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ASSOCIATION OF LOW MUSCLE MASS AND ISOKINETIC STRENGTH WITH METABOLIC SYNDROME

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ABSTRACT

Background and objectives

Sarcopenia and metabolic syndrome (MetS) increase incidence with age. This study evaluated the prevalence of MetS in middle-age to elderly men according to knee and grip strength and muscle mass.

Methods

Data from 256 males aged 40–69 years were analyzed. The impedance method was used to assess appendicular skeletal muscle mass (ASM). Muscle strength was measured grip strength with a dynamometer and 60°/s knee strength with isokinetic machine. Strength and muscle mass were divided into quartiles, and logistic regression analyses were performed.

Results

Absolute strength was not significantly prevalent in MetS, but MetS prevalence was significantly higher in participants with lower relative strength and muscle mass values ($p<0.05$). The group with the lowest relative ASM showed a 3.604-fold increase in MetS prevalence compared to highest ASM. Lowest relative knee extension strength group increased by 3.308 (95% CI 1.201–8.064) and relative knee flexion strength increased by 2.390 (95% CI 1.006–5.560) in MetS prevalence compared to the highest strength group. Lowest muscle mass and extension strength group increased by 6.8-fold compared to the highest muscle mass and strength group.

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Conclusions
Relative values of strength and muscle mass divided by body weight were significantly associated with MetS. Therefore, having high muscle strength and muscle mass along with low body weight will prevent MetS.

Key Words: *metabolic syndrome; strength; muscle mass; prevalence*

INTRODUCTION

Sarcopenia is diagnosed by measuring low muscle strength, low muscle quantity and quality, and low physical performance according to the European Working Group on Sarcopenia in Older People 2 (EWGSOP 2).[1] Because sarcopenia is considered to be a major health-related factor, WHO (World Health Organization) assigned it as disease code ICD-10-CM in 2016.[2]

Decreased muscle mass and function reduces metabolic rate, insulin sensitivity, and physical activity; and these events increased the accumulation of excess energy in the body and lowered the glucose metabolism.[3,4] Sarcopenia is also known to have a negative impact on cardiovascular disease, related risk factors, and mortality.[5–7]

Metabolic syndrome (MetS) seems to be associated with low physical activity, low fitness, and reduced strength, as well as age.[8,9] Among these, muscle strength is the cause of cardiovascular disease and is also a major diagnostic factor of sarcopenia. Because of this relevance, previous researchers have conducted studies on decreased muscle mass, strength, and MetS. Kawamoto et al.[10] reported that high grip strength lowers the prevalence of MetS. One study found that elderly group without MetS had significantly higher knee extension (EXT) strength than the group with MetS.[11] However, isokinetic muscle strength measuring instrument, one of the various muscle strength measuring instruments, is relatively rare compared to grip strength study. It is likely that isokinetic equipment has relatively long test times and high cost compared to grip strength.[12] Thus, this study analyzed the prevalence of MetS associated with leg muscle strength, as well as appendicular skeletal muscle (ASM) mass, and relative weight by examining the relationship between strength and MetS prevalence using grip strength and isokinetic strength measurement equipment.

METHODS

The total number of subjects was 458 in Seoul Asan Medical Center during 2015–2016, excluding 202 women and subjects under 40 years of age. Final data from 256 males aged 40–69 years who performed all tests indicated in this study among those who visited the health screening center were selected and analyzed. Subjects were asked to fast for at least 8 h; water was permitted. Light clothing and slippers were provided. Participants were asked to fill out and submit medical questionnaires. This information was checked during the examination, as were any additional complaints, and then vitals were measured, and tests were conducted. Body measurements, blood sampling, and blood pressure were obtained first, and then impedance and body circumference were measured.

Strength tests were performed last. Participants warmed up before the test. Only the data of those who agreed to participate in the study were analyzed, and all personally identifiable information was deleted or encrypted. This study was conducted following Institutional Review Board (IRB) approval (Asan Medical Center, S2018-0155-0004).

MetS Diagnosis

The criteria for the diagnosis of MetS were adapted from The National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) as follows: blood pressure, above 130/85 mmHg, below high density lipoprotein cholesterol (HDL-C) 40 mg/dL, fasting blood glucose above 100 mg/dL, and triglycerides above 150 mg/dL.[13] Hypertension, diabetes, and dyslipidemia were also included in diagnoses, and the criterion for abdominal obesity was above 90 cm of waist circumference.[14] Hematologic hemorrhage was analyzed by clinicians, and abdominal obesity, height, and weight were measured by the nurse. Waist circumference was measured horizontally using a tape measure with reference to the umbilicus line.

Appendicular Skeletal Muscle Mass

ASM was measured by bioelectrical impedance analysis method Inbody 770 (Inbody Inc., Seoul, Korea). Contact areas were wiped with alcohol (hands and feet), and the arms and legs were spread apart so there were no skin overlaps. In this study, ASM was measured by totaling the muscle mass values from all limbs. Absolute (ASM) and relative (ASM/body weight) values were analyzed.

Grip and Isokinetic Knee Strength Measurement

A CSMi isokinetic dynamometer and HUMAC software (CSMi HUMAC NORM, USA) were used to measure knee EXT and flexion (FLX). The test was conducted according to standard guidelines by device company.[15] The test was performed four times at 60°/s, and the highest value was selected. Values were recorded as Newton meter divided by body weight (Nm/kg). Experiments were conducted by an exercise specialist, and participants were urged to exert maximum strength during EXT and FLX. Right and left sides were examined, and the highest values for each were used. In subsequent analysis, EXT and FLX were evaluated.

In tests for grip strength, the patient was instructed to stand with his legs shoulder width apart, arm extended, and hand pointed toward the thigh. A grip strength Takei 5401 (Takei Inc., Japan) was used, and the length was adjusted to the 2nd middle phalanx bone. The participant would grip his fist upon the start signal as much as possible. Absolute values were isokinetic knee strength (Nm) and grip strength (kg), and relative values were isokinetic knee strength (Nm/weight) and grip strength (kg/weight).

Data Analysis

Statistical calculations were performed using SPSS 25.0 (IBM SPSS Inc., USA). For general characteristics, the mean and standard deviation were divided by the presence of MetS and then analyzed by independent *t*-test. Participants were placed in four groups by quartile using absolute and relative values. Strength and muscle mass were highest in G1 and lowest in G4. Strength and muscle mass were then divided into four different groups: HH, high muscle mass and strength; HL, high muscle mass and low strength; LH, low muscle mass and high strength; LL, low muscle mass and strength. Logistic regressions were performed to analyze the prevalence (odds ratio, OR) of MetS. Adjustment variables were age, alcohol consumption, and smoking. Significant value was considered $p<0.05$.

RESULTS

Patient Characteristics

The experimental group comprised 78 MetS and 178 non-MetS patients. Age, weight, and BMI were significantly higher in the MetS group than the non-MetS group (Table 1). No significant differences in height among patients were observed, but differences in MetS- and obesity-related factors were significant. For body composition, fat percentages and mass were significantly higher in MetS patients, while ASM percentages were significantly higher in non-MetS patients ($p<0.05$). Non-MetS patients also scored significantly higher in grip strength (kg/BW), knee EXT (Nm/kg), and knee FLX (Nm/kg) than MetS patients ($p<0.05$).

MetS Prevalence According to ASM and Strength

Table 2 shows the absolute and relative values for muscle mass and strength in the study

TABLE 1 General Characteristics of Subjects

	Non-MetS (n=178)	MetS (n=78)	p
Age, years	55.6±8.5	59.8±9.3	<0.001*
Height, cm	169.9±5.9	169.5±6.7	0.648
Weight, kg	68.7±7.8	76.1±10.0	<0.001*
BMI, kg/m^2	23.8±2.0	26.4±2.6	<0.001*
MetS factors			
SBP, mmHg	120.5±13.9	132.8±16.3	<0.001*
DBP, mmHg	74.5±10.3	82.2±10.5	<0.001*
Waist circumference, cm	83.8±6.3	92.9±7.7	<0.001*
HDL-C, mg/dL	56.6±13.8	48.7±11.3	<0.001*
TG, mg/dL	115.4±73.9	179.1±94.1	<0.001*
Glucose, mg/dL	101.3±21.3	115.9±24.1	<0.001*
Strength factors			
Knee EXT, Nm	130.1±33.7	123.1±33.0	0.124
Knee EXT, Nm/BW	189.4±41.2	162.5±42.3	<0.001*
Knee FLX, Nm	73.5±20.0	70.1±22.4	0.238
Knee FLX, Nm/BW	106.3±25.8	92.2±26.3	<0.001*
Grip strength, kg	37.7±6.5	36.2±6.4	0.089
Grip strength, kg/BW	54.9±8.4	48.2±9.9	<0.001*
Body composition			
Body fat mass, kg	13.1±3.7	17.8±5.5	<0.001*
Body fat percent, %	18.8±4.1	23.1±5.2	<0.001*
ASM, kg	16.8±2.2	17.3±2.3	0.105
ASM, %	24.6±2.4	22.9±1.9	<0.001*

*Data are presented as mean ± SD. *p<0.05.*
MetS, metabolic syndrome; SBP, systolic blood pressure; DBP, diastolic blood pressure; EXT, extension; FLX, flexion; HDL-C, high density lipoprotein cholesterol; TG, triglyceride; Nm/BW, Newton meter/ body weight.

participants. Because both sarcopenia and MetS are associated with increased age, this study adjusted age, alcohol consumption, and smoking. Prevalence of MetS in absolute values decreased only in ASM; no significant differences were observed for the other variables. Values for the relative-low ASM group were 2.6-fold higher, the values for the lowest ASM group were 3.6-fold higher, and the values for the lowest knee EXT strength group were 3.3–3.4-fold higher than the highest EXT strength group. Values for the lowest FLX strength increased 2.3-fold compared to

TABLE 2 MetS Prevalence According to Muscle Mass and Strength

	G1	G2	G3	G4
Absolute value				
ASM, kg	1	0.386 (0.172–0.870)*	0.217 (0.086–0.544)*	0.146 (0.048–0.449)*
Knee EXT, Nm	1	0.571 (0.259–1.258)	0.536 (0.238–1.205)	0.414 (0.160–1.069)
Knee FLX, Nm	1	0.918 (0.433–1.944)	0.604 (0.270–1.351)	0.760 (0.310–1.866)
Grip strength, kg	1	0.839 (0.397–1.772)	0.533 (0.238–1.191)	0.731 (0.310–1.723)
Relative value				
ASM, kg/BW	1	1.556 (0.638–3.794)	2.681 (1.159–6.202)*	3.604 (1.201–8.064)*
Knee EXT, Nm/BW	1	2.063 (0.924–4.608)	3.457 (1.498–7.977)*	3.308 (1.346–8.131)*
Knee FLX, Nm/BW	1	2.045 (0.964–4.338)	1.105 (0.484–2.522)	2.390 (1.006–5.680)*
Grip strength, kg/BW	1	2.120 (0.965–4.660)	1.929 (0.876–4.248)	4.755 (2.092–8.810)*

*Logistic regression analyses of the association of muscle mass and strength quartiles with MetS Data are presented as adjusted OR (95% CI). *p <0.05. All data were adjusted to age, alcohol consumption and smoking. ASM, appendicular skeletal muscle mass; EXT, extension; FLX, flexion; G1, highest muscle or strength; G2, high muscle or strength; G3, low muscle or strength; G4, lowest muscle or strength; Nm/BW, Newton meter/body weight; OR, odd ratio; CI, confidence interval.*

the highest FLX. The highest OR value was found for relative grip strength (OR 4.755, 95% CI 2.092–8.810).

For absolute ASM, significant results obtained for G4 (OR 0.146, 95% CI 0.048–0.449) suggested that as ASM decreased, the prevalence of MetS decreased.

Combination of Strength and Muscle Mass, and MetS Prevalence

Table 3 displays the four groups divided according to strength and ASM. The LH and LL groups showed significant results. Absolute ASM values for LH and LL decreased as prevalence decreased, but relative values of body weight demonstrated an inverse relationship. In relative values, the prevalence rate of 2.465- to 3.644-fold was increased in the LH group. In the LL group, it increased 3.654- to 6.845-fold. These findings suggest that increasing muscle mass may help prevent MetS.

DISCUSSION

Sarcopenia is a syndrome of great interest to scholars and clinicians and is now classified as its own disease (disease code ICD-10-CM).[2] Of the many ways to diagnose and interpret sarcopenia, muscle mass alone is less than ideal due to its proportional relationship with weight gain and increase in fat mass. Therefore, in the elderly, sarcopenic-obesity using relative ASM and weight values will be more meaningful than ASM values alone, as they can reveal whether the body has less muscle relative to the increase in body weight.[16,17]

This study investigated the prevalence of MetS associated with reductions in isokinetic leg strength, grip strength, and muscle mass as analyzed by impedance. This study did find an association between isokinetic knee strength and MetS prevalence. In the results of the study, an analysis of absolute values did not yield significant results. However, in quartile analyses using relative values, EXT, FLX, and grip strength were significant that the lower the relative strength, the higher the prevalence of MetS. These results are similar to those from previous studies. Analyses of whole-body lean mass percentages and MetS prevalence showed a 3.34-fold increase in the

TABLE 3 MetS Prevalence According to Combination of Muscle Mass and Strength

	HH	HL	LH	LL
Absolute value				
ASM and EXT	1	0.597 (0.289–1.234)	0.309 (0.14–0.679)	0.144 (0.054–0.383)
ASM and FLX	1	1.286 (0.585–2.828)	0.356 (0.141–0.902)*	0.279 (0.119–0.658)*
ASM and grip	1	1.121 (0.525–2.395)	0.316 (0.125–0.798)*	0.274 (0.119–0.629)*
Relative value				
ASM and EXT	1	1.964 (0.657–5.874)	3.522 (1.275–5.734)*	6.845 (3.596–9.954)*
ASM and FLX	1	0.457 (0.134–1.563)	2.867 (1.343–6.122)*	3.654 (1.644–8.124)*
ASM and grip	1	0.695 (0.206–2.349)	2.465 (1.115–5.448)*	4.990 (2.396–7.391)*

*Logistic regression analyses of the association of muscle mass and strength quartiles with MetS data are presented as adjusted OR (95% CI). *p <0.05. All data were adjusted to age, alcohol consumption, and smoking. ASM, appendicular skeletal muscle mass; EXT, extension; FLX, flexion; HH, high muscle and high strength; HL, high muscle and low strength; LH, low muscle and high strength; LL, low muscle or low strength; OR, odd ratio; CI, confidence interval.*

least muscle group and 2.15-fold increase in the lowest grip strength group.[18]

Decreases in strength and muscle mass occur with aging naturally. Strength and muscle mass peak between 20 and 30 years of age and decrease thereafter.[19] According to a study conducted by Goodpaster et al.,[20] muscle mass decreased by an average of 1% per year, with muscle strength decrease of 3.4% in white men, 4.1% in black men, 2.6% in white women, and 3.0% in black women. Decreases in strength were greater than decreases in muscle mass.[20] Another study reported that strength was at its highest between 20 and 30 years of age, remained virtually unchanged until age 50, and then declined by 12 to 15% per decade thereafter,[21] and also reported greater decreases in strength than muscle mass overall. In another study measuring muscle mass and strength in the legs, decreases in muscle mass averaged about 1%, while decreases in strength averaged from 1.5 to 5%.[19]

Although the muscle mass and muscle strength decrease with aging, the muscle mass and muscle strength increase with weight gain. Therefore, this study is divided into relative value by divided body weight and absolute value.

As a result, the lower the absolute value of ASM, the lower the prevalence of MetS (OR 0.146, 95 % CI 0.048–0.449). These results may be related to the increased risk MetS as well as increased muscle mass, as explained above. Conversely, the lower the relative strength and ASM, the higher MetS prevalence (Tables 2 and 3). This may be a natural consequence. These results were similar to those of previous studies in which relatively high grip strength lowered the prevalence of MetS.[10,22]

One of the major results of this study is about the isokinetic knee strength. Knee strength is important in the elderly because it is strongly linked with mobility for all activities of daily living (ADL) as walking, stair and sit to stand.[23] Reduced mobility and reduced activity are important indicators therein because problems due to lack of exercise, including outdoor activity, occur chronologically.

When relative EXT and FLX isokinetic strength were compared in terms of MetS, higher OR (3.308 vs. 2.390) values were found for EXT than for FLX (Table 2). This might be because the knee EXT has greater weight-bearing capacity and is more involved in walking and daily living than the knee FLX, which acts in more of an auxiliary capacity; hamstring muscle development is naturally lower than that for quadriceps muscles.[24]

The reason for this result can be deduced from the study of leg muscle and aging relationship. A high correlation between aging and quadriceps muscle strength was reported inversely in a Japanese study that measured muscle mass at eight areas, including the quadriceps and hamstring. Results of this study indicated that the most prominent decrease in mass due to aging occurred in the quadriceps.[25] Significant differences between the young and the elderly were also noted for the individual regions of the quadriceps (the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis).[26]

Table 3 displays comparisons between the HL (high muscle and low strength) and LH (low muscle and high strength) groups. Significant OR values were found in the LH and LL groups with less muscle mass than in the HH and HL groups with more muscle mass. These results suggest that MetS is more related to muscle mass than strength. In a study by Hurley,[21] reductions in strength were not seen until after age 50. This means that when you are an elderly person, strength and muscle mass decrease rapidly, so different results may be obtained from many elderly with reduced strength in this study. In a study by Artero et al.,[27] high strength could reduce abdominal obesity, hypertension, and body weight. And Srikanthan et al.[28] reported that the low fat-high muscle group had lower cardiovascular mortality (HR: 0.38) than the low fat-low muscle group. It is very cautious to draw conclusions about what is more important in muscle and strength in this result, and it is thought that further research is necessary.

There are several hypotheses for this decrease in muscle mass and strength with aging. Physical inactivity may explain the chemical and hormonal changes caused by changes in muscle-related acetylcholine or myostatin secretion, or by unloading or immobilization of muscles to promote muscle regression, but no apparent cause has been identified.[29] Until now, the most realistic solution to prevent obesity and sarcopenia is to combine resistance exercise with aerobic exercise.[30]

This study does have some limitations that must be acknowledged. Because it is a cross-sectional study, we cannot prove a causal relationship between muscle strength, muscle mass and MetS. Thus, it is not known how much improvement in MetS will occur when strength and muscle mass are improved. In addition, we cannot be certain if grip strength is higher than knee strength in Table 2, or which extremity should be exercised more as a result. Also, subject selection bias was unavoidable due to the fact that only screened patients were considered for the study. To address these issues, we recommend conducting an intervention study in the future to verify the effectiveness of strength and fundus training in the elderly and to confirm the effectiveness thereof via longitudinal, follow-up observations. While some have suggested that strength training is dangerous in the elderly, such training practiced and supervised by a professional reduces the chance of injury.[31] Additionally, gait speed was used as a tool to evaluate physical performance and function in sarcopenia, but this study could not measure and include it. In future studies, it will be necessary to analyze the impact of walking speed. Finally, since this study was conducted exclusively on men, further studies are needed for women.

CONCLUSION

Relative values of ASM and strength divided by body weight were correlated with MetS. The higher the absolute muscle mass and strength, the higher the prevalence of MetS. However, the higher the relative muscle mass and strength, the lower the prevalence of MetS.

MetS prevalence increased by 3.6-fold in the lowest relative ASM group, 3.3-fold in the lowest leg EXT strength group, and 4.7-fold in the lowest grip strength group. Therefore, having high muscle strength and muscle mass along with low body weight will prevent MetS.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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