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■ Original Article

Association between Relative Handgrip Strength and Dyslipidemia in Korean Adults: Findings of the 2014–2015 Korea National Health and Nutrition Examination Survey

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Background: Grip strength is a convenient method to measure muscle strength. Recently, relative handgrip strength (HGS) was recommended as a clinical predictor of metabolic health and disease, such as dyslipidemia, which is considered a risk factor for cardiovascular disease. The purpose of this study was to characterize the association between relative HGS and dyslipidemia.

Methods: We included 6,027 adults (2,934 men, 3,093 women) aged 30–69 years who participated in the Korea National Health and Nutrition Examination Survey in 2014 and 2015. Relative HGS was obtained by dividing the HGS by body mass index. Complex sampling analysis was conducted to compare the general characteristics of participants according to the quartiles of relative HGS. Logistic regression analysis was used to examine the association between quartiles of relative HGS and dyslipidemia.

Results: After adjustment for age, prevalence of diabetes mellitus, prevalence of hypertension, alcohol consumption, smoking status, exercise, income, and education level, relative HGS was inversely associated with dyslipidemia in both men and women. In multivariable logistic regression analysis, the odds ratios (95% confidence intervals) for dyslipidemia in quartiles 1, 2, and 3 relative to quartile 4 were 1.36 (1.00–1.83), 1.29 (0.98–1.70), 1.23 (0.95–1.60) in men and 1.81 (1.30–2.50), 1.81 (1.32–2.47), 1.39 (1.07–1.81) in women, respectively.

Conclusion: Relative HGS was inversely associated with dyslipidemia risk in Korean adults. Muscle-strengthening exercise is recommended to enhance health outcomes.

Keywords: Hand Strength; Muscle Strength; Dyslipidemias; Metabolic Syndrome

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INTRODUCTION

Cardiovascular deaths account for 31% of annual global deaths.[1] In Korea, cardiovascular disease was the second leading cause of death in 2016.[2] Dyslipidemia is a major risk factor for cardiovascular disease. The prevalence of dyslipidemia in Korean adults aged 30 years or older was 47.8% (57.6% for men and 38.3% for women) in 2013, and the prevalence increases with age.[3] The most common risk factors for cardiovascular disease in men were hypertension, smoking, dyslipidemia, and diabetes, and the combined risk for cardiovascular disease in the presence of all four risk factors was 64%. The most common risk factors for cardiovascular disease in women were hypertension, dyslipidemia, diabetes, and smoking.[4] For these reasons, dyslipidemia is a common and important health problem from the perspective of cardiovascular disease prevention in Korea.

Handgrip strength (HGS) is a useful predictor of muscle mass and strength that is convenient and simple to measure.[5,6] In several studies, low HGS has been associated with metabolic diseases, cardiovascular disease, and mortality.[7-9] One study reported that sarcopenia was associated with the presence of cardiovascular disease independent of other cardiovascular risk factors after adjusting for renal function and medications in Korean elders.[10] There is also evidence that grip strength is inversely associated with all-cause mortality, cardiovascular mortality, and cardiovascular disease.[11] The relationship between grip strength and the metabolic syndrome has also been examined in many studies, with conflicting results. In a cross-sectional study of 2,677 adults in the United Kingdom, lower HGS was associated with higher triglycerides (TG), blood pressure (BP), and insulin resistance after adjusting for age, weight, and health behavior.[9] In a cross-sectional study of 5,014 Korean adults, the group with metabolic syndrome had a higher HGS than the group without metabolic syndrome.[12]

Grip strength is known to be affected by weight, height, and body mass, and has a positive correlation with body mass index (BMI).[13] There is no standardized grip strength index, but previous studies have used relative HGS, which is calculated as absolute HGS divided by BMI. In recent studies on muscle health, the use of relative HGS adjusted for BMI has been recommended. Relative to absolute HGS, relative HGS has stronger associations with metabolic syndrome and its component parameters, including high-density lipoprotein cholesterol (HDLC), TG, fasting glucose, and BP.[12] In addition, previous reports have shown that relative HGS is negatively associated with cardiometabolic risk[14,15] and predicts cardiovascular and all-cause mortality among middle-aged and elderly people.[16]

This study aimed to evaluate the association between relative HGS and dyslipidemia, and to investigate the hypothesis that low relative HGS is associated with dyslipidemia.

METHODS

1. Study Population

We analyzed data from the second and third years of the Korea National Health and Nutrition Examination Survey (KNHANES) VI (2014–2015). The KNHANES was performed to examine the health and nutritional status of the Korean population. The survey used data from complex, nationwide, stratified, multistage probability sampling to represent the Korea population. Data on participants' demographic characteristics, health behavior, and health examinations were obtained by the Korea Centers for Disease Control and Prevention (KCDC) annually. The KNHANES protocol, following the Declaration of Helsinki, was reviewed and approved by the institutional review board of the KCDC (2013-12EXP-03-5, 2015-01-02-6C). Written informed consent for individual data was obtained from all participants.

Of the individuals aged ≥19 years who participated in the 2014–2015 KNHANES (n=11,921), those aged 30–69 years were included (n=8,361). Those who had missing data, including missing survey entries on the treatment of dyslipidemia, level of lipids, HGS measurement, and BMI, were excluded (n=2,334). Altogether, 6,027 participants were ultimately included in this study.

2. Measurement of Handgrip Strength

A digital grip strength dynamometer (Model TKK 5401; Takei Scientific Instruments Co. Ltd., Tokyo, Japan) was used to measure grip strength. The grip strength measurement was performed in a standing position with the arm extended. The middle finger was held at 90° to the handle and measured while exhaling. The maximal hold time of the dynamometer was 3 seconds, and each hand was tested 3 times. Absolute HGS was calculated as the average of the three measurements of the dominant hand. Relative HGS was defined as the absolute HGS divided by BMI.

3. Definition of Dyslipidemia

A health questionnaire confirmed the use of medication for dyslipidemia. After at least 8 hours of fasting, blood samples were collected and analyzed within 24 hours. The Hitachi Automatic Analyzer 7600-210 (Hitachi, Tokyo, Japan) was used to measure total cholesterol (TC), HDLC, TG, and low-density lipoprotein cholesterol (LDLC) levels. According to the "2015 Korean guidelines for management of dyslipidemia," published by the Korean Society of Lipidology and Atherosclerosis, dyslipidemia was defined as having one of the following criteria: currently under medication for dyslipidemia, TC ≥240 mg/dL, HDLC <40 mg/dL, TG ≥200 mg/dL, and LDLC ≥160 mg/dL.[17]

4. Data Collection

A self-administrated health questionnaire was used to collect information on age, sex, pharmacologic treatment for diabetes mellitus and hypertension, alcohol consumption, smoking status, aerobic exercise, family income, and education level. Anthropometric variables such as height (cm), weight (kg), and waist circumference (WC, cm) were measured by a trained health technician following the standardized procedure. BMI was calculated as weight in kg divided by height in meters squared (m^2). BP measurements were obtained from the right arm using a standard mercury sphygmomanometer (Baumanometer,

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Copiague, NY, USA). The average systolic BP (SBP) and diastolic BP (DBP) were obtained by calculating the mean of the second and third measurements after measuring the participant's BP 3 times at 5-minute intervals. Venous blood samples were obtained after an 8-hour minimum overnight fast. The level of fasting blood glucose (FBG) was measured using the Hitachi Automatic Analyzer 7600-210 (Hitachi, Tokyo, Japan). Glycated hemoglobin (HbA1c) values were measured using a G8 high-performance liquid chromatography analyzer (Tosoh, Tokyo, Japan).

5. Assessment of Covariates

For the purposes of calculating prevalence, diabetes mellitus was defined as the participant taking an antidiabetic medication, exhibiting an FBG level ≥126 mg/dL, or exhibiting an HbA1c level ≥6.5%. Hypertension was defined as the participant taking an antihypertensive medication, exhibiting a SBP level ≥140 mm Hg, or exhibiting a DBP level ≥140 mm Hg. Alcohol consumption was defined as self-reported consumption of alcohol in the previous year. Smoking status was classified as current smoker, ex-smoker, and non-smoker. Aerobic exercise was defined as the performance of >150 minutes of moderate intensity exercise or >75 minutes of high intensity exercise during the last week. Family income was divided into quartiles for analysis (<25th, 25–50th, 50–75th, and >75th percentile values), while education level was divided into categories including: elementary school or less, graduated from middle school, graduated from high school, and graduated from college or higher.

6. Statistical Analysis

In KNHANES, the sampling results were weighted to provide a nationally representative prevalence estimate within the Korean population. The weights were calculated by accounting for the complex survey design, survey non-response, and post-stratification. The statistical analysis accounted for the complex sampling design of the KNHANES to minimize selection errors; the estimates reported in this study were obtained based on the primary sampling unit, stratification variables, and sampling weights. The analysis was adjusted for survey year to minimize the variations between survey years.[18,19]

Statistical analysis was performed with IBM SPSS ver. 21.0 (IBM

Table 1. Baseline characteristics of the study population

Characteristic	Total (n=6,027)	Male (n=2,934)	Female (n=3,093)	P-value
Age (y)	47.5	42.6±0.4	44.0±0.5	0.003
BMI (kg/m^2)	23.9	24.4±0.1	23.2±0.1	0.000
Waist circumference (cm)	82.4	85.5±0.2	78.3±0.3	<0.001
Absolute grip strength (kg)*	30.5	39.5±0.2	23.7±0.1	<0.001
Relative grip strength (kg/BMI)†	1.2903	1.6351±0.0088	1.0430±0.0070	<0.001
Total cholesterol (mg/dL)	189.0	189.1±0.9	189.8±0.8	0.483
High-density lipoprotein cholesterol (mg/dL)	49.9	46.9±0.3	54.1±0.3	<0.001
Triglycerides (mg/dL)	152.5	187.9±4.3	120.3±2.3	<0.001
Low-density lipoprotein cholesterol (mg/dL)	112.3	112.9±0.8	112.4±0.6	0.606
Medication for dyslipidemia	9.3	5.3 (0.4)	8.6 (0.5)	<0.001
Diabetes mellitus‡	12.4	11.7 (0.7)	8.5 (0.6)	<0.001
Hypertension§	15.4	17.0 (0.9)	10.4 (0.6)	<0.001
Alcohol consumption‖	68.2	81.1 (0.8)	63.5 (1.2)	<0.001
Smoking status				<0.001
Current smoker	18.2	36.7 (1.1)	4.9 (0.5)	
Ex-smoker	20.4	32.8 (1.0)	5.4 (0.5)	
Non-smoker	61.4	30.5 (1.0)	89.7 (0.7)	
Aerobic exercise¶	50.4	57.6 (1.2)	49.4 (1.3)	<0.001
Family income (percentile)				<0.001
<25th	17.0	11.9 (0.8)	16.0 (1.1)	
25–50th	24.8	24.0 (1.2)	23.8 (1.2)	
50–75th	28.4	31.6 (1.4)	29.9 (1.4)	
75–100th	29.8	32.5 (1.5)	30.3 (1.7)	
Education level				<0.001
Elementary school or less	26.2	15.7 (0.8)	23.6 (1.1)	
Middle school graduate	13.0	10.9 (0.7)	12.4 (0.7)	
High school graduate	31.3	36.9 (1.2)	32.2 (1.1)	
College graduate or higher	29.5	36.5 (1.3)	31.7 (1.4)	

Values are presented as mean±standard error for continuous variables using generalized linear models and % (standard error) for categorical variables using Pearson's chi-square tests, unless otherwise stated.
BMI, body mass index.
*Average of three measurements of dominant hand. †Absolute hand grip strength divided by BMI. ‡Took an antidiabetic medication, with a fasting blood glucose level ≥126 mg/dL or with a glycated hemoglobin level ≥6.5%. §Took an antihypertensive medication, with a systolic blood pressure level ≥140 mm Hg or with a diastolic blood pressure level ≥140 mm Hg. ‖Had consumed alcohol in the past year. ¶Had >150 minutes of moderate intensity exercise or >75 minutes of high intensity exercise in the previous week.

Corp., Armonk, NY, USA). To compare groups within sex according to quartile of relative HGS, continuous variables were summarized as mean values with standard errors (SEs) using generalized linear models, and categorical variables were evaluated as percentages with SEs using Pearson's chi-square tests.

Because the baseline characteristics differed according to sex, the analyses were stratified by sex. To examine the relationship between relative HGS and dyslipidemia, we divided the participants into four groups according to the quartiles of relative HGS: first (Q1, ≤1.3427 kg/BMI), second (Q2, 1.3428 kg/BMI–1.5772 kg/BMI), third (Q3, 1.5773 kg/BMI–1.8194 kg/BMI), and fourth (Q4, ≥1.8195 kg/BMI) in men and first (Q1, ≤0.8406 kg/BMI), second (Q2, 0.8407 kg/BMI–1.0134 kg/BMI), third (Q3, 1.0135 kg/BMI–1.1852 kg/BMI), and fourth (Q4, ≥1.1853 kg/BMI) in women. For each sex, a multivariate adjusted logistic regression analysis was performed with three models to evaluate the relationship between relative HGS and dyslipidemia. The first model was unadjusted. The second model was adjusted for age. The third model was adjusted further for prevalence of diabetes mellitus, prevalence of hypertension, alcohol consumption, smoking status, aerobic exercise, family income, and education level. Odds ratios (ORs) and their corresponding 95% confidence intervals (CIs) for each group were shown with reference to participants with highest quartile of relative HGS. A P-value of <0.05 was considered significant.

RESULTS

Altogether, 6,027 participants were included in the study. Baseline characteristics of the 2,934 men and 3,093 women are shown in Table 1. The mean age for men was 42.6 years and 44.0 years for women. The mean BMI for men was 24.4 kg/m^2 and 23.2 kg/m^2 for women. The mean absolute HGS for men was 39.5 kg and 23.7 kg for women; the corresponding mean relative HGS for men was 1.6351 kg/BMI and 1.0430 kg/BMI for women. There were significant differences in these characteristics between men and women.

Tables 2 and 3 present the association between relative HGS and clinical variables. Lower relative HGS was associated with cardiovascular risk in this study. The group with the highest relative HGS was younger, had lower rates of hypertension, and had higher HDL levels in both sexes and lower TG levels in women only. However, there was a positive relationship between relative HGS and alcohol consumption. Relative HGS was inversely associated with diabetes mellitus and menopause.

Table 2. General characteristics of men according to the quartiles of relative HGS

Characteristic	Relative HGS				P-value
	Q1	Q2	Q3	Q4	
No. of participants	741	739	740	714	
Age (y)	45.0±1.0	45.8±0.7	42.1±0.6	38.7±0.5	<0.001
Total cholesterol (mg/dL)	184.2±1.7	190.5±1.6	192.2±1.5	188.1±1.7	0.001
High-density lipoprotein cholesterol (mg/dL)	45.3±0.5	45.9±0.5	46.7±0.5	49.1±0.5	<0.001
Triglyceride (mg/dL)	174.8±7.5	198.9±7.9	197.9±7.4	177.6±6.9	0.25
Low-density lipoprotein cholesterol (mg/dL)	110.7±1.4	114.2±1.5	114.9±1.4	111.2±1.5	0.71
Medication for dyslipidemia	7.2 (1.0)	8.5 (1.1)	4.5 (0.8)	2.3 (0.6)	<0.001
Diabetes mellitus*	17.0 (1.5)	13.2 (1.4)	11.8 (1.4)	6.9 (1.1)	<0.001
Hypertension†	17.7 (1.7)	20.6 (1.9)	19.6 (1.9)	11.1 (1.3)	<0.001
Alcohol consumption‡	62.4 (2.2)	83.1 (1.5)	84.8 (1.3)	87.9 (1.2)	<0.001
Smoking status					<0.001
Current smoker	23.1 (1.9)	33.0 (2.0)	40.3 (2.1)	45.8 (2.2)	
Ex-smoker	36.7 (2.1)	37.9 (2.1)	30.7 (1.9)	27.0 (1.7)	
Non-smoker	40.2 (2.2)	29.1 (1.9)	29.0 (1.9)	27.2 (1.9)	
Aerobic exercise§	51.9 (2.5)	55.4 (2.4)	60.7 (2.1)	60.3 (2.1)	0.20
Family income (percentile)					<0.001
<25th	19.7 (2.0)	11.1 (1.2)	10.8 (1.4)	8.8 (1.5)	
25–50th	25.9 (2.0)	27.2 (2.2)	19.9 (1.9)	24.2 (2.0)	
50–75th	25.9 (2.3)	29.7 (2.4)	33.9 (2.2)	34.6 (2.2)	
75–100th	28.5 (2.0)	32.0 (2.6)	35.5 (2.4)	32.5 (2.3)	
Education level					<0.001
Elementary school or less	36.4 (2.3)	16.3 (1.5)	11.2 (1.4)	5.4 (0.9)	
Middle school graduate	11.5 (1.3)	11.7 (1.3)	10.2 (1.3)	10.5 (1.3)	
High school graduate	27.8 (2.1)	34.2 (2.2)	39.6 (2.3)	44.2 (2.3)	
College graduate or higher	24.3 (2.2)	37.8 (2.4)	29.0 (2.2)	39.9 (2.4)	

Values are presented as mean±standard error for continuous variables using generalized linear models and % (standard error) for categorical variables using Pearson's chi-square tests, unless otherwise stated.
HGS, handgrip strength.
*Took an antidiabetic medication, with a fasting blood glucose level ≥126 mg/dL or with a glycated hemoglobin level ≥6.5%. †Took an antihypertensive medication, with a systolic blood pressure level ≥140 mm Hg or with diastolic blood pressure level ≥140 mm Hg. ‡Had consumed alcohol in the past year. §Had >150 minutes of moderate intensity exercise, or >75 minutes of high intensity exercise in the previous week.

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Table 3. General characteristics of women according to the quartiles of relative HGS

Characteristic	Relative HGS				P-value
	Q1	Q2	Q3	Q4	
No. of participants	774	773	773	773	
Age (y)	52.4±1.0	45.4±0.9	42.9±0.7	37.4±0.6	<0.001
Total cholesterol (mg/dL)	192.6±1.6	194.4±1.6	189.9±1.4	183.7±1.2	<0.001
High-density lipoprotein cholesterol (mg/dL)	49.5±0.5	52.6±0.6	55.1±0.5	57.9±0.6	<0.001
Triglycerides (mg/dL)	139.6±3.8	134.8±4.3	116.0±3.8	97.2±3.2	<0.001
Low-density lipoprotein cholesterol (mg/dL)	117.4±1.3	116.8±1.3	111.8±1.1	105.6±1.1	<0.001
Medication for dyslipidemia	14.4 (1.3)	11.7 (1.2)	7.0 (1.0)	3.0 (0.6)	<0.001
Diabetes mellitus*	17.6 (1.7)	10.6 (1.2)	5.7 (0.9)	2.5 (0.5)	<0.001
Hypertension†	17.5 (1.7)	12.5 (1.4)	8.2 (1.0)	5.4 (0.8)	<0.001
Alcohol consumption‡	47.6 (2.2)	61.4 (2.2)	69.9 (2.1)	71.2 (2.0)	<0.001
Smoking status					0.391
Current smoker	3.4 (0.8)	5.4 (1.2)	5.1 (1.0)	5.5 (1.1)	
Ex-smoker	5.1 (1.0)	4.7 (0.9)	4.8 (0.9)	6.8 (1.1)	
Non-smoker	91.5 (1.2)	89.9 (1.4)	90.1 (1.2)	87.7 (1.4)	
Aerobic exercise§	40.0 (2.3)	45.5 (2.6)	51.5 (2.3)	57.5 (2.0)	<0.001
Family income (percentile)					<0.001
<25th	29.6 (2.1)	15.9 (1.6)	11.4 (1.6)	10.0 (1.3)	
25–50th	22.9 (1.9)	27.4 (2.2)	24.1 (1.8)	21.4 (1.9)	
50–75th	26.2 (2.1)	31.0 (2.2)	30.3 (2.3)	31.1 (2.2)	
75–100th	21.4 (2.2)	25.7 (2.3)	34.2 (2.3)	37.5 (2.4)	
Education level					<0.001
Elementary school or less	50.0 (2.4)	28.8 (2.0)	14.4 (1.6)	7.9 (1.1)	
Middle school graduate	13.0 (1.4)	12.5 (1.4)	12.9 (1.4)	11.6 (1.4)	
High school graduate	16.9 (1.8)	33.1 (2.0)	36.2 (2.0)	29.0 (2.1)	
College graduate or higher	20.0 (2.1)	25.6 (2.2)	36.5 (2.4)	41.4 (2.3)	
Menopause	62.2 (2.5)	46.3 (2.6)	34.2 (2.0)	19.8 (1.6)	<0.001

Values are presented as mean±standard error for continuous variables using generalized linear models and % (standard error) for categorical variables using Pearson's chi-square tests, unless otherwise stated.
HGS, handgrip strength.
*Took an antidiabetic medication, with a fasting blood glucose level ≥126 mg/dL or with a glycated hemoglobin level ≥6.5%. †Took an antihypertensive medication, with a systolic blood pressure level ≥140 mm Hg or with diastolic blood pressure level ≥140 mm Hg. ‡Had consumed alcohol in the past year. §Had >150 minutes of moderate intensity exercise, or >75 minutes of high intensity exercise in the previous week.

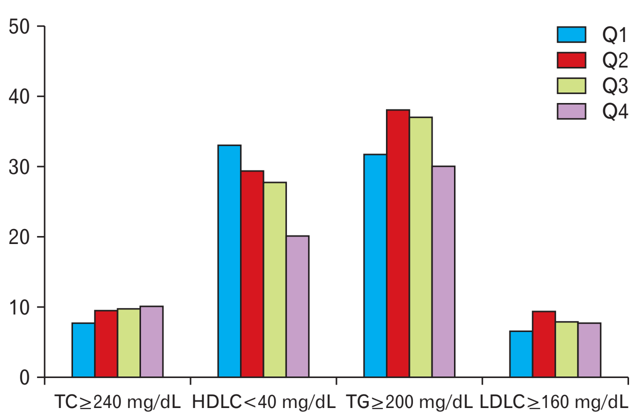

Figure 1. Components of dyslipidemia by quartile of relative handgrip strength in men. TC, total cholesterol; HDLC, high-density lipoprotein cholesterol; TG, triglyceride; LDLC, low-density lipoprotein cholesterol.

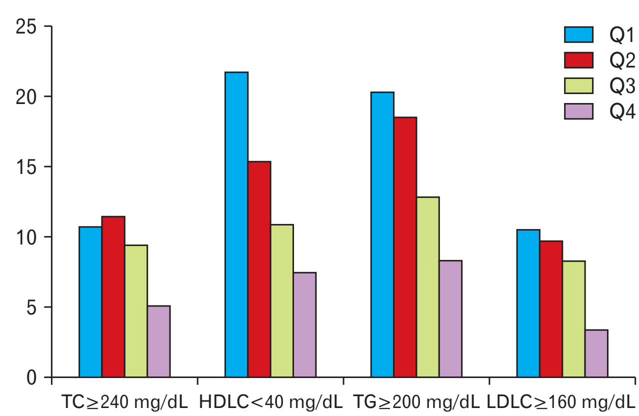

Figure 2. Components of dyslipidemia by quartile of relative handgrip strength in women. TC, total cholesterol; HDLC, high-density lipoprotein cholesterol; TG, triglyceride; LDLC, low-density lipoprotein cholesterol.

The categories of dyslipidemia by quartiles of relative HGS are shown in Figures 1 and 2. We observed a statistically significant relationship between lipid profiles and quartiles of relative HGS. Among men, a higher relative HGS was associated with lower risk of low HDLC (P<0.001; Q1, 33.1%; Q2, 29.5%; Q3, 27.8%; and Q4, 20.3%). Among women, a higher relative HGS was associated with lower risk of low HDLC (P<0.001; Q1, 21.7%; Q2, 15.4%; Q3, 10.9%; and Q4, 7.5%), high TG (P<0.001; Q1, 20.3%; Q2, 18.5%; Q3, 12.8%; and Q4, 8.3%), and high LDLC (P<0.001; Q1, 10.5%; Q2, 9.7%; Q3, 8.3%; and Q4, 3.3%).

In men, the unadjusted ORs for dyslipidemia were significantly higher among those in the lower relative HGS quartile groups than among those in the highest quartile group. There was a significantly negative correlation between relative HGS and dyslipidemia in women. After adjusting for age, prevalence of diabetes mellitus, prevalence of hypertension, alcohol consumption, smoking status, aerobic exercise, family income, and education level, relative HGS was inversely related to dyslipidemia in both men and women. The multivariableadjusted ORs for dyslipidemia in Q1, Q2, and Q3 relative to quartile 4 were 1.36, 1.29, and 1.23 in men, and 1.81, 1.81, and 1.39 in women, respectively (Table 4).

DISCUSSION

This study examined the relationship between relative HGS and dyslipidemia using a nationwide survey of Korean adults. The results showed that there was a significant inverse association between relative HGS and dyslipidemia in both men and women. In this study, relative HGS was significantly inversely related to cardiovascular risk factors, particularly low HDL, aging, and hypertension. The prevalence of hypertension was higher in the group with lower relative HGS than in the group with the highest relative HGS. Diabetes mellitus also exhibited a negative relationship with relative HGS. The prevalence of diabetes was higher in the lowest group than in the highest group.

In a study of 350 schoolchildren, improved muscle strength has been shown to reduce cardiometabolic risk. ORs (95% CIs) for borderline/low HDLC in the low, moderate, and high grip strength group were 1.00, 0.58 (0.35–0.98), and 0.28 (0.16–0.48), respectively. ORs (95% CIs) for borderline/high TGs in the low, moderate, and high grip strength group were 1.00, 0.79 (0.44–1.40), and 0.47 (0.25–0.88), respectively. After adjustment for BMI, grip strength was no longer associated with HDLC and TG levels.[20] In contrast, our study used relative HGS, a BMI-adjusted index, and the results were statistically significant. Some previous studies reported that absolute HGS was associated with metabolic syndrome, including abnormal lipid metabolism. A previous study conducted in UK adults demonstrated that lower HGS was associated with higher TG levels, BP, and WC, but not with lower HDLC and higher FBG levels.[9] In a study of Japanese adults aged 65 years and older, a correlation was observed between HGS and metabolic syndrome. In the study's analysis of HGS and each component of the metabolic syndrome, abdominal obesity was a primary contributor to the occurrence of metabolic syndrome, while the other components (high TG levels, low HDLC levels, high FPG levels, and high BP) did not contribute to the occurrence of this condition.[21] In summary, the reported relationship between absolute HGS and lipid profiles differed between studies.

Recent studies investigated the association between relative HGS and metabolic syndrome. A study conducted among American adults showed that higher relative HGS was significantly associated with favorable HDLC, TG, FBG, and SBP levels, but not with LDLC level.[14] In China, using multivariable regression, relative HGS showed a favorable association with lipid metabolism (all P<0.001; LDLC: b=-0.14 [men], -0.19 [women]; TC: b=-0.20 [men], -0.19 [women]; TG: b=-0.58 [men], -0.55 [women]; HDLC: b=0.19 [men], 0.22 [women]).[22] There were inverse relationships between relative HGS and lipid profile in American and Chinese adults, and our study found similar results. Particularly favorable results for the relationship between relative HGS and HDL have been observed in all studies.

It is noteworthy that our findings indicate an inverse relationship between grip strength and dyslipidemia. In men, there was an inverse relationship between relative HGS and low HDL. In women, there was a negative association between relative HGS and low HDL, high TG, and high LDL. After adjusting for various covariates, we found that low grip strength and dyslipidemia were significantly correlated in women, and the same tendency was observed in men. However, further studies are needed to determine the effect of muscle strength on blood cholesterol and TG. The development of dyslipidemia is known to be

Table 4. Association between relative handgrip strength and dyslipidemia

	Model 1		Model 2		Model 3	
	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Male		0.008		0.080		0.194
Q1	1.20 (0.95–1.52)		1.05 (0.83–1.35)		1.36 (1.00–1.83)	
Q2	1.46 (1.15–1.85)		1.26 (0.99–1.62)		1.29 (0.98–1.70)	
Q3	1.37 (1.08–1.74)		1.29 (1.01–1.64)		1.23 (0.95–1.60)	
Q4	1 (Reference)		1 (Reference)		1 (Reference)	
Female		<0.001		<0.001		0.001
Q1	3.46 (2.66–4.51)		2.12 (1.59–2.84)		1.81 (1.30–2.50)	
Q2	2.75 (2.09–3.63)		2.13 (1.60–2.85)		1.81 (1.32–2.47)	
Q3	1.79 (1.38–2.32)		1.50 (1.16–1.94)		1.39 (1.07–1.81)	
Q4	1 (Reference)		1 (Reference)		1 (Reference)	

Values are presented as odd ratios (95% confidence interval) from the logistic regression models. Model 1 was unadjusted. Model 2 was adjusted for age. Model 3 was adjusted for age, prevalence of diabetes mellitus, prevalence of hypertension, alcohol consumption, smoking status, aerobic exercise, family income, and education level. Additionally, model 3 in women was adjusted for menopause.
OR, odd ratio; CI, confidence interval.

influenced by many factors, including obesity, alcohol consumption, high carbohydrate diet, estrogen, and heredity. When considering these factors, the difference between men and women in this study can be explained by differences in sex hormones[23,24] and drinking behavior (Table 1).

The present study shows that the prevalence of hypertension and diabetes mellitus increased as relative HGS decreased in both men and women, which was consistent with the results of recently published studies. Muscle strength measured by grip strength was inversely related to FBG level, HbA1c level, insulin resistance, and type 2 diabetes mellitus in Korean adults.[25] In a large and nationally representative survey of adults with normal weight, grip strength was lower among individuals with both undiagnosed and diagnosed diabetes (β=-10.02, P<0.0001 for undiagnosed; β=-8.21, P=0.03 for diagnosed) and hypertension (β=-6.6, P=0.004 for undiagnosed; β=-4.27, P=0.04 for diagnosed) than among those without diabetes mellitus and hypertension after adjustment for age, sex, race, smoking status, and presence of a first-degree relative with the disease.[26]

Despite the significant findings for grip strength and cardiometabolic risk factors, the percentage of men who were current smokers increased as grip strength increased, although this relationship was not observed among women. These findings could be attributed to other factors, such as biochemical or anthropometric factors that might have affected grip more than smoking status. The proportion of current smokers was 36.7% in men and 4.9% in women. Most of the women included in the study were nonsmokers, and the prevalence of current smokers and ex-smokers was significantly lower in among women than among men.

Skeletal muscles play a central role in the regulation of whole body metabolism, including energy expenditure and glucose storage stimulated by insulin.[27-29] Because a decrease in muscle mass and contraction intensity reduces the area responsible for glucose transport and worsens insulin resistance, muscle is considered to be an important component of systemic insulin resistance.[30] In a healthy skeletal muscle, the rate of fatty acid (FA) uptake is equivalent to the rate of FA oxidation. Skeletal muscle dysfunction causes the rate of FA uptake to exceed the rate of FA oxidation, resulting in the deposition of lipid intermediates. This process is involved in the development of dyslipidemia by triggering an increase in TG and LDLC, and a decrease in HDLC, although muscle strength and muscle function are not equivalent.

Body weight, height, and body mass are known to affect grip strength.[13] As we have noted, the associations between grip strength and other characteristics have differed between studies, depending on whether the analyzed measures of grip strength controlled for BMI. In recent studies, relative HGS, adjusted for BMI, was inversely related to cardiometabolic risk.[12,15,22] The results of our study are consistent with this previous research. On the other hand, the relationship between absolute muscle strength and dyslipidemia remains controversial.[12,20] Although the results were not shown, absolute grip strength was not significantly associated with dyslipidemia in this study. There is no standardized method for evaluating grip strength. However, we have found that relative HGS is a more significant indicator than absolute grip strength when assessing cardiometabolic risk factors, including dyslipidemia.

This study had some limitations. Because the study was cross-sectional in nature, longitudinal analyses are still necessary to support conclusions about the effect of grip strength on cardiometabolic risk factors. Additionally, the evaluation of muscle strength was only based on the measurement of grip strength; greater muscle strength generally may not equate to improved muscular health or efficiency. Grip strength is also known to be greatly affected by age; although we adjusted for age in our analyses, it would also be useful to perform analyses that are stratified by age in future research. Because data regarding the ingredients of the drugs taken by participants were not obtained, we could not consider the effect of drugs such as statins on muscles. Finally, confounding factors such as a high carbohydrate diet and a family history of dyslipidemia were not considered.

This study also had several strengths. To consider the effect of BMI on grip strength, we used relative HGS. To our knowledge, this is the first study to examine associations between relative grip strength and dyslipidemia among a nationally representative sample from Korean adults who participated in the Korea National Health and Nutrition Examination Survey (KNHANES) VI 2014–2015. We also adjusted for variables, such as health behavior and socioeconomic level, that affect both grip strength and dyslipidemia, and our results suggest the possibility that relative HGS could be used as an indicator for dyslipidemia. Additionally, we suggest that increasing muscle strength could prevent dyslipidemia and cardiovascular disease.

In conclusion, our findings suggest that greater relative HGS is associated with healthier HDLC concentrations in Korean adults. While longitudinal analyses are warranted to determine whether grip strength is an independent predictor of dyslipidemia, muscle-strengthening exercise should nevertheless be considered for enhancing health outcomes.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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