Relationship between Adult Handgrip Strength and Metabolic Syndrome

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Abstract

Background: Metabolic syndrome is becoming more prevalent around the world, with insulin resistance and obesity as particularly critical factors determining the condition. It is known that insulin resistance has a very strong correlation with muscle mass and muscular strength. However, there are few studies on the relationship between handgrip strength and metabolic syndrome, and those studies that have been carried out have mainly focused on the elderly. The purpose of the current study is to use the Korea National Health and Nutrition Examination Survey to identify the relationship between handgrip strength and metabolic syndrome among Korean adults aged 19 years old and above.

Participants and methods: The Korea National Health and Nutrition Examination Survey is a nationwide cross-sectional survey that assesses the health and nutritional status of the Korean population. The current study analyzed the relationship between grip strength and metabolic syndrome of 10,094 Korean adults aged ≥19 years (4,402 men and 5,692 women) in the Korea National Health and Nutrition Examination Survey (2014-2017). Those with cancer or those who had experienced a stroke, angina or myocardial infarction were excluded, as were pregnant or breast-feeding women. The diagnostic criteria for metabolic syndrome were based on those of the American Heart Association/National Heart Long and Blood Institute, which are altered versions of the National Cholesterol Education Program – Adult Treatment Panel III criteria. Grip strength was measured data using a digital grip strength dynamometer.

Results: Logistic regression analysis was performed by dividing grip strength into quintiles. A significant decrease in figures compared to Q1 in the odds ratio for both men and women was observed due to age adjustment (Q2: 0.84, Q3: 0.43, Q4: 0.24, Q5: 0.15 for men; Q2: 0.63, Q3: 0.41, Q4: 0.23, Q5: 0.08 for women). Also, due to the correction of demographic factors (age, educational status, marital status, income status, smoking status, drinking status, and menopausal status for women), the odds ratio significantly decreased figures compared to Q1 for both men and women (Q2: 0.80, Q3: 0.37, Q4: 0.21, Q5: 0.13 for men; Q2: 0.63, Q3: 0.45, Q4: 0.24, Q5: 0.09 for women).

Conclusions: Higher grip strength brought down the risk of metabolic syndrome for both men and women. Theref ore, to prevent and treat metabolic syndrome, it is recommended that patients exercise steadily to enhance muscula r strength and muscle mass for better health outcomes. [*Ethiop. J. Health Dev.* 2020;34(Special issue-3):18-27]

Key words: Muscle strength, metabolic syndrome, grip strength, grip strength/body weight

Background

Generally speaking, metabolic syndrome (MetS) is a syndrome in which symptoms such as high blood sugar, hypertension, and dyslipidemia occur simultaneously. Dyslipidemia is considered to be dangerous for MetS, including factors such as waist circumference, hypertriglyceridemia, low level of high-density lipoprotein, increased blood pressure, and impaired fasting glucose (1).

MetS is becoming more prevalent around the world, affecting 10% to 40% of the total population (2). It is rising as a major social issue, and is the most accurate predictor of all causes of death, including type 2 diabetes and cardiovascular diseases, and increases the incidence of kidney diseases and cancers, such as breast cancer and colorectal cancer (3-7).

The pre-stage of MetS is not clearly identified to date (8,9), however unhealthy lifestyle factors, such as smoking and drinking alcohol, are closely associated (10), and insulin resistance and obesity are particularly critical factors (11). In this context, insulin resistance has a very strong correlation with muscle mass and muscular strength (12), and a decline in muscular strength causes a metabolic disorder in the body, as an excessive accumulation of lipids in skeletal muscles induces toxic fat and insulin resistance (13,14). Also, as skeletal muscles secrete peptides (myokines) to maintain metabolic homeostasis in the body, a drop in muscular strength leads to MetS (15-18).

Handgrip strength is a measure used to assess overall muscular strength, muscle mass, and the nutritional status of a subject, and is useful for the early diagnosis of people with weak muscular strength and high risk of physical disorders (19). Also, it can be used as a predictive scale for health-related prognoses, such as functional limitation or decline, difficulties in performing daily activities, and has even been used as an indicator of the onset of death (20). However, previous research on the relationship between grip strength and MetS used insufficient samples of a variety of groups, or were mainly focused on the elderly (21-24). Therefore, this study conducted a cross-sectional study to find out whether grip strength influences MetS by utilizing large-scale data in the Korea National Health and Nutrition Examination Survey (KNHANES) collected from Korean adults.

Participants and methods

Design: To begin with, data from the KNHANES, conducted from 2014 to 2017, was adopted for the study. The KNHANES is a representative and reliable nationwide cross-sectional survey conducted by the Korean Centers for Disease Control and Prevention (Seoul, Korea) to assess the health and nutritional status of the population in the Republic of Korea. Here

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it is noted that the institutional review board of the Korean Centers for Disease Control and Prevention approved the study. The statistics are composed of health examination, nutrition survey, and health interviews, and are used as base data for the establishment and assessment of health policies, such as objectives, evaluation, and development of health promotion programs of the Health Plan 2020. From 1998 to 2005, the KNHANES was conducted as a short-term tri-annual survey. Since 2007, it has been conducted every year to continue preliminary research efforts. The primary stratification categorizes provinces and cities; secondary stratification categorizes general regions into 26 strata based on age and population ratio per age group, and apartment-clustered regions into 24 strata based on price per unit space and mean housing size per apartment complex. Sample enumeration districts are calculated thereafter. In general, within the sample enumeration districts, 20 target households are sampled per district by adopting the systematic sampling method (25-26).

Participants: This research enrolled 24,525 males and females aged 19 and above from a total of 31,207 male and female participants who had participated between 2014 and 2017 when the KNHANES measured grip strength.

According to the data, the participants included cancer patients (n=13,588), those who had experienced stroke (n=534), those with angina and myocardial infarction (n=634), pregnant women (n=128), and breast-feeding women (n=113). These groups were excluded from the study. Those who did not have their grip strength measured (n=3,093) and those who were not diagnosed with MetS (n=1,178) were also excluded. As a result, 10,094 (4,402 males, 5,692 females) were chosen as subjects (see Figure 1).

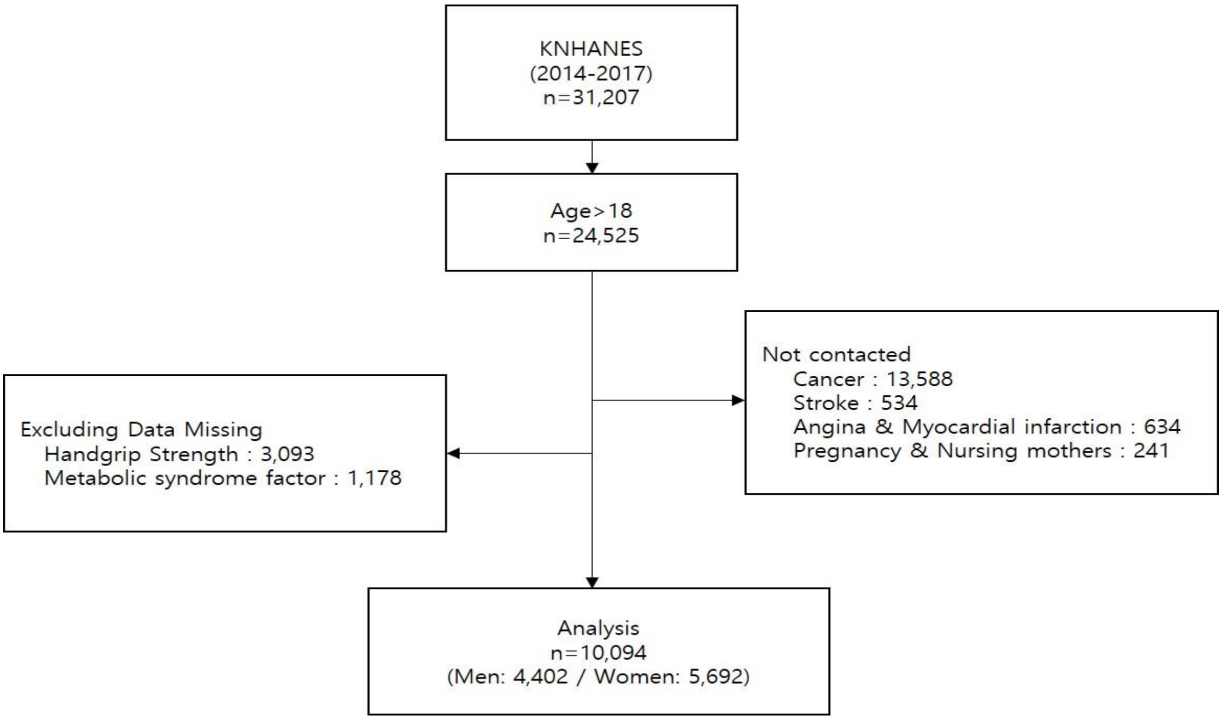

Figure 1: **Flowchart of participants in the study**

Grip strength measurement: In this study, grip strength was measured with the use of a Takei Digital Grip Strength Dynamometer (TKK 5401, Japan). Next, the subjects were asked to stand straight and look forward, with their elbows and wrists stretched straight down, while keeping their arms distanced from their body. Their feet were apart to the width of the pelvis, pointing forward. The subjects were told to keep this posture during the measurement. The dominant hand was measured first, followed by the other hand; both hands were measured three times in this order. The subjects had a 60-second break between each measurement. The highest value of the dominant hand was used as the parameter of the grip strength measurement. Those subjects with functional limitations that make ocular inspections or interviews for grip strength measurement difficult to be conducted, or those who had wrist surgery in the last three months or had pain in their wrist, were excluded from the study (27). For the convenient interpretation of the results, the grip strengths of each gender were divided into quintile groups.

Definition of metabolic syndrome: Generally speaking, the diagnostic criteria for MetS were based on those of the American Heart Association/National Heart Long and Blood Institute (AHA/NHLBI), which are altered versions of the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) criteria. Among the five components of MetS stated in the criteria, subjects with three or more components were assessed as having MetS. The five components are as follows: fasting blood sugar level (≥100mg/dL), neutral fat (≥150mg/dL), HDL cholesterol (<40mg/dL for men, <50 mg/dL for women), systolic blood pressure (≥130mmHg) or diastolic blood pressure (≥85mmHg), and abdominal obesity (>90cm for men, >85cm for women, the WHO standard of the Western

Pacific Region) (28, 29).

Statistical analysis: In this study, SAS 9.4 was employed in all of the statistical analyses. Additionally, a complex sample analysis was adopted using weights based on the KNHANES by the Korean Centers for Disease Control and Prevention. All of the analyses were divided into male and female, as the two genders had differences in grip strength as tested. The Complex Samples General Linear Model (CSGLM) was adopted to see how MetS causes a difference in grip strength among the groups. The subjects' grip strength/body weight were divided into five groups (quintiles), and basic statistics were calculated, followed by the CSGLM and complex sample cross-tabulations (Rao-Scott chi-square test). Also, logistic regression was employed to determine whether grip strength/body weight affect MetS.

Results

Metabolic syndrome's impact on grip strength/body weight: In total, 21.1% (1,018) of males and 10.6% (749) of females were found to have MetS. Both males and females with MetS showed an average of 0.36 (SE=0.004) for grip strength/body weight, while those without the syndrome showed an average of 0.44 (SE=0.002), indicating a significant difference (p<.001). Accordingly, both males and females with MetS had less-than-average grip strength/body weight (Table 1).

Table 1: **Differences in grip strength and grip strength/body weight depending on the presence of metabolic syndrome**

Sex	Variable	Metabolic syndrome				t (p)
		No		Yes		
		Mean	SE	Mean	SE	
Male	Grip strength(kg)	41.72	0.181	42.15	0.323	1.23 (.219)
	Grip strength(kg)/ Body weight(kg)	0.44	0.002	0.36	0.004	-16.19 (<.001)
Female	Grip strength(kg)	24.85	0.105	23.23	0.252	-6.00 (<.001)
	Grip strength(kg)/ Body weight(kg)	0.44	0.002	0.36	0.004	-20.54 (<.001)

Analysis of the characteristics of different grip strength/body weight groups and metabolic syndrome: It was shown that the incidence of MetS in all five groups of grip strength/body weight gradually decreased in both males and females.

In this context, the age, educational status, income status, and alcohol drinking status of each grip/body weight group showed a statistically significant difference. Here, the proportion of group Q5 (strongest grip strength) gradually decreased with older age in both male and female participants. With regard to educational status, the proportion gradually increased with the designation of a higher educational level. Meanwhile, the proportion of the Q5 group increased with higher income status of males and females. In terms of drinking status, the ratio of the Q5 group was high when males drank '2-4 times a month'; for females, those who answered 'never drink' showed the highest Q5 proportion.

Regarding marital status, only females showed a significant difference, and those who were married showed the highest Q5 proportion. Incidentally, smoking status did not have a statistically significant difference in both genders. In terms of females, menopausal status resulted in a significant difference: those who had reached menopause had a low Q5 proportion (see Table 2).

Table 2: **Association between the socio-demographic characteristics, metabolic syndrome and quintile of grip strength/body weight**

		Male							Female						
		Quintile of grip strength/body weight					**Total**	**X^2(p)**	**Quintile of grip strength/body weight**					**Total**	**X^2(p)**
		Quintile 1	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**			**Quintile 1**	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**		
Case N		1,020	880	881	880	741	4,402		1,482	1,138	1,139	1,138	795	5,692	
MetS		353(33.7)	274(31.5)	203(20.3)	122(12.6)	66(7.8)	1,018(21.1)	203.449(<.0001)	375(22.6)	181(13.5)	122(8.3)	56(4.3)	15(1.4)	749(10.6)	315.369(<.0001)
Age	20-29	114(20)	105(18.7)	94(17.4)	102(18.5)	109(21.7)	524(19.2)	244.917(<.0001)	94(10.4)	133(17.8)	148(19.5)	152(17.6)	116(19.2)	643(16.6)	652.833(<.0001)
	30-39	117(14.7)	139(19.2)	140(18.6)	183(22.5)	192(27.2)	771(20.4)		125(10.8)	132(13)	194(18)	235(22.8)	234(28.8)	920(18.1)	
	40-49	142(17.6)	159(20.7)	175(22.4)	184(23.4)	183(25.6)	843(21.9)		174(14.8)	189(18.8)	224(22.1)	293(26.4)	216(27.7)	1,096(21.6)	
	50-59	151(16.7)	165(20.4)	196(22.3)	201(21.8)	160(19)	873(20.1)		251(18.9)	237(21)	231(19.8)	258(21.2)	148(17.8)	1,125(19.8)	
	60-69	189(13.5)	160(11.9)	177(13.5)	153(11)	58(4.4)	737(10.9)		325(16.4)	242(16)	209(13.1)	137(8.2)	67(5.4)	980(12.2)	
	70+	307(17.5)	152(9.1)	99(5.8)	57(2.9)	39(2.1)	654(7.5)		513(28.6)	205(13.4)	133(7.6)	63(3.7)	14(1.1)	928(11.7)	
Educational status	Below elementary school	221(14.7)	119(10)	112(10.1)	86(6.3)	50(4.5)	588(9.1)	67.291(<.0001)	608(37.6)	331(23.8)	233(15.3)	147(10.4)	55(5.4)	1,374(19.2)	390.699(<.0001)
	Finished middle school	111(9.8)	84(7.9)	93(9.2)	91(9.2)	68(8.1)	447(8.9)		136(9.4)	113(9.8)	100(8.1)	103(8.9)	54(6.1)	506(8.6)	
	Finished high school	269(33.9)	246(31.9)	274(36.7)	288(39)	286(43.5)	1,363(37)		309(26.8)	317(31.8)	339(34.9)	389(36.8)	267(36.5)	1,621(33.1)	
	Above college	326(41.6)	371(50.2)	351(43.9)	350(45.5)	290(43.9)	1,688(45)		277(26.2)	309(34.6)	398(41.7)	448(44)	376(52.1)	1,808(39)	
Marital status	Married	826(71.7)	714(73.1)	723(75.6)	704(73.1)	559(68.2)	3,526(72.4)	7.841(0.0976)	1365(88.3)	988(81.6)	967(79.3)	957(80.3)	652(78)	4,929(81.8)	31.428(<.0001)
	Unmarried	194(28.3)	166(26.9)	158(24.4)	176(26.9)	182(31.8)	876(27.6)		117(11.7)	150(18.4)	172(20.7)	181(19.7)	143(22)	763(18.2)	
Income status	Low	288(21.9)	143(12.2)	132(11.7)	103(9.1)	62(6.3)	728(12.2)	101.814(<.0001)	502(28.8)	279(20.4)	188(13.6)	117(9.5)	72(8)	1,158(16.7)	198.481(<.0001)
	Low-mid	246(24.1)	206(22.5)	185(20.8)	213(23.4)	166(22)	1,016(22.6)		364(24.9)	282(23.7)	289(26.6)	283(25.2)	171(21.9)	1,389(24.6)	
	Mid-high	235(25.4)	242(30.6)	270(32)	292(35)	249(35.5)	1,288(31.7)		324(24.3)	304(30.1)	313(27.5)	352(31.3)	262(33.4)	1,555(29)	
	High	244(28.6)	288(34.7)	293(35.5)	271(32.6)	263(36.2)	1,359(33.5)		280(22)	270(25.8)	344(32.3)	379(34)	287(36.7)	1,560(29.7)	
Smoking status	Never	265(28.9)	238(29.2)	228(27.8)	205(25.8)	168(25.4)	1,104(27.4)	14.565(0.0682)	1,348(89.3)	1,028(89.8)	1018(88.2)	1009(88)	703(87.3)	5,106(88.6)	4.582(0.8012)
	Smoker	337(36.7)	303(36.6)	333(40.9)	349(40.4)	339(45.4)	1661(40)		56(4.8)	40(4)	54(5.7)	61(5.6)	48(6)	259(5.2)	
	Smoked in the past	418(34.3)	339(34.2)	320(31.3)	326(33.8)	234(29.3)	1,637(32.6)		78(5.9)	70(6.2)	67(6.1)	68(6.4)	44(6.6)	327(6.2)	
Drinking status	Never	284(24.7)	161(15.7)	141(13.7)	128(13.6)	95(12.9)	809(16.2)	63.054(<.0001)	725(43.6)	418(33.3)	364(29)	307(25)	216(24.1)	2,030(31.6)	120.481(<.0001)
	Less than once a month	108(12)	96(11.6)	99(12.7)	85(10.2)	87(11.5)	475(11.6)		301(20.6)	254(22.9)	287(24.5)	296(26.7)	190(24.3)	1,328(23.7)	
	Once a month	89(8.9)	87(9.6)	69(7.4)	76(9.8)	73(10.2)	394(9.2)		124(8.8)	113(10.4)	132(11.6)	138(12.2)	106(14.9)	613(11.4)	
	Two to four times a month	208(22.5)	235(28.8)	238(28.5)	233(28.3)	213(30.2)	1,127(27.6)		196(15.9)	215(20.2)	224(23.1)	247(23.5)	168(21.3)	1,050(20.7)	
	Two to three times a week	189(20.6)	202(24.7)	212(25.2)	252(27.4)	182(24.2)	1,037(24.5)		96(8.4)	95(9.6)	107(9.7)	117(10)	94(12.6)	509(9.9)	

	More than four times a week	142(11.2)	99(9.6)	122(12.5)	106(10.7)	91(11)	560(11)		40(2.6)	43(3.6)	25(2.1)	33(2.7)	21(2.8)	162(2.7)	
Menopausal status	No								548(46.2)	519(54.8)	632(64.4)	728(70.7)	582(78)	3,009(61.8)	245.285(<.0001)
	Yes								934(53.8)	619(45.2)	507(35.6)	410(29.3)	213(22)	2,683(38.2)	

With regards to MetS, the results were statistically different depending on age, educational status, marital status, income status, and drinking status. While the incidence of MetS for males rises and falls by the age of 50s, it continuously rose with age for females. Meanwhile, for both genders, the incidence of MetS fell with the designation of a higher educational status. When both males and females were married, the incidence was noted as high. For both genders, it fell with the factor of a higher income status. However, in terms of smoking status, only males showed a statistically significant difference, and those non-smokers showed a lower incidence of MetS. In terms of drinking status, the incidence was the lowest when males drank 'once or less a month'; for females, those who answered '2-4 times a month' showed the lowest incidence of MetS. Also, the results were statistically significant for females in the menopausal state, with the highest incidence of MetS (see Table 3).

Table 3: **Association between the socio-demographic characteristics and metabolic syndrome**

Variable		Male				Female			
		MetS			X^2 (p)	MetS			X^2 (p)
		No	Yes	Total		No	Yes	Total	
Age	20-29	490(92.8)	34(7.2)	524(100)	131.658(<.0001)	641(99.8)	2(0.2)	643(100)	380.231(<.0001)
	30-39	626(81.5)	145(18.5)	771(100)		886(96.8)	34(3.2)	920(100)	
	40-49	634(75.6)	209(24.4)	843(100)		1,019(92.5)	77(7.5)	1,096(100)	
	50-59	611(70.3)	262(29.7)	873(100)		963(86.5)	162(13.5)	1,125(100)	
	60-69	516(72.4)	221(27.6)	737(100)		747(77.9)	233(22.1)	980(100)	
	70+	507(78.3)	147(21.7)	654(100)		687(73.9)	241(26.1)	928(100)	
Educational status	Below elementary school	425(71.4)	163(28.6)	588(100)	15.294(.002)	979(72.2)	395(27.8)	1,374(100)	457.766(<.0001)
	Finished middle school	324(72.6)	123(27.4)	447(100)		406(82.4)	100(17.6)	506(100)	
	Finished high school	1,029(79.1)	334(20.9)	1,363(100)		1,470(91.9)	151(8.1)	1,621(100)	
	Above college	1,324(79.2)	364(20.8)	1,688(100)		1,735(96.6)	73(3.4)	1,808(100)	
Marital status	Married	2,628(75.8)	898(24.2)	3,526(100)	39.794(<.0001)	4,194(87.2)	735(12.8)	4,929(100)	165.151(<.0001)
	Unmarried	756(87.1)	120(12.9)	876(100)		749(99)	14(1)	763(100)	
Income status	Low	543(75.7)	185(24.3)	728(100)	4.420(.220)	880(79.4)	278(20.6)	1,158(100)	146.619(<.0001)
	Low-mid	769(78)	247(22)	1,016(100)		1,186(87.8)	203(12.2)	1,389(100)	
	Mid-high	1,013(80.3)	275(19.7)	1,288(100)		1,394(91.5)	161(8.5)	1,555(100)	
	High	1,050(79.3)	309(20.7)	1,359(100)		1,458(94.3)	102(5.7)	1,560(100)	
Smoking status	Never	921(86)	183(14)	1,104(100)	41.84(<.0001)	4,428(89.3)	678(10.7)	5,106(100)	0.597(.742)
	Smoker	1,251(77.1)	410(22.9)	1,661(100)		226(90.7)	33(9.3)	259(100)	
	Smoked in the past	1,212(75.1)	425(24.9)	1,637(100)		289(89.8)	38(10.2)	327(100)	
Drinking status	Never	647(83.9)	162(16.1)	809(100)	100.434(<.0001)	1,680(85.7)	350(14.3)	2,030(100)	55.674(<.0001)
	Less than once a month	402(85.2)	73(14.8)	475(100)		1,155(89.2)	173(10.8)	1,328(100)	
	Once a month	318(83.7)	76(16.3)	394(100)		552(91.4)	61(8.6)	613(100)	
	Two to four times a month	912(83.4)	215(16.6)	1,127(100)		958(93.2)	92(6.8)	1,050(100)	
	Two to three times a week	729(71.6)	308(28.4)	1,037(100)		466(93)	43(7)	509(100)	
	More than four times a week	376(65.8)	184(34.2)	560(100)		132(81.9)	30(18.1)	162(100)	
Menopausal status	No					2,864(95.5)	145(4.5)	3,009(100)	343.932(<.0001)
	Yes					2,079(79.3)	604(20.7)	2,683(100)	

Except for the smoking status of women MetS had a statistically significant relevance to all demographic factors. Also, grip strength had a statistically significant relevance to all demographic factors except smoking status and men's marital status. In short, to identify the relationship between MetS and grip strength, demographic variables that affect the outcome, including age, educational status, marital status, income status, drinking status, and menopausal status, were added as covariates for analysis in this study.

Effects of grip strength/body weight on metabolic syndrome: Grip strength changes with age, and MetS is affected by several factors. Therefore, to figure out whether MetS has an impact on grip strength, the level grip strength was divided into five groups (quintiles; Q), followed by logistic regression (see Table 4).

Table 4: **Odds ratio of quintile of grip strength/body weight for metabolic syndrome in males and females**

Sex	Model	Quintile of grip strength/body weight				
		Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Male	Model 1	1	0.84(0.66-1.06)	0.43(0.33-0.56)	0.24(0.18-0.32)	0.15(0.11-0.21)
	Model 2	1	0.80(0.62-1.02)	0.37(0.28-0.49)	0.21(0.16-0.28)	0.13(0.09-0.18)
Female	Model 1	1	0.63(0.49-0.80)	0.41(0.31-0.54)	0.23(0.16-0.32)	0.08(0.05-0.14)
	Model 2	1	0.63(0.48-0.81)	0.45(0.34-0.59)	0.24(0.17-0.34)	0.09(0.05-0.16)

Adjusted
Model 1: age
Model 2: age, educational status, marital status, income status, smoking status, drinking status
(Menopausal status added for women)

Notably, the age-adjusted (for females menopausal status was additionally added to the calibration) measurement on the effects of grip strength on MetS was conducted first. The results were as follows: men showed gradually decreasing figures compared to Q1 for MetS incidence, with Q2 OR showing 84% (CI: 0.66-1.06), followed by Q3 43% (CI: 0.33-0.56), Q4 24% (CI: 0.18-0.32), and Q5 16% (CI: 0.11-0.21); Q3, Q4, and Q5 showed significant declines. It was found that the odds ratio of MetS decrease as the grip strength increases in men.

Women also showed significant declines in the OR for MetS incidence compared to Q1, as follows: Q2 63% (CI: 0.49-0.80), Q3 41% (CI: 0.31-0.54), Q4 23% (CI: 0.16-0.32), and Q5 8% (CI: 0.05-0.14). It was found that the odds ratio of MetS decrease as the grip strength increases in women.

In addition, as educational status, marital status, income status, smoking status, and drinking status were additionally calibrated, it was revealed that males showed a downward trend in the OR for MetS incidence: Q2 OR was 80% (CI: 0.62-1.02), with Q3 37% (CI: 0.28-0.49), Q4 21% (CI: 0.16-0.28), and Q5 13% (CI: 0.09-0.18); Q3, Q4, and Q5 showed significant declines. Female groups also showed similar outcomes, with a significant decrease in the OR for MetS incidence compared to Q1, as follows: Q2 63% (CI: 0.48-0.81), Q3 45% (CI: 0.34-0.59), Q4 24% (CI: 0.17-0.34), and Q5 9% (CI: 0.05-0.16).

Conclusions

Both males and females with MetS were proved to have a significantly low average of grip strength/body weight, while stronger grip strength and heavier body weight in both genders brought down the incidence of MetS.

It was revealed in the study that the incidence of MetS was 21.1% (1,018) for men and 10.6% (749) for women, which is slightly lower than results published in 2014 (male 24.2%, female 14.4%) and 2015 (male 26.9%, female 17.9%) (30). In contrast, the higher incidence of MetS among males compared to females was similar to the results of other research (31-37).

Generally speaking, insulin resistance plays a crucial role in the determination of MetS (38). Insulin resistance is a condition in which insulin, the blood sugar reducer, is not properly secreted – making cells fail to effectively burn glucose in the blood. This is mainly caused by impaired functions of the liver, skeletal muscles, and pancreas (39). Therefore, a drop in muscle mass and muscular strength may cause associated disorders in insulin signals, glucose delivery, and glucose metabolism; this may influence skeletal muscle's absorption of glucose (40), and may also affect the quantity of glucose transporter protein 4 (GLUT4), which leads blood glucose to skeletal muscles, dropping the amount of absorbed glucose and causing hyperglycemia (41). For this reason, it is considered that this mechanism may support the outcome of the current research.

This research identified the relationship between MetS and grip strength in all adult age groups, with both males and females with MetS discovered to have relatively less muscular strength. Also, as participants were divided into five grip strength/body weight groups (quintile groups), those with stronger grips had a significantly lower risk of MetS. As noted, elderly women with MetS had a higher risk of metabolic disorders and a drop in physical functions, muscular strength and flexibility compared to those without the syndrome (42), and women with MetS in their 30s were found to have less mobility and relatively less muscular strength compared to other groups (43).

Several researchers have identified the relationship between MetS and demographic factors, and have confirmed the following factors: low educational status and income status may result in differences in workers' access to healthcare services; low socio-economic status and poor income or working conditions may result in increased exposure to health-related risks; and excessive drinking raises the risk of males getting MetS (44-47).

This research found that in four of the quintile groups for grip strength/body weight (age, educational status, income status, and drinking status), both males and females showed a statistically significant difference, while only in the marital status group did females show a significant difference with this test. After conducting a logistic regression by dividing grip strength into five groups based on this result, it was evaluated that in Model 1 corrected by age, males showed a significant drop in Q3, Q4, and Q5 groups, while females showed a significant drop in Q2, Q3, Q4, and Q5. In other words, the research implies that too low grip strength in both males and females does not reduce the risk of MetS in either gender group. Model 2 corrected by age, educational status, marital status, income status, smoking status, drinking status(Menopausal status results added for women) produced the same outcome.

Higher grip strength brought down the risk of MetS for both men and women. Therefore, to prevent and treat MetS, it is recommended that patients exercise steadily to enhance muscular strength and muscle mass. Also, as grip strength is highly associated with MetS, further intervention studies need to be performed, focused on looking at the syndrome as a predictor of MetS; longitudinal studies and experimental studies also need to be carried out to establish a correlation between muscular strength and MetS.

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