



Sarcopenia is associated with Framingham risk score in the Korean population: Korean National Health and Nutrition Examination Survey (KNHANES) 2010–2011

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Abstract

Background Sarcopenia is a risk factor for metabolic disorders and cardiovascular disease, but the association between sarcopenia and cardiovascular risk factors according to age and obesity status in the general population remains unknown. We thus investigated these associations in the Korean population. **Methods** We included 8,958 and 8,518 subjects from the fifth Korean National Health and Nutrition Examination Survey (KNHANES) (from 2010 and 2011, respectively). The study was restricted to participants ≥ 20 years old who had completed the health examination survey, including whole body dual-energy X-ray absorptiometry scans. After exclusion, 7,366 subjects (3,188 men, 4,178 women) were included in our final analysis. Age was categorized according to three age groups (20–39, 40–59, and ≥ 60 years), and subjects were categorized according to their sarcopenic and obesity status. Cardiovascular risk was assessed with Framingham risk score (FRS). **Results** The sarcopenic obese group had a higher FRS than the non-sarcopenic obese group, which had a higher FRS than the non-sarcopenic non-obese group. Age-wise, the 20–39 year-old group showed a non-significant association between sarcopenia and FRS. In the 40–59 year-old group, regardless of obesity status, sarcopenic subjects had a higher FRS than non-sarcopenic subjects. In the ≥ 60 year-old group, sarcopenic subjects had a higher FRS than non-sarcopenic subjects for the non-obese group. **Conclusions** Sarcopenia was associated with cardiovascular disease and may be an early predictor of its susceptibility in both elderly and middle-aged subjects. Thus, management of sarcopenia is necessary to prevent cardiovascular disease.

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Keywords: Age; Cardiovascular disease; Cardiovascular risk factor; Framingham risk score; Sarcopenia

1 Introduction

Aging is related to increased fat mass and decreased skeletal muscle mass, which are important factors in the development of metabolic syndrome and cardiovascular diseases.^[1,2] In a cohort study of sarcopenia and cardiovascular disease in the United Kingdom, in general, sarcopenia was associated with increased mortality from cardiovascular disease, although it was not associated with mortality from cardiovascular disease in obese individuals with sarcopenia.^[3]

Various methods for determining cardiovascular risk factors have been presented, and many are based on the Framingham heart study. The Framingham risk score (FRS)

was first presented in 1967, and is accepted as a typical guideline for predicting the risk of cardiovascular diseases and managing risk factors. In 2001, the National Centers for Environmental Prediction-Adult Treatment Panel III (NCEP-ATP III) proposed a new method for evaluating the risk of cardiovascular diseases based on the Framingham study. According to that method, the risk of mortality from coronary heart disease for individuals aged 20 to 79 years is assessed for the next 10 years using gender-specific scoring based on age, smoking status, systolic blood pressure, total cholesterol, and high density lipoprotein cholesterol (HDL-C). Total cholesterol is used instead of low-density lipoprotein cholesterol (LDL-C) as a risk factor as a result of extensive information on total cholesterol in the Framingham research data.

Studies of sarcopenia have primarily targeted the elderly. Total lean body mass begins to decrease early in the third decade of life and shows a sharp decline at 45 years of age and older.^[4] Although the prevalence of sarcopenia is lower in younger populations, it is important to conduct studies in

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younger people with sarcopenia. To the best of our knowledge, no study has reported the association of sarcopenia and cardiovascular risk factors according to age group and obesity status in a general population. In order to elucidate these relationships, we investigated the relationship of sarcopenia and cardiovascular risk factors in the Korean population based on the Korea National Health and Nutrition Examination Survey (KNHANES) conducted in 2010 and 2011.

2 Methods

2.1 Subjects

This study was based on data, including DXA data, obtained from the most recent KNHANES, a cross-sectional and nationally representative survey conducted by the Korean Ministry of Health and Welfare in 2010 and 2011. The survey target population was non-institutionalized civilians over one year of age in Korea. The sampling units were households selected through a stratified, multistage, probability-sampling design based on geographic area, sex, and age group using household registries. Participants completed four parts of a questionnaire that consisted of a health interview survey, a health behavior survey, a health examination survey, and a nutrition survey. This survey included about 3,800 households from January to December 2010; the investigation from January to December 2011 was carried out in the same way.^[5] In this study, 8,958 subjects and 8,518 subjects were included from the 2010 and 2011 surveys, respectively. The current cross-sectional study was restricted to participants who were ≥ 20 years of age and who completed the health examination survey, including whole body dual-energy X-ray absorptiometry (DXA) scans ($n = 9,581$ overall). The surveys were completed by 5,247 participants in 2010 (58.6% of the total target population of 8,958) and 2,119 participants in 2011 (24.9% of the total target population of 8,518). After exclusion, 7,366 subjects (3,188 men and 4,178 women) were included in our final analysis. The study was approved by the Institutional Review Board of the Center for Disease Control and Prevention of Korea (2010-02CON-21-C, 2011-02CON-06-C).

2.2 Metabolic syndrome

We investigated the association between sarcopenia and metabolic syndrome, which is known to increase the risk of cardiovascular diseases and diabetes. Diagnosis of metabolic syndrome was based on the standards of the NCEP-ATP III and the 2005 Guidelines of the modified Adult Treatment Panel III of the American Heart Association and the National Heart, Lung, and Blood Institute.^[6]

Metabolic syndrome was diagnosed when three or more of the following five conditions were satisfied: (1) a waist circumference of greater than 90 cm in males or 85 cm in females; (2) a triglyceride value of 150 mg/dL or higher, or subjects being treated for hyperlipidemia; (3) blood pressure of 130/85 mmHg or higher, or subjects being treated for hypertension; (4) an HDL-C concentration lower than 40 mg/dL in males or 50 mg/dL in females; and (5) a fasting plasma glucose value of 100 mg/dL or higher, or subjects being treated for diabetes.

Abdominal obesity was defined as a waist circumference measurement greater than 90 cm in males or 85 cm in female.^[7] Waist circumference was measured while the subject exhaled by placing a tape measure at the intermediate point between the bottom of the last rib and the top of the iliac ridge in the mid-axillary line. Blood pressure was measured three times while subjects were comfortably seated in a chair; the mean value of the second and third measurements was used for analysis. Serum triglycerides, HDL-C, and fasting plasma glucose were measured by the enzyme method using the Hitachi Automatic Analyzer 7600 (Hitachi Solutions, Ltd., Tokyo, Japan).

2.3 FRS and cardiovascular risk factors

The FRS was used to assess the risk of death from cardiovascular disease over the next 10 years using the 2001 NCEP-ATP III method (Table 1).^[8] The traditional risk factors for cardiovascular disease include age, gender, smoking habits, systolic blood pressure, total cholesterol, LDL-C, and HDL-C, while levels of triglyceride, homocysteine, lipoprotein(a), fibrinogen, and C-reactive protein were recently added to the list.^[9-11]

In the current study, the traditional risk factors, such as total cholesterol, LDL-C, HDL-C, and systolic blood pressure, as well as the FRS were analyzed for their association with sarcopenia. In addition, the association of sarcopenia with cardiovascular disease risk factors, particularly with the FRS, was investigated by age group to confirm any correlation that may be seen in the elderly population.

2.4 Obesity and sarcopenia

Obesity was determined according to body mass index (BMI). The height (Ht) in meters and weight (Wt) in kilograms of each subject were used for the equation $BMI = Wt/Ht^2$. Obesity was defined as a $BMI \geq 25$ kg/m². Metabolic syndrome is associated with abdominal obesity; however, it has not yet been established whether sarcopenia is associated with abdominal obesity. Therefore, this study was used as a general diagnostic method of obesity to classify the study population based on obesity and sarcopenia.

Table 1. Comparisons of cardiovascular risk factors according to category of sarcopenia and obesity.

Category risk factor	Sarcopenic Obese	Non-sarcopenic Obese	<i>P</i>	Sarcopenic Non-obese	Non-sarcopenic Non-obese	<i>P</i>
Participants, <i>n</i> (%)	230 (3.1)	2135 (29.0)	< 0.001	89 (1.2)	4912 (66.7)	< 0.001
Age (yr)	54.21 ± 1.22	45.72 ± 0.49	< 0.001	56.42 ± 2.01	43.59 ± 0.40	< 0.001
Body height, cm	159.29 ± 0.74	165.07 ± 0.28	< 0.001	156.82 ± 0.95	164.19 ± 0.18	< 0.001
Body weight, kg	74.78 ± 1.32	74.91 ± 0.34	0.922	56.75 ± 0.83	59.06 ± 0.16	0.006
BMI, kg/cm ²	29.31 ± 0.34	27.40 ± 0.08	< 0.001	23.03 ± 0.17	21.83 ± 0.04	< 0.001
WC, cm	96.11 ± 0.82	90.24 ± 0.24	< 0.001	80.76 ± 0.70	76.48 ± 0.17	< 0.001
ASM, kg	16.89 ± 0.41	21.25 ± 0.15	< 0.001	12.38 ± 0.31	17.45 ± 0.09	< 0.001
ASM/Wt, %	22.34 ± 0.22	28.10 ± 0.11	< 0.001	21.64 ± 0.28	29.26 ± 0.10	< 0.001

Data are presented as mean ± SD or *n* (%); *P*-value was calculated using analysis of variance and the χ^2 test. ASM: appendicular skeletal muscle mass; BMI: body mass index; FPG: fasting plasma glucose; WC, waist circumference.

Sarcopenia was diagnosed using the modified method of Janssen, *et al.*^[18] The DXA was used to measure the appendicular skeletal muscle mass (ASM). This number was then divided by the body weight of the subject and expressed as a percentage [ASM/Wt (%)]. As with the osteoporosis standards, sarcopenia was determined when the subject's ASM/Wt (%) value was more than two standard deviations below that of the young reference group.^[12] In this study, the mean ASM/Wt (%) level was 26.88% for the 974 males aged 20–39 years old and 21.02% for the 1,367 females in the same age group. These mean values were used as the reference values.

Based on their BMI and ASM/Wt (%) values, subjects were classified into one of four groups: the sarcopenic obese group, the non-sarcopenic obese group, the sarcopenic non-obese group, or the non-sarcopenic non-obese group.

2.5 Statistical analysis

All categorical data were expressed as frequencies, and continuous data were expressed as means ± SD. Statistical processing was conducted using the SPSS program, version 22 (IBM Corp., Armonk, NY, USA). Differences in the FRS and cardiovascular disease risk factors according to the presence of sarcopenia were analyzed with the χ^2 test and analysis of variance. Statistical significance was set at *P* < 0.05.

3 Results

3.1 Characteristics of the study population

The mean age of the overall sarcopenic group (obese and non-obese) was 54.71 years, which was significantly higher than the mean age of 44.24 years for the overall non-sarcopenic group (*P* < 0.001). The total cholesterol, triglycerides,

and LDL-C levels for the overall sarcopenic group were significantly higher than those for the overall non-sarcopenic group (all *P*'s < 0.001), and the HDL-C level for the overall sarcopenic group was significantly lower (*P* = 0.026). The prevalence of metabolic syndrome in the overall sarcopenic group was 58.7%, much higher than the prevalence of 25.3% in the overall non-sarcopenic group (*P* < 0.001). The FRS for the overall sarcopenic group was 12.05, which was much higher than the FRS of 6.84 in the overall non-sarcopenic group (*P* < 0.001) (Table 2).

3.2 Association of cardiovascular disease risk factors with sarcopenia and obesity

The sarcopenic obese group had significantly higher fasting plasma glucose levels (*P* = 0.012), systolic blood pressure (*P* < 0.001), metabolic syndrome prevalence (*P* < 0.001), and FRS (*P* < 0.001) than did the non-sarcopenic obese group. The sarcopenic non-obese group had significantly higher total cholesterol levels (*P* < 0.001), LDL-C levels (*P* < 0.001), systolic blood pressure (*P* = 0.006), prevalence of metabolic syndrome (*P* < 0.001), and FRS (*P* < 0.001) than did the non-sarcopenic non-obese group. The sarcopenic obese group was similar to the sarcopenic non-obese group in terms of their systolic blood pressure, metabolic syndrome, and FRS (Table 1).

3.3 Associations between sarcopenia and cardiovascular disease risk factors by age

The LDL-C level of subjects aged 40–59 years in the sarcopenic non-obese group was 125.16 mg/dL and was 113.97 mg/dL in the non-sarcopenic non-obese group in the same age range (*P* = 0.020) and was the only group in the age-stratified analysis with a significantly higher LDL-C value than that of the other groups (Table 2).

Table 2. Comparisons of cardiovascular risk factors according to category of sarcopenia and obesity.

Category risk factor	Sarcopenic Obese	Non-sarcopenic Obese	<i>P</i>	Sarcopenic Non-obese	Non-sarcopenic Non-obese	<i>P</i> [†]
FPG, mg/dL						
All ages	107.47 ± 2.46	100.89 ± 0.72	0.012	98.63 ± 3.14	93.90 ± 0.39	0.136
20–39 yr	100.37 ± 3.25	94.15 ± 0.84	0.067	88.50 ± 1.70	88.62 ± 0.48	0.945
40–59 yr	105.97 ± 4.41	104.45 ± 1.24	0.745	91.86 ± 1.74	96.57 ± 0.60	0.010
60+ yr	112.59 ± 4.71	104.96 ± 1.14	0.117	109.78 ± 5.63	101.71 ± 0.75	0.155
TC, mg/dL						
All ages	200.87 ± 3.10	196.27 ± 0.96	0.147	196.25 ± 3.89	182.93 ± 0.64	0.001
20–39 yr	193.96 ± 6.55	191.93 ± 1.68	0.760	177.77 ± 6.24	172.78 ± 0.88	0.427
40–59 yr	205.00 ± 5.10	200.42 ± 1.50	0.400	201.32 ± 5.56	191.02 ± 0.96	0.073
60+ yr	200.36 ± 4.26	194.24 ± 1.67	0.164	199.37 ± 6.82	190.55 ± 1.12	0.201
Triglycerides, mg/dL						
All ages	170.61 ± 9.57	167.73 ± 3.91	0.781	127.42 ± 9.37	116.62 ± 1.90	0.266
20–39 yr	195.21 ± 29.32	162.99 ± 6.67	0.277	92.45 ± 10.60	93.74 ± 1.78	0.904
40–59 yr	160.10 ± 17.01	174.81 ± 6.19	0.406	133.68 ± 14.74	135.38 ± 3.77	0.911
60+ yr	168.32 ± 12.31	159.08 ± 4.60	0.471	136.61 ± 14.65	132.50 ± 2.61	0.784
HDL-C, mg/dL						
All ages	45.77 ± 0.88	44.82 ± 0.26	0.302	49.61 ± 1.86	50.36 ± 0.22	0.687
20–39 yr	44.03 ± 1.28	44.52 ± 0.41	0.715	55.38 ± 2.83	51.69 ± 0.33	0.199
40–59 yr	48.38 ± 1.78	44.93 ± 0.39	0.058	49.42 ± 2.28	49.98 ± 0.31	0.845
60+ yr	44.09 ± 0.90	45.12 ± 0.53	0.320	47.26 ± 2.82	47.68 ± 0.42	0.884
LDL-C, mg/dL						
All ages	120.98 ± 2.83	117.91 ± 0.97	0.281	121.16 ± 3.12	109.25 ± 0.57	< 0.001
20–39 yr	110.88 ± 6.82	114.81 ± 1.90	0.560	103.90 ± 6.05	102.34 ± 0.78	0.799
40–59 yr	124.59 ± 4.45	120.53 ± 1.42	0.376	125.16 ± 4.62	113.97 ± 0.92	0.020
60+ yr	122.61 ± 3.57	117.31 ± 1.62	0.165	124.79 ± 5.01	116.37 ± 1.04	0.101
Systolic BP, mmHg						
All ages	129.28 ± 1.44	123.40 ± 0.50	< 0.001	122.10 ± 2.14	116.14 ± 0.39	0.006
20–39 yr	122.81 ± 4.63	116.88 ± 0.66	0.192	106.44 ± 2.29	108.95 ± 0.34	0.269
40–59 yr	127.64 ± 2.19	124.43 ± 0.65	0.167	117.99 ± 2.55	118.06 ± 0.53	0.978
60+ yr	134.20 ± 1.96	133.41 ± 0.83	0.701	133.05 ± 3.00	130.99 ± 0.71	0.504
Diastolic BP, mmHg						
All ages	81.38 ± 0.98	80.65 ± 0.36	0.482	76.53 ± 1.12	75.39 ± 0.26	0.319
20–39 yr	83.20 ± 2.93	78.81 ± 0.58	0.129	70.10 ± 1.60	72.64 ± 0.34	0.111
40–59 yr	83.28 ± 1.71	82.67 ± 0.47	0.727	79.01 ± 2.12	77.89 ± 0.35	0.605
60+ yr	78.58 ± 0.94	79.11 ± 0.51	0.617	76.90 ± 1.78	76.69 ± 0.42	0.904
Metabolic syndrome, <i>n</i> (%)						
All ages	167 (66.4)	1159 (49.2)	< 0.001	28 (32.2)	858 (14.7)	< 0.001
20–39 yr	10 (43.5)	185 (31.0)	0.222	0 (0.0)	42 (2.2)	0.620
40–59 yr	46 (63.3)	514 (54.7)	0.183	4 (22.2)	329 (18.4)	0.714
60+ yr	111 (81.1)	460 (70.8)	0.068	24 (56.3)	487 (39.4)	0.033
FRS						
All ages	12.11 ± 0.58	8.82 ± 0.22	< 0.001	11.84 ± 0.93	5.96 ± 0.17	< 0.001
20–39 yr	4.36 ± 1.05	2.93 ± 0.28	0.204	0.78 ± 1.42	−0.49 ± 0.15	0.374
40–59 yr	11.79 ± 0.48	10.53 ± 0.17	0.023	11.43 ± 0.43	9.26 ± 0.14	< 0.001
60+ yr	16.40 ± 0.33	15.87 ± 0.15	0.130	17.12 ± 0.71	15.39 ± 0.12	0.016

Data are presented as means ± SD; [†]*P*-value was calculated by analysis of variance and the χ^2 test. BP: blood pressure; FPG: fasting plasma glucose; FRS: Framingham risk score; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TC: total cholesterol.

3.4 Association between sarcopenia and metabolic syndrome by age

Among non-obese subjects aged 60 years or older, the prevalence of metabolic syndrome in the sarcopenic group was 56.3% and in the non-sarcopenic group was 39.4% ($P = 0.033$). There were no age-stratified differences for obese subjects with, or without sarcopenia, in the prevalence of metabolic syndrome (Table 2).

3.5 Association between sarcopenia and FRS by age

Among 20–39 year-olds, neither obese nor non-obese subjects showed an association between sarcopenia and FRS. Among 40–59 years old, the FRS for sarcopenic obese subjects was significantly higher than for non-sarcopenic obese subjects (11.79 ± 0.48 vs. 10.53 ± 0.17 , respectively, $P = 0.023$). In this same age group, the FRS for the sarcopenic non-obese group was significantly higher than that for the non-sarcopenic non-obese group (11.43 ± 0.43 vs. 9.26 ± 0.14 , respectively, $P < 0.001$). Among obese subjects aged 60 years or older, there were no statistically significant differences in FRS. In this age group, the FRS for the sarcopenic non-obese group was significantly higher than for the overall obese group (17.12 ± 0.71 vs. 15.39 ± 0.12 , respectively, $P = 0.016$) (Table 2).

4 Discussion

This was a cross-sectional study that targeted Korean adults to investigate risk factors for cardiovascular diseases and the association between FRS and sarcopenia. Among the risk factors, fasting plasma glucose, LDL-C, and systolic blood pressure were found to be associated with sarcopenia. In particular, systolic blood pressure was associated with sarcopenia regardless of the obesity status of the subject, fasting plasma glucose was associated with sarcopenia in the obese group, and LDL-C was associated with sarcopenia in the non-obese group. These data indicate that sarcopenia is associated with risk factors for cardiovascular disease and may itself be an individual risk factor for cardiovascular disease. The FRS, which predicts the risk for cardiovascular disease, was also associated with sarcopenia regardless of the obesity status of the subject, confirming the possibility that sarcopenia is a risk factor for cardiovascular disease.

The underlying mechanisms for the relationships between sarcopenia and risk factors for cardiovascular disease have never been explored. As noted above, systolic blood pressure and FRS were associated with sarcopenia, regardless of obesity status. Systolic blood pressure is associated with cardiovascular diseases, and the FRS is a cardiovascu-

lar disease risk score. Thus, the two factors have in common that they are direct predictors of cardiovascular disease. Some possible mechanisms to explain how sarcopenia influences the cardiovascular system and the development of hypertension, include decreased mass in insulin-responsive target tissues,^[13] decreased myokine secretion,^[14–16] and alterations within the rennin angiotensin-aldosterone system.^[17]

In the case of fasting plasma glucose, we speculate that sarcopenia and obesity may interact with each other. Increased fat mass in obesity promotes the inflammatory process by increasing the secretion of pro-inflammatory cytokines. In addition, the loss of muscle mass in sarcopenia means there is less insulin-responsive target tissue available, thereby promoting insulin resistance, which plays a key role in the pathogenesis of elevated fasting plasma glucose in the sarcopenic obese group.

These facts are worthy of notice, because people in Asia tend to develop type 2 diabetes with less obesity compared to non-Asians,^[18] The current study shows that non-obese individuals are more affected by sarcopenia with regard to LDL-C. We assumed that Asians develop hyper-LDL-cholesterolemia under the condition of sarcopenia with less obesity than their non-Asian counterparts, as in the case of Asians with type 2 diabetes.

Therefore, our results suggest that the pathogenic mechanisms of sarcopenia may differ between obese and non-obese individuals. Further research is necessary to improve understanding of the pathogenesis.

In a study by Sanada, *et al.*^[19] on the association between sarcopenia and risk factors for cardiovascular diseases in a Japanese population, glycosylated hemoglobin level in males and vascular stiffness in females were found to be associated with sarcopenia, again confirming that sarcopenia is a risk factor for cardiovascular disease. Similarly, Chin, *et al.*^[16] reported that sarcopenia was independently associated with cardiovascular diseases in a study of Korean adults. However, Liu, *et al.*^[20] reported that sarcopenia was not associated with risk factors for cardiovascular diseases. Accordingly, further large-scale studies on the association between sarcopenia and the risk factors for cardiovascular diseases are needed.

One reason that sarcopenia, which involves a decrease in the skeletal muscles, may be associated with cardiovascular diseases is related to the fact that skeletal muscles are not only locomotive organs, but also endocrine organs that secrete signal transduction molecules from their autocrine, paracrine, and endocrine glands. The substance secreted from skeletal muscles is called myokine.^[21, 22]

In obese individuals, adipose tissues are inflamed, meta-

bolic diseases such as insulin-resistant type 2 diabetes develop, and a substance called adipokine is secreted, which facilitates the development of metabolic syndrome and cardiovascular diseases. Myokine is thought to counterbalance the abnormal adipokine.^[23] Walsh reported the functions of FSTL1, a type of myokine, protect the cardiovascular system.^[14] Therefore, with aging, the skeletal muscle mass decreases, body adipose tissue increases, myokine secretion decreases, and adipokine secretion increases. Consequently, insulin resistance increases, and the risks for metabolic diseases, such as type 2 diabetes and metabolic syndrome, and cardiovascular diseases may also increase.

Most studies involving sarcopenia and cardiovascular disease have been conducted among elderly populations. Some studies targeted adults 18 years of age or older,^[19] but only a few studies have examined the relationships between sarcopenia and cardiovascular disease by age. In the current study, the association between FRS and sarcopenia was investigated by age group. In the 20–39 year-old age group, no association between sarcopenia and FRS was observed, regardless of obesity status (obese group, $P = 0.204$; non-obese group, $P = 0.374$). In the 40–59 year-old age group, the FRS was higher in sarcopenic subjects than in non-sarcopenic subjects, regardless of obesity status (obese group, $P = 0.023$; non-obese group, $P < 0.001$). Non-sarcopenic non-obese subjects 60 years of age or older had significantly higher FRS than did individuals in the other age groups ($P = 0.016$).

Thus, an association between sarcopenia and Framingham risk factors was confirmed in the elderly group rather than in the younger groups. The effects of sarcopenia by age may have differed due to differences in the causes of sarcopenia with-age. Sarcopenia in younger individuals may be associated with a reduction in the total mass of skeletal muscle, whereas sarcopenia in the elderly may have been due to a selective reduction in type 2 muscle fibers that prevent metabolic and cardiovascular diseases.^[24, 25]

It is notable that the 40–59 year-olds show a statistically significant association between sarcopenia and FRS regardless of obesity status (obese group, $P = 0.023$; non-obese group, $P < 0.001$), suggesting sarcopenia status is significant not only for elderly individuals, but also for middle-aged individuals. In a study by Moon, individuals 40–59 years of age and those 60 years of age or older showed a correlation between metabolic diseases and sarcopenia.^[26] Thus, an association between sarcopenia and metabolic and cardiovascular diseases was confirmed not only in an elderly population, but also in a middle-aged population.

Another notable finding is that obese individuals 60 years of age or older did not show a statistically significant asso-

ciation between sarcopenia and FRS ($P = 0.130$), in contrast to our expectation that obesity and sarcopenia would have a synergistic influence on cardiovascular diseases. This result suggests that obesity and sarcopenia may affect cardiovascular diseases in different ways. Future studies should focus on the interactions between obesity and sarcopenia. In contrast, the subjects 60 years of age or older in the sarcopenic non-obese group had high FRS. From this, we assume that sarcopenia may be a meaningful risk factor for cardiovascular diseases in non-obese elderly populations ($P = 0.016$).

The limitations of this study are as follows. First, muscle power and/or muscle function was not measured before diagnosing sarcopenia in the subjects in our study. Sarcopenia was simply defined as low skeletal muscle mass for body weight, and a substantial decrease in muscle power and function was not considered. Second, this was a cross-sectional study, so causality between sarcopenia and cardiovascular diseases could not be determined. Third, diagnoses were made without blood tests or radiologic evidence of cardiovascular diseases, so the effects of the presence or absence of cardiovascular diseases were not considered. Fourth, gender differences were not considered.

Despite these limitations, we believe that this study is meaningful. We utilized data from the KNHANES, which represent the Korean population. In addition, sarcopenia was confirmed to be associated with risk factors for cardiovascular diseases. In particular, an association between sarcopenia and FRS was confirmed. Accordingly, sarcopenia appears to be a predictive or risk factor for cardiovascular diseases. We also found that the association between sarcopenia and risk factors for cardiovascular diseases increased with age. Particularly among sarcopenic middle-aged individuals, the risk of cardiovascular diseases increased regardless of obesity status, suggesting that sarcopenia is not just a risk factor for cardiovascular diseases among the elderly. Therefore, sarcopenia, which has been used as an important indicator of cardiovascular risk in the elderly population, may also be used as such in middle-aged populations. Further large-scale cohort studies should focus on the associations between sarcopenia and cardiovascular diseases with regard to gender differences and the pathophysiology of sarcopenia.

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