METABOLIC SYNDROME AND RELATED DISORDERS
Volume 17, Number 10, 2019
Mary Ann Liebert, Inc.
Pp. 494–499
DOI: 10.1089/met.2019.0059

Association of Sarcopenia with Metabolic Syndrome in Korean Population Using 2009–2010 Korea National Health and Nutrition Examination Survey

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Abstract

Background: Some studies have investigated the relationship between sarcopenia and metabolic syndrome, and they have focused mainly on older subjects. Therefore, we assessed the association between sarcopenia and metabolic syndrome in South Korean adults 20 years of age or older using data from the 2009–2010 Korean National Health and Nutrition Examination Survey (KNHANES).
Methods: This study involved 12,256 (5350 males and 6906 females) participants from the 2009–2010 KNHANES 20 years of age or older. Appendicular skeletal muscle mass (ASM) was measured by dual X-ray absorptiometry. Sarcopenia index (SI) was calculated as ASM/body mass index and sarcopenia was defined as an SI of <0.789 in males and <0.521 in females. Metabolic syndrome was defined by the presence of at least three of the following abnormalities: abdominal obesity, high blood pressure, high blood glucose level, high triglyceride level, and low high-density lipoprotein cholesterol level.
Results: After adjustment for covariates, the association between sarcopenia and metabolic syndrome was significant (odds ratio [OR] 2.06, 95% confidence interval [CI] 1.74–2.45). In addition, when stratified by age groups, the significant associations between sarcopenia and metabolic syndrome remained in all age groups (20–39 years: OR 2.13, 95% CI 1.08–4.19; 40–64 years: OR 2.13, 95% CI 1.68–2.71; ≥65 years: OR 1.98, 95% CI 1.54–2.54).
Conclusion: The association between sarcopenia and metabolic syndrome was significant in South Korean adults. Moreover, the significant associations were present in every age group evaluated.

Keywords: sarcopenia, central obesity, dyslipidemia, hypertension, impaired fasting glucose

Introduction

The prevalence of metabolic syndrome is increasing globally.[1] The prevalence was ~34.7% in 2011–2012 in the United States,[2] and ~23% of Japanese adults in their 30s or older were diagnosed with metabolic syndrome in 2011.[3] The prevalence of metabolic syndrome in Korea increased steadily from 27.5% in 2008 to 28.9% in 2013.[4] As a result, the cost of medical treatment for metabolic syndrome in Korea increased from 3.7 trillion won in 2010 to 4.7 trillion won in 2014, with an expected increase of 6.2% per year.[5]

Insulin resistance is the major cause of metabolic syndrome.[6] As blood glucose levels increase in response to an increase in insulin resistance, insulin secretion further increases and results in hyperinsulinemia, and hyperinsulinemia restricts sodium excretion in the kidneys, resulting in hypertension.[7] It also increases triglyceride (TG) and decreases high-density lipoprotein cholesterol (HDL-C) levels, resulting in dyslipidemia.[8]

Sarcopenia is defined as reductions in muscle mass and muscle strength due to changes in body composition.[9] The prevalence of sarcopenia was estimated to be more than 50 million adults worldwide in 2000 and is expected to increase to more than 200 million by 2040.[10] The 2008–2011 Korea National Health and Nutrition Examination Survey (KNHANES) estimated the prevalence of sarcopenia in Korea to be 26.8%.[11]

The mechanism of sarcopenia has not yet been clarified, but it has been associated with various factors such as aging,

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malnutrition, lack of exercise, and reduced levels of hormones such as testosterone and cortisol.[12] Furthermore, increased body fat resulting from decreased muscle mass seen in patients with sarcopenia is associated with cardiovascular and metabolic diseases.[13] However, the relationship between sarcopenia and metabolic syndrome is still unclear. Several authors have reported an association between sarcopenia and metabolic syndrome,[14] whereas others found no such association,[15] and yet others reported that the association differs depending on sex.[16] In addition, previous studies on the association between sarcopenia and metabolic syndrome have focused mainly on older subjects.[14,17] However, the prevalence of metabolic syndrome is also increasing in younger populations.[18] Therefore, we investigated the association between sarcopenia and metabolic syndrome in all adults in Korea using the 2009–2010 KNHANES.

Materials and Methods

Study population

This study used data from the 2009–2010 KNHANES. As previously published in detail,[19] the KNHANES is a nationwide cross-sectional survey conducted annually by the Korea Centers for Disease Control and Prevention (KCDCP). The KNHANES uses a rolling sampling design involving a complex, stratified, multistage probability-cluster survey of a representative sample of the noninstitutionalized Korean citizens residing in Korea. KNHANES consisted with three component surveys: the health interview, health examination, and nutrition survey. The health interview and nutrition survey questionnaires are administered by trained interviewers, and the health examinations are performed by trained medical staff. The KCDCP Ethics Committee approved the study protocol (2009-01CON-03-2C, 2010-02CON-21-C), and written informed consent was obtained from all subjects or their parents.

The number of participants in the 2009–2010 KNHANES was 19,491 (10,533 in 2009 and 8958 in 2010), among whom, 14,963 (7920 in 2009 and 7043 in 2010) people participated in both the health interview and the health examination, including whole body dual-energy X-ray absorptiometry (DXA) scans, and 13,201 were older than 20 years. In total, 12,256 participants (5350 males and 6906 females) were analyzed, after excluding 272 subjects with missing appendicular skeletal muscle mass (ASM) data and 673 who did not undergo blood testing.

Data collection

Trained investigators interviewed the subjects individually using a questionnaire. Monthly household income was divided into quartiles. Educational level was divided into <6, 7–9, 10–12, and ≥13 years. Marriage status was classified as unmarried or married, and area of residence was classified as urban or rural. Current smoking was defined as smoking frequently or occasionally, and monthly drinking was defined as one or more drinks during the last month. Physical activity was defined as walking for >30 min at a time at least six times per week. Strength training was defined as exercising the muscles more than once per week. Weight was measured to the nearest 0.1 kg, while the subjects were dressed in light clothes, and height was measured to the nearest 0.1 cm in stocking feet. Waist circumference was measured to the nearest 0.1 cm at expiration through a horizontal plane around the abdomen midway between the lowest rib and iliac crest. Blood pressure was measured after the subject had rested for 5 min in a sitting position. Three readings each of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded, and the average values were used in the analyses. Number of co-morbidities was categorized as diagnosis of 0, 1, 2, or ≥3 of hypertension, diabetes, dyslipidemia, stroke, myocardial infarction, angina pectoris, cancer, cirrhosis, and kidney failure. The blood samples were collected by a trained nurse and transported daily to the central laboratory of NEODIN Medical Institute (Seoul, Korea). The total cholesterol, TG, and HDL-C levels were determined using the Hitachi Automatic Analyzer 7600 (Hitachi Ltd., Tokyo, Japan) according to standard procedures.

Sarcopenia

ASM was measured by dual X-ray absorptiometry (QDR 4500A; Hologic, Inc., Bedford, MA). The sarcopenia index (SI) was calculated as ASM (kg)/body mass index (BMI, kg/m^2), and sarcopenia was defined as an SI of <0.789 in males and <0.521 in females based on the criteria of the Sarcopenia Project.[20]

Metabolic syndrome

A diagnosis of metabolic syndrome was defined as the presence of three or more of the following five components: high blood pressure, high blood glucose level, high TG level, and lower HDL-C level using the diagnostic criteria of the National Cholesterol Education Program Adult Treatment panel III (NCEP-ATP III) based on common clinical measures,[21] and the abdominal obesity using the criteria of the Korean Society for the Study of Obesity.[22] Among the metabolic syndrome components, abdominal obesity was defined as a waist circumference ≥90 cm for males or ≥80 cm for females, high blood pressure as SBP ≥130 mmHg or DBP ≥85 mmHg or the use of antihypertensive medication, high blood glucose as a fasting blood glucose (FBG) level ≥100 mg/dL or the use of diabetic medication, a high TG level as ≥150 mg/dL or the use of dyslipidemia medication, and a low HDL-C level as <40 mg/dL for males or <50 mg/dL for females, or the use of dyslipidemia medication.

Statistical analysis

Data were analyzed using SPSS (version 23.0; IBM, Armonk, NY). The survey responses were weighted by reference to the multistage, complex, probability sampling design. Data were expressed as absolute number and estimated percentages (with standard errors) or as mean ± standard deviation (SD). The survey responses were weighted by reference to the multistage, complex probability sampling design. The χ^2 test or Student's *t*-test was used to evaluate the differences in demographic and clinical characteristics according to sarcopenia. A multivariate logistic regression analysis was performed to investigate the association of sarcopenia with metabolic syndrome. Adjustment for sex, age, monthly household income, educational level, marital status, area of residence, current smoking, monthly drinking, physical activities and strength training, and number of co-morbidities were performed. A value of $P < 0.05$ was considered indicative of statistical significance.

Table 1. Baseline Characteristics of Subjects According to Sarcopenia

Variable	Total		Sarcopenia		Nonsarcopenia		P
	N	e% (SE) or mean ± SD	N	e% (SE) or mean ± SD	N	e% (SE) or mean ± SD	
Number	12,256	100.0 (0.0)	1442	9.5 (0.5)	10,814	90.5 (0.5)	
Metabolic syndrome patient	3305	24.7 (0.5)	739	51.1 (1.7)	2566	21.9 (0.5)	<0.001
Male	5350	50.2 (0.5)	603	44.4 (1.5)	4747	50.8 (0.5)	<0.001
Age (years)							<0.001
20–39	3903	40.3 (0.9)	111	11.8 (1.2)	3792	43.3 (1.0)	
40–64	5799	47.0 (0.8)	593	48.8 (1.6)	5206	46.8 (0.8)	
≧65	2554	12.7 (0.5)	738	39.4 (1.7)	1816	9.9 (0.4)	
Monthly household income							<0.001
Lowest	2402	16.1 (0.6)	514	32.6 (1.7)	1888	14.4 (0.6)	
Medium-lowest	2942	24.6 (0.8)	385	25.7 (1.7)	2557	24.5 (0.8)	
Medium-highest	3393	29.7 (0.8)	308	25.1 (1.6)	3085	30.2 (0.8)	
Highest	3377	29.5 (0.9)	214	16.6 (1.5)	3163	30.9 (1.0)	
Education level							<0.001
≦Elementary school	3149	18.9 (0.7)	766	47.6 (1.9)	2383	15.9 (0.6)	
Middle school	1382	10.3 (0.4)	215	15.0 (1.2)	1167	9.8 (0.4)	
High school	4150	38.6 (0.7)	286	23.5 (1.4)	3864	40.1 (0.8)	
≧College	3499	32.2 (0.9)	162	14.0 (1.3)	3337	34.1 (0.9)	
Marital status							<0.001
Married	10,600	79.9 (0.7)	1385	93.9 (0.9)	9215	78.4 (0.8)	
Unmarried	1638	20.1 (0.7)	54	6.1 (0.9)	1584	21.6 (0.8)	
Residence							0.002
Urban	9317	79.9 (2.0)	1008	74.2 (3.0)	8309	80.5 (2.0)	
Rural	2939	20.1 (2.0)	434	25.8 (3.0)	2505	19.5 (2.0)	
Current smoking	2670	27.2 (0.5)	223	19.5 (1.4)	2447	28.0 (0.6)	<0.001
Monthly drinking	6580	59.9 (0.7)	617	48.5 (1.7)	5963	61.1 (0.7)	<0.001
Physically active[a]	5237	43.4 (0.6)	616	41.4 (1.6)	4621	43.6 (0.7)	0.220
Strength training[b]	3149	29.0 (0.6)	245	19.6 (1.4)	2904	30.0 (0.6)	<0.001
No. of co-morbidities[c]							<0.001
0	6403	57.8 (0.7)	388	28.6 (1.5)	6015	60.9 (0.7)	
1	3310	25.7 (0.5)	439	32.1 (1.5)	2871	25.0 (0.5)	
2	1695	11.5 (0.4)	387	25.6 (1.5)	1308	10.0 (0.4)	
≧3	799	5.0 (0.2)	222	13.6 (1.1)	577	4.1 (0.2)	
Height (cm)		164.0 ± 0.1		154.5 ± 0.3		165.0 ± 0.1	<0.001
Weight (kg)		63.9 ± 0.1		62.0 ± 0.4		64.1 ± 0.1	<0.001
BMI (kg/m^2)		23.7 ± 0.0		25.9 ± 0.1		23.4 ± 0.0	<0.001
Waist circumference (cm)		80.9 ± 0.2		86.6 ± 0.4		80.3 ± 0.2	<0.001
SBP (mmHg)		116.5 ± 0.3		126.4 ± 0.6		115.5 ± 0.3	<0.001
DBP (mmHg)		75.3 ± 0.2		77.5 ± 0.4		75.0 ± 0.2	<0.001
FBG (mg/dL)		96.8 ± 0.3		105.9 ± 1.0		95.8 ± 0.3	<0.001
TG (mg/dL)		135.8 ± 1.4		166.8 ± 4.2		132.5 ± 1.6	<0.001
HDL-C (mg/dL)		48.1 ± 0.1		45.7 ± 0.4		48.4 ± 0.1	<0.001

[a]Physically active was indicated as ''yes'' when the subject walked for more than 30 min at a time and more than five times per week.
[b]Strength training was indicated as ''yes'' when the subject exercised strength training for more than 30 min at a time and more than one time per week.
[c]Co-morbidities included hypertension, diabetics, dyslipidemia, cerebral vascular disease, arthritis, cancer, liver cirrhosis, and renal insufficiency.
BMI, body mass index; DBP, diastolic blood pressure; e%, estimated percentage; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; SD, standard deviation; SE, standard error; TG, triglyceride.

Results

Baseline characteristics of subjects according to sarcopenia

The baseline characteristics of subjects according to sarcopenia are shown in Table 1. The prevalence of sarcopenia and metabolic syndrome was 9.5% and 24.7%. Among the subjects, 27.2% currently smoked, 59.9% had consumed alcohol in the past month, and 43.4% were physically active. The subjects with sarcopenia were older, had a lower monthly household income, had a lower educational level, were predominantly married, resided mainly in a rural area, smoked and drank less, and performed less strength training than those with nonsarcopenia (all $P < 0.001$, except $P = 0.002$ for residing in a rural area). The mean BMI, waist circumference, and levels of SBP, DBP, FBG, and TG were higher, whereas the HDL-C level was lower, in the subjects with sarcopenia than in those with nonsarcopenia (all $P < 0.001$).

Prevalence of metabolic syndrome according to sarcopenia

The prevalence of metabolic syndrome according to sarcopenia is shown in Table 2. The five components of metabolic syndrome (abdominal obesity, high blood pressure, high blood glucose level, high TG level, and low HDL-C level) were all higher in subjects with sarcopenia than in those with nonsarcopenia (all $P < 0.001$). In addition, metabolic syndrome prevalence was higher in the subjects with sarcopenia than in those with nonsarcopenia ($P < 0.001$).

Odds ratios for sarcopenia according to metabolic syndrome

The odds ratios (ORs) for sarcopenia according to metabolic syndrome are shown in Table 3. The crude ORs for sarcopenia were statistically significant (OR 3.73, 95% confidence interval [CI] 3.21–4.33). After adjusting for sex, age, monthly household income, education level, marital status, residence, current smoking, monthly drinking, physical activities, strength training, and number of co-morbidities, the OR showed that the significant association between metabolic syndrome and sarcopenia remained (OR 2.06, 95% CI 1.74–2.45).

Table 2. Prevalence of Metabolic Syndrome According to Sarcopenia

Variable	*Sarcopenia*	*Nonsarcopenia*	P
Abdominal obesity[a]	49.2 (2.1)	22.4 (0.6)	<0.001
Higher blood pressure[b]	54.6 (1.7)	29.3 (0.7)	<0.001
Higher blood glucose[c]	45.9 (1.5)	24.0 (0.6)	<0.001
Higher triglyceride[d]	43.6 (1.6)	27.3 (0.5)	<0.001
Lower HDL-C[e]	54.3 (1.7)	41.1 (0.6)	<0.001
Metabolic syndrome	51.3 (1.7)	21.9 (0.5)	<0.001

All values are presented as estimated percentage (SE).
[a]Abdomal obesity is defined as waist circumference ≥90 cm (male) or ≥80 cm (female).
[b]Higher blood pressure is defined as SBP ≥130 mmHg or DBP ≥85 mmHg.
[c]Higher blood glucose is defined as FBG ≥100 mg/dL.
[d]Higher triglyceride is defined as TG ≥150 mg/dL.
[e]Lower HDL-C is defined as HDL-C < 40 mg/dL (male) or <50 mg/dL (female).

Table 3. Odds Ratios for Sarcopenia According to Metabolic Syndrome

	Nonadjusted	*Adjusted*[a]
Variables	*OR (95% CI)*	*OR (95% CI)*
Nonmetabolic syndrome	*Reference*	*Reference*
Metabolic syndrome	3.73 (3.21–4.33)	2.06 (1.74–2.45)

[a]Adjusted by sex, age, monthly household income, education level, marital status, residence, current smoking, monthly drinking, physical activities, strength training, and number of co-morbidities.
CI, confidence interval; OR, odds ratio.

ORs for sarcopenia according to metabolic syndrome stratified by age group

The ORs for sarcopenia according to metabolic syndrome stratified by age group are shown in Table 4. After adjusting for same covariates, the association between metabolic syndrome and sarcopenia was significant in subjects 20–39 years (OR 2.13, 95% CI 1.08–4.19), 40–64 years (OR 2.13, 95% CI 1.68–2.71), and ≥65 years (OR 1.98, 95% CI 1.54–2.54) of age.

Discussion

This study investigated the relationship between sarcopenia and metabolic syndrome in Korean adults using data from the 2009–2010 KNHANES. After adjustment for covariates, we found that sarcopenia was significantly associated with metabolic syndrome. In addition, after stratifying the study population by age, this significant association remained in all age groups.

There is no consensus on clinical diagnostic standards for sarcopenia, and previous researchers have used different diagnostic criteria: ASM/height^2,[23] ASM/weight,[24] and ASM/BMI.[20] Baumgartner et al.[23] diagnosed sarcopenia as an ASM/height^2 > 2 SD below the mean in a young reference population and they reported that sarcopenia prevalence of 14% and >50% in those 65–69 and ≥80 years of age, respectively, in New Mexico. Janssen et al.[24] defined sarcopenia using ASM/weight and the sarcopenia prevalence was 7% and 11% in male and female ≥80 years of age. A problem associated with the various diagnostic methods in prior studies is the selection of a young healthy reference population. In addition, the ability to compare results is limited since the reference populations differ among studies. Therefore, to clarify the diagnostic criteria for sarcopenia, the Foundation for the National Institutes of Health (FNIH) Sarcopenia Project used data from nine cohorts and defined sarcopenia as an ASM/BMI of <0.789 for males and <0.521 for females, without comparison to a young reference population.[20]

The prevalence of sarcopenia in South Koreans differed from study to study due to various diagnostic criteria. In this study using the FNIH definition, we found that the prevalence of sarcopenia was 9.5% (male 8.4% and female 10.7%) in ≥20 years of age and 14.1% (male 12.7% and female 15.4%) in ≥40 years of age. In a study using 2008–2009 KNHANES data, sarcopenia was defined according to two methods: ASM/height^2 and ASM/weight that was greater than 2 SD below the mean in healthy individuals 20–

Table 4. Odds Ratios for Sarcopenia According to Metabolic Syndrome Stratified by Age Group

		Nonadjusted	*Adjusted*[a]
Age (years)	*Metabolic syndrome*	*OR (95% CI)*	*OR (95% CI)*
20–39	Nonmetabolic syndrome	Reference	Reference
	Metabolic syndrome	3.42 (2.08–5.63)	2.13 (1.08–4.19)
40–64	Nonmetabolic syndrome	Reference	Reference
	Metabolic syndrome	2.53 (2.06–3.11)	2.13 (1.68–2.71)
≥65	Nonmetabolic syndrome	Reference	Reference
	Metabolic syndrome	2.07 (1.68–2.55)	1.98 (1.54–2.54)

[a]Adjusted by sex, monthly household income, education level, marital status, residence, current smoking, monthly drinking, physical activities, strength training, and number of co-morbidities.

39 years of age. The prevalence of sarcopenia in males and females >40 years of age was 12.4% and 0.1% according to ASM/height^2 and 9.7% and 11.8% according to ASM/-weight, respectively.[25] In another study based on 2008–2011 KNHANES data, sarcopenia was defined according to ASM/weight, and the prevalence of sarcopenia in subjects >20 years of age was 26.8%,[11] which was significantly higher than our results (9.5%). The reason for the higher prevalence of sarcopenia is that the authors used an ASM/weight >1 SD below the mean in a young reference population instead of an ASM/weight >2 SD as the diagnostic criteria for sarcopenia.

In this study, after adjustment for other covariates, the association between sarcopenia and metabolic syndrome was significant. In a meta-analysis of middle-aged and older nonobese adults,[26] sarcopenia was significantly associated with metabolic syndrome (OR 2.01, 95% CI 1.63–2.47), which is consistent with our results. In a previous study involving 1971 elderly Japanese subjects ≥65 years of age,[16] metabolic syndrome was significantly associated with sarcopenia in males (OR 2.08, 95% CI 1.22–3.54), but not in females. In Korea, 4183 postmenopausal females were analyzed using the 2008–2011 KNHANES data,[14] and a statistically significant relationship was identified between sarcopenia and metabolic syndrome (OR 1.97, 95% CI 1.51–2.56).

In this study, after stratifying the study population by age, the association between sarcopenia and metabolic syndrome was significant in all age groups evaluated (20–39, 40–64, and ≥65 years). In a previous study of 5300 adults 19–39 years of age, which used 2008–2010 KNHANES data, low muscle mass was defined according to ASM/weight and was significantly associated with metabolic syndrome in young adults, which is consistent with our results.[27] Most previous studies have evaluated the relationship between sarcopenia and metabolic syndrome in the elderly because muscle mass and muscle strength are assumed to decrease the most with age. However, it has been reported that the percentage of total lean body mass begins to decrease starting in the early 30s, and that sarcopenia can occur in younger populations.[28] However, in the case of sarcopenia, the pattern varies according to age. Sarcopenia in the elderly is accompanied by selective atrophy of type II muscle fibers, whereas sarcopenia in young adults is accompanied by an overall decrease in muscle mass.[29]

Metabolic syndrome consists of five components: abdominal obesity, high blood pressure, high blood glucose level, high TG level, and low HDL-C level. Insulin resistance and inflammation are considered the central mechanisms responsible for metabolic syndrome.[30] Several mechanisms may underlie the association between sarcopenia and metabolic syndrome. First, skeletal muscle is the most important organ for systemic glucose homeostasis[31] and is responsible for ~80% of normal glucose absorption and metabolism by insulin stimulation under normal conditions.[32] Second, a decrease in muscle mass leads to an increase in fat mass by reducing the basal metabolic rate.[33] Increased levels of fat increase the secretion of inflammatory cytokines such as tumor necrosis factor-alpha and interleukin (IL)-6[34] and increase insulin resistance, which can eventually lead to metabolic syndrome.[31,35] Third, skeletal muscle cells express and secrete many myokines, including IL-6, IL-8, IL-15, fibroblast growth factor 21, irisin, myonectin, and myostatin.[36] Most myokines are controlled primarily by exercise and muscle exertion. They offset the deleterious effects of inflammatory cytokines and have beneficial effects on glucose and lipid metabolism as well as inflammation.[37]

The limitations of this study are as follows. First, it was difficult to clarify causality because of the cross-sectional design. Second, a new guideline of the European Working Group on Sarcopenia in Older People in 2018 recommended measuring muscle strength as well as muscle mass to diagnose sarcopenia.[10] However, the 2009–2010 KNHANES did not measure muscle strength. Nevertheless, this study is meaningful in that, it investigated the relationship between sarcopenia and metabolic syndrome in all adults older than 20 years using representative data from Korea.

In conclusion, after adjusting for covariates, the association between sarcopenia and metabolic syndrome was significant in South Korean adults. Moreover, after stratifying by age groups, the significant associations between sarcopenia and metabolic syndrome remained in all age groups.

Author Disclosure Statement

No conflicting financial interests exist.

Funding Information

This study was supported by research fund from Chosun University, 2018.

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