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Original Research

Sex Differences in the Prevalence of Metabolic Syndrome Based on Leg Strength, Cardiorespiratory Fitness, and Skeletal Muscle Mass in Elderly

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Abstract

Background: Metabolic syndrome (MetS) is characterized by abdominal obesity, high blood glucose, and dyslipidemia. Low fitness, muscle mass, and strength increase the risk of MetS. The characteristics of these variables are highly interrelated. This cross-sectional study aimed to analyze the prevalence of MetS by combining leg strength (LSTR), cardiorespiratory fitness (CRF), and appendicular skeletal muscle mass (ASM) in elderly men and women. **Methods**: Participants included 1420 persons aged 65–79 years (men: 753, women: 667). An isokinetic dynamometer was used to measure LSTR; CRF was evaluated by measuring maximum oxygen uptake; and ASM was assessed using bio-impedance analysis. The measured CRF, LSTR, and ASM were converted to relative values by dividing by body weight and grouped into 'high' and 'low' based on the median value. The diagnosis of MetS was based on five criteria: waist circumference, blood pressure, high-density lipoprotein cholesterol, triglycerides, and fasting glucose. MetS was diagnosed when the participant fulfilled 3 or more of the criteria, and odds ratios (ORs) were analyzed using logistic regression. **Results**: MetS was diagnosed in 32.1% and 30.3% of men and women, respectively. The relative LSTR and ASM values were significantly higher in the non-MetS group compared to those of the MetS group in both sexes. The OR for MetS in men was 3.6-fold higher in the low LSTR group, 3.5-fold higher in the low CRF group, and 2.3-fold higher in the low ASM group than in the high groups. In women, the OR for MetS increased 1.3-fold in the group with low LSTR and 3.7-fold in the group with low CRF. The OR for MetS exhibited a 3.5-fold increase in men and a 2.4-fold increase in women for combined low LSTR and low ASM compared to those of the combined high LSTR and high ASM group. Despite high ASM, the OR for MetS was a 3.5-fold higher in men and a 3.9-fold in women for low LSTR and low CRF group. **Conclusions**: The prevalence of MetS increased in elderly with relatively decreased LSTR, ASM and decreased CRF. Furthermore, the prevalence of MetS is increased when both LSTR and ASM are low despite high CRF. In addition, even if ASM was low, the risk of metabolic syndrome did not increase when both CRF and LSTR were high. In conclusion, when two or more of the three variables CRF, LSTR, and ASM were low, the prevalence of MetS increased.

Keywords: leg strength; cardiorespiratory fitness; appendicular skeletal muscle mass; prevalence; metabolic syndrome; sex differences

1. Introduction

Metabolic syndrome (MetS) is diagnosed when several cardiovascular risk factors such as high waist circumference, blood pressure, blood glucose, and triglycerides, and low levels of high-density lipoprotein cholesterol (HDLC), are simultaneously present. Individuals with MetS are more likely to develop coronary heart disease or stroke [1,2]. A meta-analysis reported that MetS increased the risk of stroke 1.7-fold [3]. Thomsen *et al*. [4] reported that individuals with MetS exhibited a 1.39-fold increased risk of myocardial infarction despite having normal weight.

Factors contributing to MetS include unmodifiable factors like age and heredity, and modifiable factors such as unhealthy dietary habits and low activity [1]. Moreover, typical exercise-related factors include low cardiorespiratory fitness (CRF), leg strength (LSTR), and appendicular skeletal muscle mass (ASM) [2]. Among them, high CRF has been studied for a long time as having a preventive effect on cardiovascular diseases [5,6]. A follow-up study with a large sample size revealed that MetS occurred in 31% of men with the lowest CRF whereas the prevalence was only 4% in men with the highest CRF [6]. In the CRF study of middle-aged men, the prevalence of MetS was reduced by 57% in the highest quartile group compared to the lowest quartile group [7]. The LSTR is one of the representative lower body functions that measure the strength of the quadriceps or hamstrings. A high LSTR not only facilitates sports and daily activities, but also lowers the risk of MetS [8]. For the LSTR, Jurca *et al*. [9] measured the bench press and leg press strengths of 3233 men and grouped them into quartiles. The hazard ratio of MetS in the upper one-fourth group decreased by 24% compared to the lower four-fourth group. Lastly, ASM is not only related to muscle strength, but also a space where glucose metabolism takes place. Thus, individuals with high ASM have lower insulin resistance and lower risk of cardiovascular disease due to active glucose metabolism [10]. A previous study revealed that individuals with low ASM exhibited a 3.3-fold increased prevalence with MetS compared to individuals with high ASM [11].

However, the CRF, LSTR, and ASM variables are closely related, but not necessarily consistent with each other. CRF measures aerobic capacity, whereas ASM is the muscle mass of the arms and legs, and strength is the force generated by the muscle, and evaluates the quality of the muscle [12,13]. The CRF does not necessarily exhibit a linear relationship with LSTR because aerobic exercise is required to improve CRF, and strength training is required to increase ASM and LSTR [14,15]. Depending on the individual, the ASM may be high even if the CRF is low, or the CRF may be high even if the muscle strength is low. However, few studies use these combinations of variables for MetS prevalence in elderly.

In the past, cardiovascular disease was more noted in men than in women, but in recent years, the risk of MetS appears equal for both sexes [16,17]. A Chinese study reported that the prevalence of MetS was 50.99% in men and 49.01% in women [18], and Korean study reported a prevalence of 57.1% in women and 43.7% in men. Therefore, this study aimed to analyze the prevalence of MetS in elderly men and women using combination of CRF, LSTR, and ASM. Additionally, we studied the sex differences in MetS prevalence and characteristics.

2. Methods

2.1 Participants

The participants were 1420 patients (men: 753; women: 667) aged 65–79 years who visited the Healthcare Center of Hospital for disease prevention and care. They voluntarily participated based on information advertised on a bulletin board and a recruitment guide. Written informed consent was obtained from all participants before enrollment in the study. This study conformed to the guidelines of the Declaration of Helsinki and was approved by the institutional review board of Gangneung-Wonju National University (approval number: 202016).

2.2 Medical Examination

All test equipment and devices were calibrated and accuracy was confirmed by the biomedical engineering team each morning. The medical examination sequence was designed considering safety and the effect of interference between tests. Participants were instructed to fast for at least 8 h, and the examinations were conducted in the morning. Additionally, smoking, caffeine intake, and excessive exercise with sweaty intensity were prohibited. All participants completed a health questionnaire that included disease and medication history, smoking status, alcohol consumption, and physical activity. When the participants visited, their identities were confirmed by the receptionist on duty before consultation with a doctor. The physician assessed the current health condition based on the medical examination, and if there were abnormalities, further medical tests were conducted.

2.3 Body Composition

Body weight and body composition were measured using Inbody 770 (InBody Co., Seoul, Korea); height was measured using a stadiometer (BSM230; Inbody Co., Seoul, Korea). The appendicular skeletal muscle mass (ASM) was evaluated using bioelectrical impedance analysis with the Inbody 770 (Inbody Inc., Seoul, Korea). For the bioelectrical impedance analysis measurement, the hands and the feet were cleaned using alcohol before the test. Electrodes were placed on the handle and footrest, and the foot and hand were properly positioned. The participants adopted the measurement posture with the arms and legs spread and the waist and chest straight. The absolute ASM was calculated using the sum of the muscle mass of the arms and legs, whereas the relative value was calculated using this value, divided by the body weight of the patient.

2.4 Metabolic Syndrome

Trained nurses used a validated mercury sphygmomanometer to measure blood pressure. For the test, the participants sat in a chair in a quiet place for at least 5 min. A cuff size that covered at least 80% of the arm was used. The participants' placed the feet on the floor and the arm was elevated to the level of the heart. The radial pulse was confirmed by palpation and the cuff was inflated 20–30 mmHg above this level for auscultation. The cuff deflation rate for auscultation readings was 2 mmHg per second. Systolic blood pressure (SBP) was defined as the point at which the first Korotkoff sound was heard, and the diastolic blood pressure (DBP) was defined as the point of the last Korotkoff sound. At least two measurements were taken and the average was reported [19].

A nurse collected blood samples (~25–30 mL) at the median cubital vein and the samples were analyzed enzymatically using an automated chemical analyzer (TBA-200FR; Toshiba, Tokyo, Japan) [20]. HDL cholesterol, triglycerides (TG), and fasting glucose values were obtained from the blood samples.

The waist circumference was measured by the research staff using a measuring tape. The participant's feet were spread about 25–30 cm apart, and the waist, chest and head were held straight before horizontal measurement of the medial area below the last rib and above the anterior iliac crest [21].

MetS was diagnosed based on the Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (NCEP-ATP III) [22]. The criteria for the waist circumference was applied based on World Health Organization (WHO) recommendations for Asians considering the characteristics of race [23]. The criteria for MetS were as follows: SBP ≥130 mmHg, DBP ≥85 mmHg, TG ≥150 mg/dL, HDL cholesterol <50 mg/dL for women and <40 mg/dL for men, and glucose ≥100 mg/dL The waist circumferences for abdominal obesity were ≥80 cm for women and ≥90 cm for men. Individuals taking related prescription medications were considered to have risk factors, even if blood pressure, lipid, and glucose values were normal. Participants with 3 or more of the 5 defined MetS criteria were classified as the MetS group, whereas those having 0–2 criteria were classified as the non-MetS group.

2.5 Leg Strength

For the LSTR test, knee extension and flexion were measured using an isokinetic dynamometer (Humac Norm, CSMi, Stoughton, USA). For safe and accurate examination, the participant's posture and the measurement method used were according to the manufacturer's standard guidelines [24]. Before the test was conducted, the health status of the knee was assessed. Participants undergoing treatment for a history of surgery or knee pain were excluded. The participants performed cycling and stretching for 15 min to warm up before the tests were conducted. Participants were seated on the test equipment with backrests; the handle was held, and the torso, pelvis, and the unexamined knee were fixed with pads. The test knee was bent at 90°, the axis of the equipment was aligned with the lateral epicondyle of the femur, and the test pad was strapped to the distal tibia.

To familiarize the participants with the test equipment, the examiner explained the process thoroughly, and the participants practiced at low, medium, and high angular velocities. The starting posture was with the knee bent at 90°. When the examiner gave a signal, the participant was instructed to perform knee extension of up to 0°. When a subsequent signal was provided, the participant was instructed to bend the knee, returning it to the initial position. The test was repeated four times at an angular velocity of 60°/s in concentric contraction mode. The maximum strength adopted was recorded in Nm, as an absolute value, and the relative value was calculated by dividing the absolute value in Nm by the body weight (Nm/BW). The sum of the extension and flexion values was used for the analysis.

2.6 Cardiorespiratory Fitness

CRF was evaluated using a stepwise exercise test to determine the maximum oxygen uptake (VO2peak) using a treadmill and gas analyzer (Vmax229; Sensormedics Corp., Yorba Linda, CA, USA). To ensure that the test was conducted safely, the procedure complied with the American College of Sports Medicine (ACSM) guidelines [25]. The Bruce graded exercise test method was used in which the treadmill speed and inclination were increased every 3 min, thereby gradually increasing the overall exercise intensity. The test began with walking speed, and the speed was gradually increased every 3 min, to achieve the intensity of brisk walking and then running. Electrocardiogram monitoring and examination under the supervision of a cardiologist were performed to ensure safety during the evaluation. The test was performed by a certified ACSM exercise physiologist and could be terminated at the request of the participant or discontinued by the tester in case of any clinical abnormality during testing. In such cases, the data were excluded from the analysis. The absolute values were recorded in L/min and relative values in mL/BW/min.

2.7 Data Analysis

To calculate the required sample size, G*power (G*power 3.1, University of Düsseldorf, Düsseldorf, Germany) was used, and the conditions were as follows: odds ratio (OR), 1.3; Pr (Y = 1Ix = 1 H0, 0.2; power, (1-β err prob) = 0.80; R2 other x, 0). SPSS 25.0 (IBM SPSS Inc., Armonk, NY, USA) was used for data analysis. General characteristics were expressed as means ± standard deviations, and participants with and without MetS were compared. A normal distribution was not obtained with the Kolmogorov–Smirnov test; accordingly, the nonparametric Mann–Whitney U-test was performed for between group comparisons. The relationship between health behaviors and MetS was evaluated using the chi-square test. Logistic regression analysis was performed to calculate the ORs. For prevalence analysis, groups were classified as High or Low as determined from the median values. Adjusted variables included age, alcohol consumption, and physical activity. The final analysis combined two independent variables to create four groups. High and Low groups for CRF, LSTR, and ASM were combined accordingly to create High–High, High–Low, Low–High, and Low–Low groups. The High–High group was set as the reference group, and ORs were calculated. The significance level was set at $p < 0.05$. The confidence interval was 95%, and the upper and lower values were indicated.

3. Results

Table 1 shows the general characteristics of the MetS and non-MetS groups. The prevalence of MetS was similar in both sexes (32.1% *vs.* 30.3% in men and women, respectively). In both men and women, age ($p < 0.001$), body weight ($p < 0.001$), and body mass index (BMI) ($p < 0.001$) exhibited significant differences between the MetS and non-MetS groups. Further, there was a significant difference in the relative and absolute values of LSTR, CRF, and ASM between the MetS and the non-MetS groups in men. The absolute values of LSTR and ASM were significantly higher in the MetS group in men, whereas the relative values were significantly higher in the non-MetS group. In women, the relative values of LSTR and CRF were significantly higher in the non-MetS compared to those of the MetS group.

In the MetS and non-MetS groups, alcohol consumption, smoking status, and physical activity displayed statistical significance in men, whereas alcohol consumption and physical activity exhibited statistical significance in women.

Table 2 classified the participants into high and low groups based on the medians of the relative values. In men, waist circumference, blood pressure, glucose, and HDLC exhibited significant differences between groups regarding LSTR, CRF, and ASM. In women, waist circumference, systolic blood pressure, and glucose were significantly different between the high and low groups with respect to LSTR, CRF, and ASM (Table 3).

Table 4 presents the ORs for MetS according to low and high values of LSTR, CRF, and ASM. Men in the low LSTR group were 3.607 times more likely to have MetS compared with those in the high LSTR group, and men with low ASM exhibited a 4.320-fold increased risk for MetS compared to men with high ASM. Women's MetS increased 1.301 and 3.774 times in the groups with low LSTR and low CRF compared to high LSTR and high CRF groups, respectively.

Table 5 shows the combinations of two variables used to analyze the OR for MetS. The reference groups were those when the two variables were high. For LSTR and CFR, men with LSTR High–CRF Low exhibited 2.236 times the OR for having MetS compared to the LSTR High–CRF High group. For men, the OR for MetS in the LSTR Low–CRF Low group increased 4.732-fold compared to the LSTR High–CRF High group. Regarding LSTR and ASM in men, the OR for MetS increased 4.586-fold in the LSTR Low–ASM Low group compared to the LSTR High–ASM High group. Despite decreased ASM in men, there was no significant increase in MetS when LSTR or CRF was high.

In women, the OR for MetS increased 4.927 times in the LSTR Low–ASM Low group compared to that of the LSTR High–ASM High group. Moreover, in women with low ASM, there was no significant increase in the OR for MetS if their LSTR or CRF was high.

In Fig. 1, OR was calculated by combining the low and high values of three variables. Similar results were obtained for both men and women. Despite high ASM in men, the OR for MetS was 3.580 times higher for low LSTR and low CRF group. In women, the OR for MetS was 3.950 times higher for low LSTR and low CRF group, despite high ASM.

4. Discussion

This study investigated the OR of MetS using the CRF, LSTR, and ASM in elderly. One of the main findings of this study was that low CRF increased the ORs for MetS up to 3.5 and 3.7 times in men and women, respectively. These results are in agreement with those of previous studies [26,27]. In a meta-analysis of 33 studies, an increase in CRF by 3.5 mL/kg/min decreased mortality and morbidity from cardiovascular disease by 13% and 15%, respectively [28]. In addition, the prevalence of MetS was 5.4% in men with high CRF and 13.9% in those with low CRF [27]. In a subsequent analysis with CRF in which the risk for MetS was evaluated per quartile, it was found that the lowest quartile group exhibited a 3.6-fold higher risk than the highest quartile group [26]. A representative strategy to improve CRF is to continuously perform moderate-intensity aerobic exercise. The pathophysiological changes through aerobic exercise are as follows. It has the effect of improving the elasticity of blood vessels, causing a blood pressure reduction effect, improving obesity through the gluconeogenesis process, and improving glucose efficiency by lowering insulin resistance. Therefore, high CRF may exert the preventive effect of MetS [13,29].

Low LSTR and CRF increased the OR for MetS in this study. In a study using isokinetic equipment similar to the equipment used in this study, the MetS increased by a factor of 3.3 in the group with the lowest leg extension strength, and 2.3 times in the group with the lowest flexion strength [11]. Similar to this study, leg extensors were classified into quartiles in a study measured using isokinetic equipment. The risk of MetS increased 2.5-fold in the group with the lowest strength compared to the group with the highest strength [30]. In a study measuring the one repetition maximum (1RM) using the leg press and the bench press, the incidence of MetS among those with the highest strength decreased by 24% [9]. Nevertheless, some studies reported no significant relationship between muscle strength and MetS. Bisschop *et al.* [31] reported that while leg extension power exhibited a significant relationship with fasting blood glucose and waist circumference, this resulted in no significant change in the prevalence of MetS. However, this result may be due to non-consideration of relative strength, as calculated considering the body weight. Mesinovic *et al.* [32] observed no significant differences in absolute values of leg strength between groups with and without MetS; however, relative values were significantly lower in the MetS group. In this study, absolute and relative values were investigated, but the main analysis used relative values for strength, CRF, and ASM. Since weight gain tends to increase muscle mass as well as fat content, analyses using relative values were conducted in several previous studies regarding ORs for MetS [31–34].

A major characteristic of this study is that we combined three variables and analyzed the ORs for High-High–High, High-High-Low, High-Low-High, and High-Low-Low groups etc. Despite high ASM in men and women, the OR for MetS was increased for low LSTR and low CRF group. This method is uncommon, but it is occasionally conducted. Similar results were also reported in previous study. In a study that analyzed 8570 participants, those in the high strength-high CRF group displayed a 0.27 decreased MetS risk, in the context of normal BMI, compared to the low strength-low CRF group [33].

Muscle strength and muscle mass exhibit a linear relationship, because with the loss of muscle mass there is

Table 1. General characteristics of participants.

Variables	Men non-MetS (*n* = 511)	Men MetS (*n* = 242)	*p*-value	Women non-MetS (*n* = 465)	Women MetS (*n* = 202)	*p*-value
%	67.9%	32.1%		69.7%	30.3%	
Age, years	69.7 ± 8.8	72.7 ± 9.4	<0.001	68.6 ± 10.5	73.3 ± 7.8	<0.001
Height, cm	169.8 ± 5.9	169.6 ± 6.5	0.803	155.2 ± 5.7	154.7 ± 5.3	0.135
Weight, kg	68.7 ± 7.9	75.7 ± 10.1	<0.001	56.3 ± 7.1	62.6 ± 8.7	<0.001
BMI, kg/m^2	23.8 ± 2.0	26.2 ± 2.6	<0.001	23.4 ± 2.8	26.5 ± 3.0	<0.001
MetS risk factors						
Waist circumference, cm	83.8 ± 6.3	92.7 ± 8.0	<0.001	78.6 ± 7.4	86.8 ± 7	<0.001
SBP, mmHg	120.8 ± 13.7	135.9 ± 16.8	<0.001	120.2 ± 17.3	134.8 ± 18	<0.001
DBP, mmHg	75.0 ± 8.9	89.0 ± 8.7	<0.001	73.4 ± 9.6	86.4 ± 8.8	<0.001
HDLC, mg/dL	46.7 ± 13.9	38.1 ± 11.1	<0.001	61.8 ± 12.8	48.7 ± 10.8	<0.001
TG, mg/dL	112.5 ± 66.7	178.9 ± 93.5	<0.001	99.1 ± 41.9	164.5 ± 74.4	<0.001
Glucose, mg/dL	97.7 ± 19.5	117.2 ± 26.3	<0.001	96.1 ± 11.2	106.1 ± 13.8	<0.001
Absolute values						
LSTR, Nm	191.5 ± 54.9	204.3 ± 51.1	0.034	108.4 ± 30.9	112.7 ± 39.8	0.316
CRF, L/min	2.43 ± 0.61	2.14 ± 0.51	<0.001	1.55 ± 0.45	1.49 ± 0.31	0.271
ASM, kg	30.4 ± 3.2	31.7 ± 3.8	<0.001	22.1 ± 2.1	22.9 ± 2.6	0.104
Relative values						
LSTR, Nm/BW	2.78 ± 0.60	2.69 ± 0.71	<0.001	1.92 ± 0.52	1.80 ± 0.60	0.023
CRF, mL/BW/min	35.3 ± 7.4	28.3 ± 6.0	<0.001	27.5 ± 5.5	23.8 ± 4.3	<0.001
ASM, kg/BW	0.48 ± 0.04	0.41 ± 0.03	<0.001	0.39 ± 0.04	0.37 ± 0.04	0.067
Alcohol consumption, %						
None	78 (15.3%)	32 (13.2%)	0.004	90 (19.4%)	36 (17.8%)	0.023
Once/month	169 (33.1%)	53 (21.9%)		184 (39.6%)	68 (33.7%)	
Once/week	175 (34.2%)	102 (42.2%)		142 (30.5%)	85 (42.1%)	
≥2 times/week	89 (17.4%)	55 (22.7%)		49 (10.5%)	13 (6.4%)	
Smoking status, %						
Never	94 (15.9%)	35 (14.4%)	0.013	434 (93.3%)	176 (87.1%)	0.088
Quit	281 (53.0%)	104 (43.0%)		13 (2.8%)	17 (8.4%)	
Current	176 (31.1%)	103 (42.6%)		18 (3.9%)	9 (4.5%)	
Physical activity, %						
5–7 days/week	68 (13.3%)	27 (11.2%)	0.019	64 (13.8%)	21 (10.4%)	0.026
3–4 days/week	188 (36.8%)	63 (26.0%)		179 (38.5%)	54 (29.2%)	
1–2 days/week	155 (30.3%)	94 (38.8%)		142 (30.5%)	64 (34.2%)	
None	100 (19.6%)	58 (24.0%)		80 (17.2%)	63 (27.2%)	

$p < 0.05$; MetS, metabolic syndrome; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDLC, high density lipoprotein cholesterol; TG, triglyceride; LSTR, leg strength; CRF, cardiorespiratory fitness; ASM, appendicular skeletal muscle mass; BW, body weight.

a consequent reduction in the muscle strength. However, there is no consensus regarding whether muscle quality or quantity is more important, because there are conflicting results in various studies. In a previous study, muscle mass displayed a weaker relationship than muscle strength for mortality [35]. Meanwhile, Song *et al*. [36] demonstrated that there is a greater association between MetS and muscle mass than with strength or physical activity among community-dwelling older adults. Conversely, Atlantis *et al*. [37] reported that peak grip strength was more highly correlated than whole-body lean mass. Because high muscle mass and strength can be achieved through strength training, it is important to increase both. As a place where glucose or glycogen is used, the muscle not only exerts high muscle strength, but also increases the efficiency of glucose metabolism during exercise and has the effect of increasing the basal metabolic rate. And, high muscle mass may be associated with efficient glucose uptake and lipid metabolism, along with high levels of favorable myokines, and decreased insulin resistanc [38,39].

The best results are achieved when both muscle mass and strength are improved, so it is recommended to combine aerobic exercise and strength exercise to increase CRF, strength, and muscle mass. Marini *et al*. [39] reported that

Table 2. Men's metabolic syndrome factors based on relative values of variables.

Variables	LSTR			CRF			ASM		
	High	Low	*p*-value	High	Low	*p*-value	High	Low	*p*-value
	(*n* = 375)	(*n* = 378)		(*n* = 376)	(*n* = 377)		(*n* = 377)	(*n* = 376)	
Waist Cir., cm	84.3 ± 7.0	88.7 ± 8.3	<0.001	84.8 ± 6.6	88.2 ± 8.8	<0.001	82.7 ± 6.5	90.7 ± 7.3	<0.001
SBP, mmHg	120.3 ± 11.7	128.4 ± 17.9	<0.001	120.5 ± 12.3	128.2 ± 17.6	<0.001	120.0 ± 12.9	129.4 ± 17.1	<0.001
DBP, mmHg	76.3 ± 9.0	78.1 ± 10.8	0.026	75.4 ± 9.4	78.8 ± 10.3	<0.001	74.8 ± 9.2	79.8 ± 10.3	<0.001
HDLC, mg/dL	57.1 ± 15.9	51.2 ± 10.7	<0.001	56.7 ± 15.3	51.6 ± 11.6	<0.001	57.0 ± 15.3	50.8 ± 11.0	<0.001
TG, mg/dL	128.9 ± 87.3	137.7 ± 77.3	0.428	129.9 ± 81.5	136.7 ± 82.8	0.188	122.7 ± 80.1	144.8 ± 82.9	0.005
Glucose, mg/dL	100.1 ± 13.5	111.1 ± 28.1	<0.001	102.9 ± 18.3	108.5 ± 26.4	0.011	101.5 ± 19.4	110.5 ± 25.7	<0.001

$p < 0.05$; Waist cir., Waist circumference; LSTR, leg strength; CRF, cardiorespiratory fitness; ASM, appendicular skeletal muscle mass; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDLC, high density lipoprotein cholesterol; TG, triglyceride; BW, body weight.

Table 3. Women's metabolic syndrome factors based on relative values of variables.

Variables	LSTR			CRF			ASM		
	High	Low	*p*-value	High	Low	*p*-value	High	Low	*p*-value
	(*n* =120)	(*n* = 122)		(*n* = 124)	(*n* = 118)		(*n* = 122)	(*n* = 120)	
Waist Cir., cm	79.6 ± 7.8	82.8 ± 8.3	<0.001	79.7 ± 7.2	82.7 ± 8.8	<0.001	76.0 ± 6.3	86.1 ± 6.6	<0.001
SBP, mmHg	120.1 ± 18.2	128.7 ± 18.1	<0.001	122.5 ± 17.5	126.4 ± 19.5	0.028	122 ± 19.6	126.9 ± 17.4	0.004
DBP, mmHg	74.3 ± 10.4	76.3 ± 9.0	0.031	74.7 ± 9.6	75.9 ± 9.9	0.156	74.2 ± 10.7	76.3 ± 8.7	0.022
HDLC, mg/dL	57.8 ± 14.4	57.4 ± 12.9	0.654	58.6 ± 12.9	56.7 ± 14.2	0.117	59.9 ± 13.0	55.5 ± 13.8	<0.001
TG, mg/dL	115.5 ± 62.0	118.5 ± 58.8	0.918	105.1 ± 44	127.6 ± 70.3	<0.001	106.1 ± 51.0	127.0 ± 66.3	<0.001
Glucose, mg/dL	97.3 ± 11.3	101.3 ± 14.1	<0.001	96.5 ± 10.0	101.9 ± 14.8	<0.001	95.5 ± 11.5	102.8 ± 13.3	<0.001

$p < 0.05$; Waist cir., Waist circumference; LSTR, leg strength; CRF, cardiorespiratory fitness; ASM, appendicular skeletal muscle mass; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDLC, high density lipoprotein cholesterol; TG, triglyceride; BW, body weight.

Table 4. The odds ratios for MetS according to relative values of variables.

Variables	Group	non-MetS	MetS	*p*-value	OR (95% CI)	*p*-value
Men						
LSTR	High	308 (60.3%)	68 (28.1%)	<0.001	Reference	-
	Low	203 (39.7%)	174 (71.9%)		3.607 (1.241–6.541)	<0.001
CRF	High	287 (56.2%)	61 (25.2%)	<0.001	Reference	-
	Low	224 (43.8%)	181 (74.8%)		3.541 (1.520–7.513)	<0.001
ASM	High	315 (61.6%)	59 (24.4%)	<0.001	Reference	-
	Low	196 (38.4%)	183 (75.6%)		2.320 (1.120–5.385)	<0.001
Women						
LSTR	High	248 (53.3%)	86 (42.6%)	0.042	Reference	-
	Low	217 (46.7%)	116 (57.4%)		1.301 (1.029–3.608)	0.034
CRF	High	270 (58.1%)	56 (27.7%)	<0.001	Reference	-
	Low	195 (41.9%)	146 (72.3%)		3.774 (1.110–5.215)	<0.001
ASM	High	259 (55.7%)	89 (44.1%)	0.102	Reference	-
	Low	206 (44.3%)	113 (55.9%)		1.252 (0.844–3.010)	0.125

p-value < 0.05; LSTR, leg strength; CRF, cardiorespiratory fitness; ASM, appendicular skeletal muscle mass. Adjusted variables included age, alcohol consumption, smoking, and physical activity.

12 weeks of short-term, combined aerobic and resistance training had a positive effect in improving microvascular reactivity and glycated hemoglobin as well as increasing muscle strength in MetS patients. However, whether the effect of combined exercise is superior to that of aerobic exercise alone remains controversial. Therefore, more research is required to clarify this [40].

In our present study, the prevalence for MetS was similar in men and women. For decades, cardiovascular disease was considered to be more common among men than

Table 5. The odds ratio for MetS based on two combined variables.

Group	Men		Women	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
LSTR and CRF				
LSTR High–CRF High	Reference		Reference	
LSTR High–CRF Low	2.236 (1.444–6.271)	0.023	1.233 (0.242–1.603)	0.251
LSTR Low–CRF High	2.374 (1.865–6.254)	0.012	1.554 (0.980–4.729)	0.186
LSTR Low–CRF Low	4.732 (1.018–8.953)	<0.001	4.477 (1.088–5.636)	0.003
LSTR and ASM				
LSTR High–ASM High	Reference		Reference	
LSTR High–ASM Low	1.942 (0.907–5.060)	0.124	1.091 (0.564–1.477)	0.112
LSTR Low–ASM High	2.795 (1.171–5.752)	0.005	2.203 (1.465–4.847)	0.021
LSTR Low–ASM Low	3.586 (1.951–6.105)	<0.001	2.457 (1.197–5.048)	<0.001
CRF And ASM				
CRF High–ASM High	Reference		Reference	
CRF High–ASM Low	1.033 (0.578–3.077)	0.334	1.011 (0.736–3.462)	0.259
CRF Low–ASM High	2.177 (1.092–3.984)	0.032	1.845 (1.119–3.083)	0.015
CRF Low–ASM Low	3.235 (2.545–6.767)	0.005	2.194 (1.104–4.057)	<0.001

p -value $<$ 0.05; LSTR, leg strength; CRF, cardiorespiratory fitness; ASM, appendicular skeletal muscle mass.

Adjusted variables included age, alcohol consumption, smoking, and physical activity.

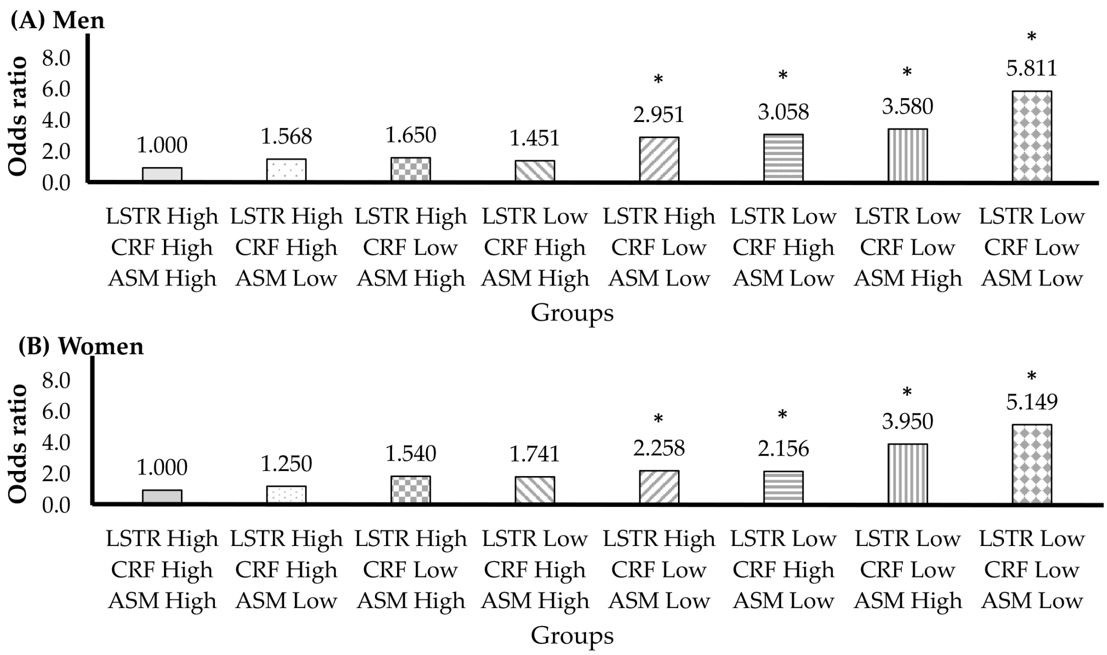

Fig. 1. The odds ratio based on combinations of leg strength, cardiorespiratory fitness, and appendicular skeletal muscle mass. (A) Men, (B) Women, * p-value $<$ 0.05; LSTR, leg strength; CRF, cardiorespiratory fitness; ASM, appendicular skeletal muscle mass. Adjusted variables included age, alcohol consumption, smoking, and physical activity.

women. However, recent studies have reported that women have an equally high incidence [16,41]. In a Korean study, 19.1% of men and 4.4% of women were affected among young adults; however, in adults >60 years of age, 34.5% of men and 39.1% of women were affected, with the ratio being apparently reversed [42]. The prevalence of MetS was 35.3% for men and 33.3% for women in a US-based study [43]. Moreover, 20.9% of men and 21.7% of women had MetS in a similar Chinese study [44].

Although women generally display lower rates of smoking and alcohol consumption than men, the high incidence of MetS may be attributed to lower physical activity and higher obesity rates [11,45]. In a Korean study that analyzed data over a period of 11 years, high physical activity of men was observed in an increasing proportion from 7.9% to 8.2%. This contrasted with women whereby high physical activity decreased from 8.1% to 7.5% [46]. Furthermore, in a Canadian study, the incidence of high TG, high SBP, and high plasma glucose in women was similar to or slightly lower than that of men. However, obesity based on waist circumference was 24.8% for men and 43.7% for women during the young adult stage, and was 48.5% for men and 65.5% for women during older adulthood [47]. In another study, it was announced that men had a higher obesity rate than women until the age of 20–44, but after that, women had a higher obesity rate than men [48]. Researchers study the phenomenon of women having a higher body fat percentage than men from the perspective of adipocyte biology or hormones such as leptin, insulin, and estrogen, but this field is still under discussion [49]. Scholars dealing with social problems have said that one of the causes of women's high disease is health inequality. It is said that there is still a class of health disadvantaged people by sex, race, region, and income level, and that they have low access to medical care and high disease morbidity [50,51].

The strengths of this study include the following factors. First, MetS was analyzed using various variables such as strength, CRF, and muscle mass. The characteristics of these variables are highly interrelated. However, even having a high CRF does not necessarily mean high LSTR and ASM. Therefore, the main strength of this study is the use of the number of cases of various variables. Second, leg muscle strength was measured using isokinetic equipment, and CRF measurement was undertaken using gas analysis and a treadmill. These test methods exhibit high accuracy and provide the most reliable values. Therefore, the measured values using these equipment are often used as gold standard values, and also serve as reference values to verify the reliability and validity of new test methods [52–54].

The results of this study suggest that for MetS prevention, aerobic exercise is required as well as resistance exercise to improve muscle strength and muscle mass. There are several limitations to this study. The cross-sectional design makes it difficult to ascertain causality. In addition, the sample size was relatively small, and investigations of socio-economic status, dietary and daily activities were not included. Recently, among the five diagnostic factors of MetS, abdominal obesity is being treated as an important factor [55]. Therefore, in future study, it will be an interesting topic to study the relationship between abdominal obesity and various physical strengths and MetS. This was a single-center study and was conducted based on voluntary participation. Therefore, there is a limit to the generalizability of the data, although MetS has regional characteristics, it was not reflected in this study [56]. Further research will require a longitudinal study design, and it will be valuable to investigate the effects of combined aerobic exercise and strength training in participants. In addition, 6-minute walking is convenient, economical, and reported very meaningful results for patients with cardiovascular disease [57]. Therefore, there is a need to replace and perform expensive tests such as gas analysis for CRF. Finally, in this study, we did not consider race. The US study conducted on various races investigated from 1988 to 2012, and the metabolic syndrome increased from 25.6% to 33.4% in men and increased from 25.0% to 34.9% in women. During that period, increases were 44% for non-Hispanic white women and 41% for non-Hispanic black women, but only 2% for Mexican American women. These results may be not only genetic, but also environmental and cultural factors [51].

5. Conclusions

Relatively lower LSTR, CRF, and ASM increase the risk of MetS in elderly men and women. Furthermore, the prevalence of MetS is increased when both LSTR and ASM are low despite high CRF. In addition, even if ASM was low, the risk of metabolic syndrome did not increase when both CRF and LSTR were high. In conclusion, when two or more of the three variables CRF, LSTR, and ASM were low, the prevalence of MetS increased. Conversely, when two or more of the three variables were high, the prevalence of MetS did not increase. This gave similar results in men and women. Therefore, having two of LSTR, CRF and ASM high could prevent MetS risk.

Author Contributions

Conceptualization—HC and YK; methodology—KY; formal analysis—KY and YK; investigation—HC; writing—original draft preparation—HC and KY; writing—review and editing—YK and KY; supervision—YK and KY; validation—KY. All authors have read and agreed to the published version of the manuscript.

Ethics Approval and Consent to Participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional review board of Gangneung-Wonju National University (approval number: 202016).

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Conflict of Interest

The authors declare no conflict of interest.

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