.4	33.0
Education level		
≤Elementary school	50.2	86.5
>Elementary school	49.8	13.5
Quartiles of equivalent income[a]		
1 (lowest)	23.2	24.4
2	25.4	23.0
3	24.4	25.4
4 (highest)	27.0	27.1
Number of chronic conditions[b]		
0	34.0	18.2
1	34.6	29.8
≥2	31.4	52.0
Antihypertensive medication use		
Yes	40.4	53.0
No	59.6	47.0
Body mass index, kg/m^2		
<25.0	75.8	60.1
≥25.0	24.2	39.9
Smoking		
Nonsmoker	14.3	88.7
Past smoker	59.8	5.6
Current smoker	25.9	5.7
Alcohol consumption, drinks/d		
≤1	72.8	98.3
>1	27.2	1.7
Food group consumption[34]		
Meat, fish, eggs, legumes (men ≥4/d, women ≥2.5/d)	27.1	51.8
Vegetables (men ≥7/d, women ≥5/d)	7.2	28.0
Fruits (≥1/d)	28.6	30.9
Exercise[36]		
Aerobic (≥150 min/wk moderate intensity or ≥75 min/wk vigorous intensity)	32.3	25.9
Resistance (≥2 times/wk)	22.2	6.1
Number of healthy lifestyle factors adhered to		
0	33.3	23.5
1	31.8	34.3
2	23.4	24.0
≥3	11.4	18.2

[a]Monthly household income/$\sqrt{}$number of household members according to sex and 5-year age group.[29]

[b]Hypertension, hyperlipidemia, stroke, myocardial infarction or angina pectoris, arthritis, asthma, chronic obstructive pulmonary disease, diabetes mellitus, cancer, depression, renal failure.

Table 2. Relationship Between Muscle Mass and Subject Characteristics: Korea National Health and Nutrition Examination Survey 2008–2011

Characteristic	Men, n = 1,486			Women, n = 1,799		
	Normal (%)	Low (%)	*P*-Value[a]	Normal (%)	Low (%)	*P*-Value[a]
Age						
65–74	73.0	57.0	.001	67.7	60.8	.13
≥75	27.0	43.0		32.3	39.2	
Education level						
≤Elementary school	50.4	48.7	.76	86.3	88.7	.42
>Elementary school	49.6	51.3		13.7	11.3	
Quartile of equivalent income[b]						
1 (lowest)	23.9	16.3	.10	24.5	24.0	.33
2	25.0	28.9		23.1	22.0	
3	23.6	32.2		24.7	31.4	
4 (highest)	27.4	22.7		27.7	22.5	
Number of chronic conditions[c]						
0	35.9	15.6	<.001	19.7	4.8	<.001
1	34.6	34.7		29.9	29.2	
≥2	29.5	49.6		50.4	66.0	
Antihypertensive medication use						
Yes	38.2	61.9	<.001	51.3	67.5	<.001
No	61.8	38.1		48.7	32.5	
Body mass index, kg/m^2						
<25.0	79.5	40.0	<.001	63.6	29.4	<.001
≥25.0	20.5	60.0		36.4	70.6	
Smoking						
Nonsmoker	13.9	18.1	.02	88.4	91.5	.20
Past smoker	59.0	67.3		5.5	6.2	
Current smoker	27.1	14.5		6.0	2.4	
Alcohol consumption, drinks/d						
≤1	72.5	75.7	.54	98.3	98.5	.85
>1	27.5	24.3		1.7	1.5	
Time since menopause, years						
<20	–	–		31.7	31.5	<.001
20–29	–	–		44.8	40.0	
≥30	–	–		23.5	28.5	
Oral contraceptive use	–	–		22.3	18.6	<.001
Hormone use	–	–		7.4	9.4	<.001

[a]Chi-square test.

[b]Monthly household income/$\sqrt{}$number of household members according to sex and 5-year age group.[29]

[c]Hypertension, hyperlipidemia, stroke, myocardial infarction or angina pectoris, arthritis, asthma, chronic obstructive pulmonary disease, diabetes mellitus, cancer, depression, renal failure.

and 4). In women, those engaging in recommended levels of vegetable consumption (OR = 0.52, 95% CI = 0.30–0.89) and aerobic exercise (OR = 0.62, 95% CI = 0.39–1.00) had a significantly lower likelihood of low muscle mass than those who did not meet the recommended levels. Moreover, for women, there was an inverse relationship between low muscle mass and number of healthy lifestyle factors. Women who engaged in three or more healthy behaviors had 55% lower odds of low muscle mass than those who practiced none (OR = 0.45, 95% CI = 0.23–0.87).

DISCUSSION

In this study of a nationally representative sample of older Koreans, healthy lifestyle factors were inversely associated with low muscle mass in women, even after adjusting for covariates. Consuming recommended levels of vegetables was associated with 48% lower odds of low muscle mass and engagement in recommended levels aerobic exercise with 38% lower odds.

There is paucity of research on the association between vegetable consumption and outcomes related to muscles. In the Hertfordshire Cohort Study, vegetable consumption was positively associated with grip strength in multivariable analyses in older women.[17] In other studies, vegetable intake was inversely associated with functional limitations in individuals in midlife.[18,19] Vegetables provide antioxidants such as carotenoids and vitamin C.[31] Dietary carotenoids and ascorbic acid protect against oxidative stress.[10–12] Also, cruciferous vegetables such as broccoli, cauliflower, radishes, kale, Brussels sprouts, watercress, and cabbage[13] provide inducers of phase 2 proteins, which are mainly enzymes that inactivate electrophiles and strong oxidants.[14] Furthermore, the alkalizing effects of vegetables may neutralize mild metabolic acidosis,[15] which has catabolic influences on muscle.[16]

Table 3. Likelihood of Low Muscle Mass According to Individual Healthy Lifestyle Factors in Logistic Regression Analysis: Korea National Health and Nutrition Examination Survey 2008–2011

	Men, n = 1,486		Women, n = 1,799	
	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[b]
Healthy Lifestyle Factors	Odds Ratio (95% Confidence Interval)			
Recommend levels of food group consumption[34]				
Meat, fish, eggs, legumes (men ≥4/d, women ≥2.5/d)	0.79 (0.45–1.38)	0.74 (0.41–1.31)	0.82 (0.56–1.22)	0.91 (0.58–1.43)
Vegetables (men ≥7/d, women ≥5/d)	0.41 (0.15–1.12)	0.53 (0.18–1.60)	0.48 (0.29–0.79)	0.52 (0.30–0.89)
Fruits (≥1/d)	0.94 (0.59–1.51)	1.09 (0.64–1.84)	0.77 (0.50–1.19)	0.92 (0.57–1.47)
Recommended levels of exercise[36]				
Aerobic (≥150 min/wk moderate intensity or ≥75 min/wk vigorous intensity)	0.66 (0.41–1.04)	0.68 (0.42–1.11)	0.59 (0.38–0.94)	0.62 (0.39–1.00)
Resistance (≥2 times/wk)	0.83 (0.52–1.34)	0.82 (0.48–1.40)	0.70 (0.34–1.44)	0.75 (0.37–1.51)

[a]Adjusted for age, education level, quartiles of equivalent income, number of physician-diagnosed chronic conditions, antihypertensive medication use, body mass index, smoking, alcohol drinking, and all of the other individual healthy lifestyle factors.
[b]Adjusted for the above factors plus time since menopause, oral contraceptive use, and hormone use.

Table 4. Likelihood of Low Muscle Mass According to Number of Healthy Lifestyle Factors in Logistic Regression Analysis: Korea National Health and Nutrition Examination Survey 2008–2011

Number of Healthy Lifestyle Factors (Reference 0)	Men (n = 1,486)		Women (n = 1,799)	
	Unadjusted	Adjusted[a]	Unadjusted	Adjusted[b]
1	0.78 (0.45–1.35)	0.96 (0.55–1.66)	0.79 (0.49–1.29)	0.78 (0.45–1.33)
2	0.65 (0.37–1.15)	0.59 (0.31–1.14)	0.48 (0.27–0.84)	0.43 (0.24–0.78)
≥3	0.58 (0.27–1.25)	0.54 (0.25–1.16)	0.43 (0.24–0.77)	0.45 (0.23–0.87)

Number of the recommended five lifestyle behaviors (meat, fish, eggs, legumes: ≥4/d for men, ≥2.5/d for women; vegetables: ≥7/d for men, ≥5/d for women; fruits: ≥1/d[34]; aerobic exercise: ≥150 min/wk of moderate-intensity or ≥75 min/wk of vigorous-intensity aerobic physical activity; resistance exercise: ≥2 times/wk[36]) that respondents accomplished.
[a]Adjusted for age, education level, quartiles of equivalent income, number of physician-diagnosed chronic conditions, antihypertensive medication use, body mass index, smoking, and alcohol drinking.
[b]Adjusted for the above factors plus time since menopause, oral contraceptive use, and hormone use.

Regarding the association between exercise and low muscle mass, there has been little research on the effects of aerobic exercise on muscle mass or strength. Age-related reductions in aerobic capacity have been noted,[39] with loss of muscle mass possibly responsible for up to half of the age-related decline.[40,41] In older women, aerobic training has been reported to increase muscle size and function.[23] Progressive aerobic exercise has been shown to induce substantial muscle hypertrophy and improve myofiber contractile function in older men.[24] In the U.S. National Health and Nutrition Examination Survey, conducted in 2003 to 2006, vigorous aerobic activity was positively associated with Appendicular Skeletal Muscle Mass Index in individuals aged 50 and older.[25]

In the current study, the number of healthy lifestyle factors was inversely associated with low muscle mass in older women. There was a graded decrease in the risk of low muscle mass in women with an increasing number of healthy lifestyle factors. A synergistic effect of vegetable intake and exercise may play a role. Vegetables, with their alkalizing effects, may enhance the effects of exercise on muscle by improving nonoxidative glycolysis in isometric contraction, reducing fatigue and increasing recovery.[42–44] Bicarbonate may buffer metabolic acidosis that high-intensity exercise induces.[45,46] An acute ingestion of sodium bicarbonate may augment the buffering capacity, delaying exhaustion and enhancing function,[47] although clinical evidence of an interaction between alkali administration and exercise is limited and research is inconclusive.[44,48] Moreover, an acid–base buffering system in exercise tolerance has not been demonstrated in older adults performing moderate-intensity exercise. Further research is needed in older adults to clarify these effects.

In men, no significant association was found between the individual lifestyle factors and low muscle mass. More women than men achieved the recommended level of vegetable consumption, which may reflect the influence of diet on low muscle mass. In the Hertfordshire Cohort Study, more women than men had a higher recommended consumption of vegetables, with vegetable intake being associated with muscle strength only in women.[17] However, it is uncertain why there was no significant relationship between lifestyle factors and low muscle mass in men. Inadequate adjustment for confounding may have

influenced the results. Alternatively, lifestyle factors might play less of a role in low muscle mass in men than in women.

One of the strengths of this study is that the subjects were obtained from a nationally representative sample of older adults in Korea, strengthening the generalizability of the findings. Significant results attained after controlling for multiple covariates attest to the robustness of the findings.

Several limitations need to be considered. First, the FFQ used in this study has not been formally validated, although its items originated from the 2001 KNHANES that identified the most frequently consumed foods stratified according to sex, from the 2002 Seasonal Nutrition Survey on seasonal food intake, and from the Dietary Behaviors Survey.[49] Second, the recommended levels chosen for lifestyle behaviors were not specific to low muscle mass; further studies are needed to determine the threshold that engenders benefits. Third, exercise was based on self-report; the correlation between self-reported and accelerometer-measured physical activity has been shown to be between 0.20 and 0.40.[50] Finally, caution should be exercised in drawing any causal inferences regarding the association between vegetable consumption, aerobic exercise, and the combined healthy behaviors and low muscle mass because of the cross-sectional study design.

In summary, vegetable consumption and aerobic exercise were inversely associated with low muscle mass in older Korean women, with a graded decrease in the risk of low muscle mass with engagement in more healthy lifestyle behaviors. The findings suggest that the adoption of combined healthy behaviors, including appropriate diet and exercise, might be protective against low muscle mass in late life. Health professionals may advise older adults to adhere to recommended levels of vegetable consumption and aerobic exercise during health consultations. Further prospective studies and intervention trials would help clarify the potential benefits of healthy lifestyle behaviors on low muscle mass.

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