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RELATIVE GRIP STRENGTH CUT-OFF VALUES AND METABOLIC SYNDROME IN THE ELDERLY: THE KOREA NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY 2014–2017

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ABSTRACT

Background and objective

The study aimed to analyze the prevalence of metabolic syndrome (MetS) according to the absolute and relative hand grip strength (HGS) in people aged >60 years.

Materials and methods

The participants included 2721 adults aged between 60 and 79 years (1589 men and 1132 women) who completed measurements of HGS and variables related to MetS. The MetS criteria were 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) guidelines; and waist circumference determined by the Korean Society for the Study of Obesity. HGS was measured three times for each hand and the highest value was retained. After dividing the HGS values into quartiles, the highest group was defined as G1 and the lowest as G4. The prevalence of MetS in each group was reported as an odds ratio (OR) calculated using logistic regression analysis. The absolute and relative HGS cut-off values were used for the receiver operating characteristic (ROC) curve.

Results

Of the total participants, 695 men (43.7%) and 646 women (57.1%) were diagnosed with MetS. The absolute cut-off values for HGS were 36.0 kg (AUC 0.533, p=0.015) for men and 19.6 kg (AUC 0.506, p=0.017) for women. The relative cut-off values were calculated as 57.5% (AUC 0.633, p=0.014) for men and 38.9% (AUC 0.617, p=0.017) for women. The participants were divided into quartiles based on the relative HGS. The risk of MetS in the group with the lowest relative HGS (G4) was 5.00 ($p<0.001$) times greater for men and 2.74 ($p<0.001$) times greater for women than the highest relative HGS (G1).

Conclusion
The relative HGS value was higherin non-MetS subjects compared to the MetS subjects, and as the relative HGS value was lower, the prevalence of MetS increased to 5.00 times for men and 2.74 times for women.

Key Words: *elderly, grip strength, metabolic syndrome, prevalence*

INTRODUCTION

A diagnosis of the metabolic syndrome (MetS) is dependent on the patient exhibiting multiple cardiovascular risk factors. MetS is diagnosed when an individual meets three or more of five possible criteria: waist circumference, blood pressure (BP), triglycerides (TG), high density lipoprotein cholesterol (HDLC), and fasting glucose.[1] MetS should be considered and managed as a major disease; patients with MetS are likely to experience heart disease and stroke.[2] In a previous study on patients with MetS, the relative risks for all-cause mortality, myocardial infarction, and stroke were increased to 1.58, 1.99, and 2.27, respectively.[3] The physical and mental comorbidities of this disease are severe; they may be fatal or disabling. For instance, typical complications of stroke include paralysis.[4] The prevalence of MetS was 22.9% in the United States of America as of 2010, and 20.3% in South Korea as of 2015.[5,6]

HGS is a well-established indicator of human health. In 1965, studies reported the use of HGS to predict aging, measuring it simultaneously with other variables, including BP, lung capacity, and cholesterol.[7] Along with gait speed, HGS is also reported to be highly correlated to cardiovascular disease, mortality, and the capacity to perform daily life activities.[8] Recently, various working groups have used HGS as an indicator for diagnosing sarcopenia in the elderly. The 2018 Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) report recommends that 27 kg and 16 kg of HGS, for men and women, respectively, be considered the threshold for sarcopenia in the elderly.[9] The greatest advantages of HGS measurement are that it is safe, simple, and affordable, and has high reliability and validity.[10]

However, HGS tends to increase with weight gain,[11,12] and weight gain is also a risk factor for MetS.[13] Thus, higher HGS may be measured for people with MetS due to their increased body weight. In consideration of this limitation, the present study sought to investigate the risk of MetS in people over 60 years of age by utilizing both absolute HGS values and relative HGS values that consider body weight. In addition, suggested optimal HGS cut-off values for preventing MetS in the elderly are presented.

METHODS

Participants

This study used data from the Korea National Health and Nutrition Examination Survey conducted from 2014 to 2017. The number of participants aged between 60 and 79 was 8508 (3721 men and 4787 women). The results of 5787 participants for whom some of the MetS-related variables, HGS information, or responses to health-related surveys were not available were excluded from the analysis. Accordingly, this study finally considered the results of 2721 participants aged 60–79 years (1589 men and 1132 women) who completed all measurements of HGS, MetS risk factors, and health-related surveys including exercise, alcohol, and smoking status.

Metabolic Syndrome

Measurements were conducted using the criteria of the NCEP-ATP III.[14] The waist circumference measurement followed the criteria of the Korean Society for the Study of Obesity.[15] The cut-off value for waist circumference was ≥90 cm for men and ≥85 cm for women. The cut-off value for systolic blood pressure (SBP) was ≥130 mmHg; for diastolic blood pressure (DBP) ≥85 mmHg; and for TG ≥150 mg/dL. The HDLC cut-off value was <40 mg/dL for men and <50 mg/dL for women, and the fasting glucose cut-off value was ≥100 mg/dL. Participants taking medication for MetS were considered to have a diagnosis of MetS for the purposes of this study.

Hand Grip Strength

HGS was measured three times for each hand using a digital HGS test dynameter (model 5401, Takei Scientific Instruments Co., Ltd., Japan). Position and test protocol was followed according to the US National Health and Nutrition Examination Survey (NHANES) Muscle Strength Procedures Manual.[16] The subject stretched his back, arms, and legs in a standing position so that his arms did not touch the torso. The handle was adjusted such that participants achieved 90° flexion between the proximal and middle phalangeal joint.

The average of the two highest values for each hand was used to analyze absolute values. Relative values were obtained by expressing absolute values as a percentage of body mass; formula: (HGS (kg)/body weight (kg))×100. HGS values were divided into quartiles, with the highest-value group (highest 25%) named as G1, and the lowest-value group (lowest 25%) named as G4.

Health Behaviors

Health behaviors were evaluated using a questionnaire. The health behavior questionnaire assessed the participants' frequencies of aerobic exercise and weight training, and their drinking and smoking status. The frequency of aerobic exercise was classified as 0, 1–2, 3–5, or 6–7 days per week, and weight training as 0–1, 2–4, or 5–7 days per week. Smoking status was defined as never smoked, quit smoking, or active smoker. The frequency of drinking was classified as no drinking at all, once a month, 2–3 times a month, or more than twice a week.

Statistical Analysis

SPSS 25.0 (IBM SPSS Inc., Armonk, NY, USA) was used for analysis. General characteristics denoting the presence of MetS were described using the mean and standard deviation of the anthropometric values and diagnostic criteria: age, height, weight, and MetS risk factors. Noncontinuous variables such as health-related habits (exercise, alcohol, and smoking) were analyzed using chi-square tests. Prevalence was calculated using logistic regression analysis, and participant age, exercise habits, and drinking and smoking habits were included as adjusted factors. ROC curve and area under the curve (AUC) were used to define cut-off values. The statistical significance level was $p < 0.05$.

RESULTS

General Characteristics of Participants

The general characteristics of the study participants are provided in Table 1. Of the 2721 participants (1589 men and 1132 women), 43.7% of men and 57.1% of women were diagnosed with MetS. Comparing the individuals positive for MetS and those who were not, we noted statistically significant differences in weight and BMI but no differences were noted between age and height. Significant differences were found in all variables representing risk factors for MetS, including waist circumference, BP, TG, HDLC, and fasting glucose, except DBP for men. Comparing the absolute and relative HGS values of MetS patients and those of nonpatients by gender, there were significant differences for men in both absolute (34.5±6.4 vs. 36.3±6.6, $p=0.024$) and relative

TABLE 1 General Characteristics of Participants

	Men			Women		
	Non-MetS	**MetS**	**p**	**Non-MetS**	**MetS**	**p**
n, %	894(56.3%)	695(43.7%)		486(42.9%)	646(57.1%)	
Age, years	72.0±4.9	71.5±4.6	0.069	70.4±4.5	71.6±4.8	0.071
Height, cm	165.3±5.4	166±5.5	0.216	153.1±5.7	152.8±5.2	0.286
Weight, kg	61.9±7.9	69.3±8.6	<0.001*	54.1±7.4	59.3±7.9	<0.001*
BMI, kg/m^2	22.6±2.5	25.1±2.7	<0.001*	23.1±2.8	25.4±3.0	<0.001*
Mets factors						
Waist circumference., cm	82.8±7.4	91.0±7.6	<0.001*	79.4±7.8	87.0±8.1	<0.001*
SBP, mmHg	126.3±18.1	130.7±15.6	<0.001*	127.6±19	134.6±17.5	<0.001*
DBP, mmHg	72.8±10.0	73.6±10.2	0.124	73.2±10.1	74.9±10.6	<0.001*
TG, mL/Dl	104.8±52.2	175.9±91.6	<0.001*	104.4±42.3	159.3±97.5	<0.001*
HDLC, mL/dL	50.3±10.9	42.5±11.5	<0.001*	56.2±11.8	46.3±10.6	<0.001*
Glucose, mL/dL	101.8±23.2	118.4±30.3	<0.001*	95.1±12.6	112.3±28.0	<0.001*
Grip strength, kg	34.5±6.4	36.3±6.6	0.024*	21.8±4.4	21.7±4.7	0.622
Grip strength, % BW	56.1±9.9	51.2±9.3	<0.001*	40.6±7.8	37.0±8.1	<0.001*
Aerobic Ex, per week						
G1 (5–7 days)	28.2%	22.6%	0.157	16.0%	9.5%	0.009*
G2 (3–4 days)	25.1%	20.7%		18.3%	18.0%	
G3 (1–2 days)	23.4%	27.7%		33.4%	34.8%	
G4 (0 days)	23.4%	29.0%		32.4%	37.7%	
Weight Tr, per week						
G1 (5–7 days)	3.9%	2.9%	0.327	2.0%	1.0%	0.026*
G2 (2–4 days)	15.3%	13.2%		8.9%	5.4%	
G3 (0–1 days)	80.9%	83.9%		89.1%	93.7%	
Smoking experience						
Never	21.3%	16.4%	0.021*	95.1%	93.5%	0.253
Quit	62.0%	63.2%		2.3%	4.0%	
Present	16.8%	20.4%		2.7%	2.5%	
Alcohol frequency						
Never	22.5%	22.9%	0.290	32.9%	37.2%	0.246
1 time/month	21.4%	17.7%		48.6%	43.8%	
2–3 times/month	20.6%	22.9%		12.1%	11.0%	
≥ 2 times/week	35.6%	36.5%		6.4%	8.0%	

**p<0.05.*
MetS = metabolic syndrome; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; TG = triglycerides; HDLC = high density lipoprotein cholesterol; Ex = exercise; Tr = training; BW = body weight.

values (56.1±9.9 vs. 51.2±9.3. p<0.001). For women, there was no difference in the absolute values (21.8±4.4 vs. 21.7±4.7, p=0.622) but there was a significant difference in their relative values (40.6±7.8 vs. 37.0±8.1, p<0.001).

Cut-Off Values for Metabolic Syndrome

Absolute and relative cut-off values for HGS (Table 2) were noted using a ROC curve. The absolute cut-off values for HGS were 36.0 kg (AUC 0.533, p=0.015) for men and 19.6 kg (AUC 0.506, p=0.017) for women. The relative cut-off values for HGS considering body mass were 57.5% (AUC 0.633, p=0.014) for men and 38.9% (AUC 0.617, p=0.017) for women.

Grip Strength and Metabolic Syndrome Odds Ratio

The prevalence of MetS by HGS quartile is as shown in Table 3. According to the analysis of differences between groups by dividing the absolute HGS values into quartiles, there was no significant difference noted among men and women. However, according to the analysis of differences in two groups based on absolute cut-off values, for men, the group having values less than the cut-off values (36.0 kg) had a 2.296 times higher prevalence of MetS than the other group (p<0.001). For women, the prevalence increased by 1.081 times (p<0.001) in the group with values less than the cut-off values (19.6 kg).

The relative values of HGS were divided into quartiles to analyze differences between groups. Comparing G1, the group with the highest relative HGS values, to the other groups, for men, prevalence increased by 1.911 times (p<0.001) in G2, 2.465 times (p<0.001) in G3, and 5.000 times (p<0.001) in G4. For women, it increased by 1.559 times (p=0.010) in G2, 2.348 times (p<0.001) in G3, and 2.747 times (p<0.001) in G4. Analysis of the differences between the two groups based on the relative cut-off values revealed that for men, the group with less than the relative cut-off values (57.5%) had 2.255 times higher prevalence of MetS than the other. For women, the rate increased by 2.202 times (p<0.001) in the group with values under the relative cut-off values (38.9%).

Health Behaviors and Metabolic Syndrome

The links between health behavior and the risks of MetS were analyzed (Table 4). The prevalence of MetS in the group that reported no aerobic exercise increased by 1.282 times (p=0.017) for men and 1.396 times (p=0.018) for women compared to the group exercising >5 days a week. In the case of weight training, men who did not do weight training showed a 1.837-times increase (p=0.040) in prevalence compared to the group that exercised >5 days a week; there was no corresponding difference for women. In the case of

TABLE 2 Hand Grip Strength Cut-Off Value for Metabolic Syndrome

	Cut-off value	AUC	Sensitivity	Specificity	p
Absolute value					
Men	36.0 kg	0.533(0.508–0.557)	43.0	63.3	0.015*
Women	19.6 kg	0.506(0.476–0.535)	36.8	67.2	0.017*
Relative value					
Men	57.5%	0.633(0.609–0.657)	76.3	42.6	0.014*
Women	38.9%	0.617(0.588–0.646)	62.4	56.2	0.017*

**p<0.05; %, Relative value = (HGS (kg) / body weight (kg)) *100.*
Abbreviation: AUC = area of under curve.

TABLE 3 Metabolic Syndrome Odds Ratio to Absolute and Relative Grip Strength

	Men		Women	
	OR(95%CI)	**p**	**OR(95%CI)**	**p**
Absolute groups by quartile				
HGS G1	Reference	-	Reference	-
HGS G2	0.964(0.726–1.279)	0.798	0.914(0.650–1.284)	0.603
HGS G3	0.899(0.672–1.203)	0.473	0.754(0.535–1.062)	0.106
HGS G4	0.772(0.564–1.056)	0.106	0.881(0.614–1.264)	0.491
Absolute groups by cut-off values				
Above HGS cut-off value	Reference	-	Reference	
Below HGS cut-off value	2.296(1.158–2.839)	<0.001*	1.081(1.070–1.091)	<0.001*
Relative groups by quartile				
HGS G1	Reference	-	Reference	-
HGS G2	1.911(1.415–2.582)	<0.001*	1.559(1.113–2.185)	0.010*
HGS G3	2.465(1.819–3.341)	<0.001*	2.348(1.663–3.614)	<0.001*
HGS G4	5.000(3.629–6.889)	<0.001*	2.747(1.923–3.925)	<0.001*
Relative groups by cut-off values				
Above HGS cut-off value	Reference	-	Reference	
Below HGS cut-off value	2.255(2.032–3.202)	<0.001*	2.202(1.558–2.572)	<0.001*

**p<0.05; Relative grip strength (%) = (grip strength, kg/body weight) × 100.*
AUC = area under the curve; G1 = highest strength; G2 = high strength; G3 = low strength; G4 = lowest strength; OR = odds ratio; HGS = hand grip strength.
Note: Adjustment factors are age, exercise habits, and drinking and smoking habits.

smoking, male smokers showed a 2.002-times increase ($p<0.001$) in the prevalence compared to the group who reported never smoking, while there was no significant difference among women. Alcohol consumption did not show any difference related to the risk of MetS in all groups of both men and women.

DISCUSSION

The motivation behind the definition of MetS was to highlight the risk of high insulin resistance.[17] High insulin resistance leads to inefficient energy utilization due to impaired blood glucose management, although the amount of insulin present in the body is not insufficient. Therefore, blood glucose levels remain high, leading to high BP and elevated cardiovascular risk.[18,19]

The components of MetS are dyslipidemia, high BP, high fasting glucose, and abdominal obesity; each of these components is considered a disease in itself. They tend to be comorbid, and all ultimately contribute to increased insulin resistance.[17] Reducing insulin resistance can be accomplished by managing risk factors for MetS: adjusting the amount of physical activity, diet patterns, obesity, and physical strength.[20,21]

It is reported that MetS risk factors have an inverse association with the absolute values of muscle strength and muscle mass.[22,23] However, since muscle strength tends to increase with weight gain in general, it may not be appropriate to use the absolute value of muscle strength as a predictor of MetS in patients who are heavier. In order to overcome this limitation, the present

TABLE 4 Metabolic Syndrome Odds Ratio According to Health Behaviors

	Men		Women	
	OR(95%CI)	**p**	**OR(95%CI)**	**p**
Aerobic Ex, per week				
G1 (5–7 days)	Reference	-	Reference	-
G2 (3–4 days)	0.887(0.633–1.242)	0.485	1.158(0.792–1.692)	0.450
G3 (1–2 days)	1.128(0.822–1.549)	0.456	1.303(0.888–1.912)	0.177
G4 (0 days)	1.282(1.052–1.638)	0.017*	1.396(1.081–1.905)	0.018*
Weight Tr, per week				
G1 (5–7 days)	Reference	-	Reference	-
G2 (2–4 days)	1.277(0.610–2.675)	0.517	0.698(0.404–1.204)	0.196
G3 (0–1 days)	1.837(1.093–3.626)	0.040*	0.375(0.116–1.213)	0.101
Smoking experience				
Never	Reference	-	Reference	-
Quit	1.332(0.984–1.804)	0.064	1.413(0.639–3.126)	0.393
Current	2.002(1.371–2.924)	<0.001*	1.200(0.493–2.922)	0.688
Alcohol frequency				
Never	Reference	-	Reference	-
1 time/month	0.746(0.522–1.065)	0.107	0.920(0.682–1.24)	0.583
2–3 times/month	0.993(0.702–1.405)	0.969	1.044(0.664–1.642)	0.851
≥2 times/week	0.990(0.728–1.346)	0.948	1.358(0.771–2.393)	0.290

**p<0.05.*
Ex = exercise; Tr = training; OR = odds ratio.
Note: Adjustment factors are age, exercise habits, and drinking and smoking habits.

study sought to determine the degree of MetS risk by utilizing the absolute and relative values of HGS in participants. In addition, this study analyzed the prevalence of MetS by calculating the cut-off values related to the disease to help formulate guidelines for preventing this disease in the elderly population.

There are various measures of physical strength including cardiorespiratory endurance, muscle strength, and flexibility; similarly, HGS has been utilized as a method to measure and predict muscle strength.[24] HGS has long been studied as a method to predict physiological variables such as aging,[7] and its association with variables such as frailness in the elderly, Alzheimer's, and mortality has been reported.[25–27]

The relationship between MetS and HGS focuses on the relationship between muscular capacity and MetS. Weight training can reduce insulin resistance as a result of increase in muscle mass; thus, it can be predicted that people with high HGS will have more muscles and be more active.[28,29] The amount of muscle is also increased as a result of weight gain, it increases with weight gain and decreases with weight loss.[30] Therefore, the prevalence of MetS is likely to be high among obese people; these people may also possibly have a high HGS.

A prior study on middle-aged and elderly participants reported that obesity could be a simple indicator of relative cardiovascular risk factors.[31] In this study, men with MetS and higher body weight had significantly higher absolute values for HGS than those without MetS. However, when relative values of HGS were calculated, the MetS group had significantly less HGS. Among women, there was no significant difference in the absolute HGS value, but in the relative HGS value, the group without MetS had statistically significant higher results. These results indicate that relative HGS, which takes weight into consideration, may be a more useful indicator when muscle strength is used to predict MetS risk among the elderly.

HGS can be very important for the elderly; a threshold value can serve as a recommendation and guideline. In this study, the HGS cut-off values for MetS were found to be 36.0 kg for men and 19.6 kg for women, slightly below the overall average. The relative HGS cut-off values considering weight were 57.5% for men and 38.9% for women. These findings suggest that having HGS values of about 60% and 40% of their body weight, respectively, can prove to be effective for men and women in order to reduce their risk of MetS. When these minimum cut-off values were not maintained, the prevalence of MetS was shown to increase by 2.2 times for both genders.

To the best of our knowledge, no study has previously reported on the HGS cut-off values with respect to MetS. However, the results of studies on cut-off values related to MetS using one repetition maximum of bench press and leg press are similar.[32] The cut-off values for men over 50 years old in that study was 2.35–2.45 kg per weight, which recommended having arm and leg forces of more than twice their weight. People with muscle strength lower than the recommended value were shown to have a 1.3–2.1-times increase in their risk for MetS.[32] In another study, which calculated cut-off values to assess the health of the elderly, the HGS cut-off values for mobility limitation were 37 kg for men and 21 kg for women,[33] while a study of sarcopenia reported slightly lower values of 27 kg for men and 16 kg for women.[9]

In this study, health behavior and MetS prevalence were also analyzed. There were significant differences in the frequencies of aerobic exercise and weight training in men, but no significant difference in the frequency of weight training in women. For men, the prevalence of MetS increased by up to 1.2 times based on the frequency of aerobic exercise, and the prevalence increased by up to 1.8 times for those who did not participate in weight training. Previous studies have reported that both aerobic exercise and weight training can have a positive effect on MetS, rather than concluding what forms of exercise were relatively more effective.[34,35] The results of the present study suggest that weight training is more effective in reducing MetS than aerobic exercise. However, for women, the frequency of aerobic exercise showed a significant difference in relation to the risk of MetS, but there was no significant result with respect to frequency of weight training. It is believed that this was due to women's low participation in weight training (nonpatients 0–1 day: 89.1% vs. MetS patients 0–1 day: 93.7%). Similarly, it was difficult to statistically analyze the effects of smoking on the risk of MetS because the female participants who reported never smoking accounted for very high rates among both nonpatients (95.1%) and MetS patients (93.5%).

The average age of the subjects in this study was 70–72 years, and HGS was 34.5 kg for men and 21.8 kg for women. In another study on Caucasian men in their 70s, the HGS values were reported to be 38 kg for men and 21 kg for women,[36] and in a Korean study, the HGS was reported to be 32.55 kg for men and 20.85 kg for women.[37] However, in the test conducted in a province of Korea, the HGS was 29.2 kg for men and 16.6 kg for women in a sample population of adults with an average age of 72.8 years, which was lower than that in this study.[38] These results show that the HGS values can change according to the study population.

In this study, further analyses were conducted on health behavior and MetS prevalence. There were significant ORs in women's aerobic and strength training and men's smoking (Table 4). Several previous studies have reported that high alcohol intake causes MetS.[39,40] However, there was no significant difference in ORs found in this study, because there was no significant difference in alcohol consumption between the healthy and MetS groups (Table 1). In addition, given that the smoking rate in women is very low, significant differences in prevalence could not be detected. In men, the importance of quitting smoking was once again confirmed for prevention of MetS.

This study may have the following limitations. First, since this study was conducted as a cross-sectional study, the direction of causality between associations cannot be determined. For example, obese people can have low HGS and be obese because they are less active. Conversely, low HGS and overall strength lead to a reduction in physical activity, which can cause obesity. Therefore, further research will be needed to resolve the causal relationships between obesity and inactivity through a longitudinal study. Second, this study may be controversial because although HGS is a valid measure of muscle strength, the present study did not deal with a case-controlled study or interventional study design. One possible question is whether an increase in HGS through intensive exercise over a period of time can address MetS risk factors and negative outcomes. Although this study collected and analyzed some confounding variables, family history and lifestyle were not included in the analysis. In addition, variables such as the intensity or duration of exercise and the amount of physical activity in participants' daily lives were not considered. Therefore, further studies will need to be conducted to examine these additional variables related to MetS.

CONCLUSIONS

The relative HGS value, taking patient weight into consideration, was more relevant for MetS prevalence than absolute HGS. The group with the lowest HGS (lowest quartile) had 5 times (men) and 2.74 times (women) higher prevalence of MetS than the highest HGS quartiles. The risk of MetS among those with lesser muscle strength than the relative cut-off values of HGS increased by about 2.2 times for both genders. Therefore, it is desirable for individuals over 60 years to have an HGS of 57.5% of their weight for men and 38.9% for women in order to prevent MetS.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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