

# Association of Handgrip Strength and Cardiovascular Disease Risk Among Middle-Aged Postmenopausal Women: An Analysis of the Korea National Health and Nutrition Examination Survey 2014–2019

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**Purpose:** Handgrip strength is an indicator of overall muscle strength and has been associated with an increased risk of cardiovascular disease. Evidence suggests that menopause is a risk factor for cardiovascular disease in women, and muscle strength decreases progressively after menopause. Despite the prognostic importance of the decline in muscle strength and increased cardiovascular disease risk among postmenopausal women, evidence of their association is limited. This study aimed to investigate the relationship between handgrip strength and cardiovascular disease risk among postmenopausal, middle-aged Korean women.

**Patients and Methods:** Using pooled cohort equations, we calculated the 10-year risk of atherosclerotic cardiovascular disease (ASCVD) among postmenopausal women (N = 2019) aged 50–64 years without cardiovascular disease history from the 2014–2019 Korea National Health and Nutrition Examination Survey. Relative grip strength was defined as measured grip strength divided by body mass index. Logistic regression analysis of a complex sampling design was performed to evaluate the association between relative grip strength and a predicted 10-year ASCVD risk  $\geq 7.5\%$ .

**Results:** The average handgrip strength was 24.8 kg, and 5.2% of women were considered for sarcopenia (<18 kg). The quartile-stratified relative grip strength was negatively associated with 10-year ASCVD risk ( $p < 0.001$ ). In the multiple logistic regression analysis, the adjusted odds ratio for the highest relative grip strength quartile was 0.53 (95% confidence interval [CI]: 0.36–0.78), and that of the group who breastfed for more than 12 months was 1.75 (95% CI: 1.36–2.25) for 10-year ASCVD risk.

**Conclusion:** Increased handgrip strength may be associated with lower cardiovascular disease risk among middle-aged postmenopausal women in Korea. Our findings provide critical evidence regarding the importance of increasing handgrip strength among postmenopausal, middle-aged women to reduce cardiovascular disease risk. Handgrip strength measurement might be a valuable screening tool for cardiovascular disease prevention.

**Keywords:** cardiovascular disease, relative grip strength, menopause, sarcopenia

## Introduction

Cardiovascular disease (CVD) is the leading cause of death globally and remains one of the most serious public health concerns. Generally, CVD encompasses a group of heart and blood vessel disorders, including coronary heart disease, cerebrovascular disease, peripheral arterial disease, rheumatic heart disease, congenital heart disease, deep vein thrombosis, and pulmonary embolism.<sup>1</sup> The overall prevalence of CVD has steadily increased, nearly doubling from 271 million in 1990 to 523 million in 2019 [Roth, 2020]. The World Health Organization<sup>1</sup> reports that CVD accounted for nearly 32% of all global deaths in 2019, with 85% of those deaths due to heart attacks and strokes. In South Korea,

heart disease has been the leading cause of death for nearly a decade, and the prevalence of atherosclerotic CVD (ASCVD) continues to increase with age until 79 years.<sup>2</sup> Over the past decade, mortality and hospitalization rates due to CVD have steadily increased in South Korea. While the mortality rate decreased until 2010, it subsequently increased to 123 per 100,000 people in 2018.<sup>3</sup> In this context, identifying and quantifying the major risk factors for CVD is essential to optimize preventive strategies.<sup>4</sup>

There are many risk factors that contribute to CVD, including modifiable factors such as high blood pressure, abdominal obesity, abnormal lipid levels, smoking, diabetes mellitus, stress, unhealthy diets, and physical inactivity. These factors are the leading causes of cardiovascular morbidity and mortality.<sup>5</sup> Recently, there has been growing interest in understanding the role of muscle strength as a CVD risk factor, given its association with other risk factors such as hypertension, diabetes, and metabolic syndrome.<sup>6</sup>

Muscle strength is an important predictor of health, but losses of skeletal muscle mass and strength typically occur with increasing age.<sup>7,8</sup> Sarcopenia, the age-related loss of skeletal muscle mass accompanied by declining strength and function,<sup>9</sup> is generally evaluated based on three criteria: muscle mass, physical performance, and strength. Handgrip strength correlates with the strength of other body compartments<sup>10</sup> and is gaining attention as a diagnostic measure for sarcopenia.<sup>11,12</sup> Higher handgrip strength has been associated with cardiac structure and function (with less cardiac hypertrophy and remodeling)<sup>13</sup> and has been used as a reliable tool for screening CVD risk. Recent studies recognize the association between strength and CVD risk.<sup>12,14</sup>

Although muscle strength has recently gained support as a consistent and reliable indicator of cardiovascular risk,<sup>15–17</sup> there is currently no formalized standard measure for muscle strength. Studies have investigated the associations between muscle strength and various diseases, leading to a wide variety of muscle strength types and measurement methods in academia and clinical practice. Recently, relative grip strength (absolute handgrip strength divided by body mass index) has been recommended as a handgrip strength measure because physical characteristics such as weight and height can affect absolute handgrip strength.<sup>16</sup> Relative grip strength has been evaluated as a more reliable predictor of CVD risk than absolute handgrip strength.<sup>15,17,18</sup>

Decreased muscle strength has been reported to increase the risk of cardiovascular death and all-cause mortality and is associated with cardiometabolic risk, including the risk of metabolic syndrome<sup>19</sup> and diabetes.<sup>20</sup> Low handgrip strength, a representative indicator of low muscle strength, has been shown to increase the risk of all-cause mortality, including mortality from CVD.<sup>14</sup> Many epidemiological studies have reported a correlation between handgrip strength and cardiometabolic diseases and mortality. The PURE (Prospective Urban Rural Epidemiology) study, a large longitudinal study conducted in 17 countries, found that handgrip strength was inversely associated with all-cause mortality, cardiovascular mortality, myocardial infarction, and stroke. Handgrip strength was a more effective predictor of CVD than systolic blood pressure over a 4-year follow-up period.<sup>21</sup> Additionally, relative grip strength was significantly associated with cardiovascular health biomarkers in adults, with higher relative grip strength associated with favorable cardiovascular profiles.<sup>16</sup>

Meanwhile, muscle strength varies with age, gender, and body size.<sup>22,23</sup> Age-related muscle strength loss correlates with a loss of skeletal muscle mass.<sup>24</sup> Although sarcopenia is known as a geriatric disease, it is seen across all age groups, including in middle age.<sup>10</sup> Muscle loss begins around 40 years of age,<sup>25</sup> with loss of muscle mass and strength becoming evident around the age of 50.<sup>26,27</sup> Although muscle mass loss with aging is more prevalent in men, sarcopenia is a more serious public health problem for women due to longer lifespans and higher disability rates.<sup>28</sup> Decreased estrogen levels, decreased bone density and muscle mass, decreased muscle strength, and increased intramuscular fat are particularly pronounced among middle-aged women during menopause.<sup>29–31</sup> A recent study in Asia found that about 12% of postmenopausal, middle-aged women were in the pre-sarcopenic stage.<sup>32</sup> Furthermore, hormonal changes in menopausal women are associated with a higher risk of CVD.<sup>33</sup> Specifically, one study found that the risk of CVD was significantly higher in middle-aged women entering menopause relative to those who were premenopausal.<sup>34</sup> This highlights middle-aged women as a population in need of early detection and prevention, as they lose muscle mass and strength during menopause and aging and face increased cardiovascular risk.<sup>35,36</sup>

Identifying patients at high risk of developing CVD is a key component of CVD prevention.<sup>37</sup> Therefore, effective screening strategies for CVD in high-risk postmenopausal women can be used to detect and prevent risk factors early,

both clinically and in everyday life. However, few studies have examined the association of relative grip strength with CVD in postmenopausal women, and most such studies have had relatively broad inclusion criteria, including both middle-aged and older adults.<sup>38</sup> Additionally, although handgrip strength has been evaluated as a reliable indicator in several health outcome and association studies of older adults,<sup>39</sup> there is a lack of evidence about muscle strength as a reliable marker in middle-aged adults. CVDs differ between the sexes and require a sex-specific and lifespan approach. To date, few studies in Korea have evaluated the independent prognostic significance of relative grip strength as a marker of muscle strength among postmenopausal, middle-aged women. Therefore, this study aimed to determine the association between relative grip strength and CVD risk and evaluate the utility of relative grip strength among middle-aged postmenopausal women using data from the latest 6 years of the Korea National Health and Nutrition Examination Survey (KNHANES), a dataset representative of the Korean population.

## Methods

### Data Collection and Participants

This study used data from the 2014–2019 KNHANES, encompassing the sixth through eighth survey waves. The KNHANES is a national research survey conducted annually by the Korean Ministry of Health and Welfare. This publicly available database contains information on Korean citizens aged 1 year or older and is designed to produce population-level statistics on health behaviors, outcomes, diet, and nutritional status. The sample design for KNHANES was drawn using a two-stage stratified cluster sampling method to ensure representativeness of the population, with household weights for household-level analysis and individual weights for individual-level analysis. The Korea Center for Disease Control and Prevention recommends using complex sampling methods when analyzing KNHANES raw data.<sup>40</sup>

A total of 45,022 individuals participated in the KNHANES from 2014–2019. Of these, we focused on 4343 postmenopausal women aged 45–64 years. The following individuals were excluded from our analysis: subjects with cancer ( $n = 292$ ); subjects with a history of CVD, liver disease, kidney disease, hepatitis, thyroid disease, or arthritis ( $n = 1241$ ); and subjects with missing data ( $n = 791$ ). This resulted in a final sample size of 2019 individuals for analysis. [Figure 1](#) depicts the sample selection procedures.

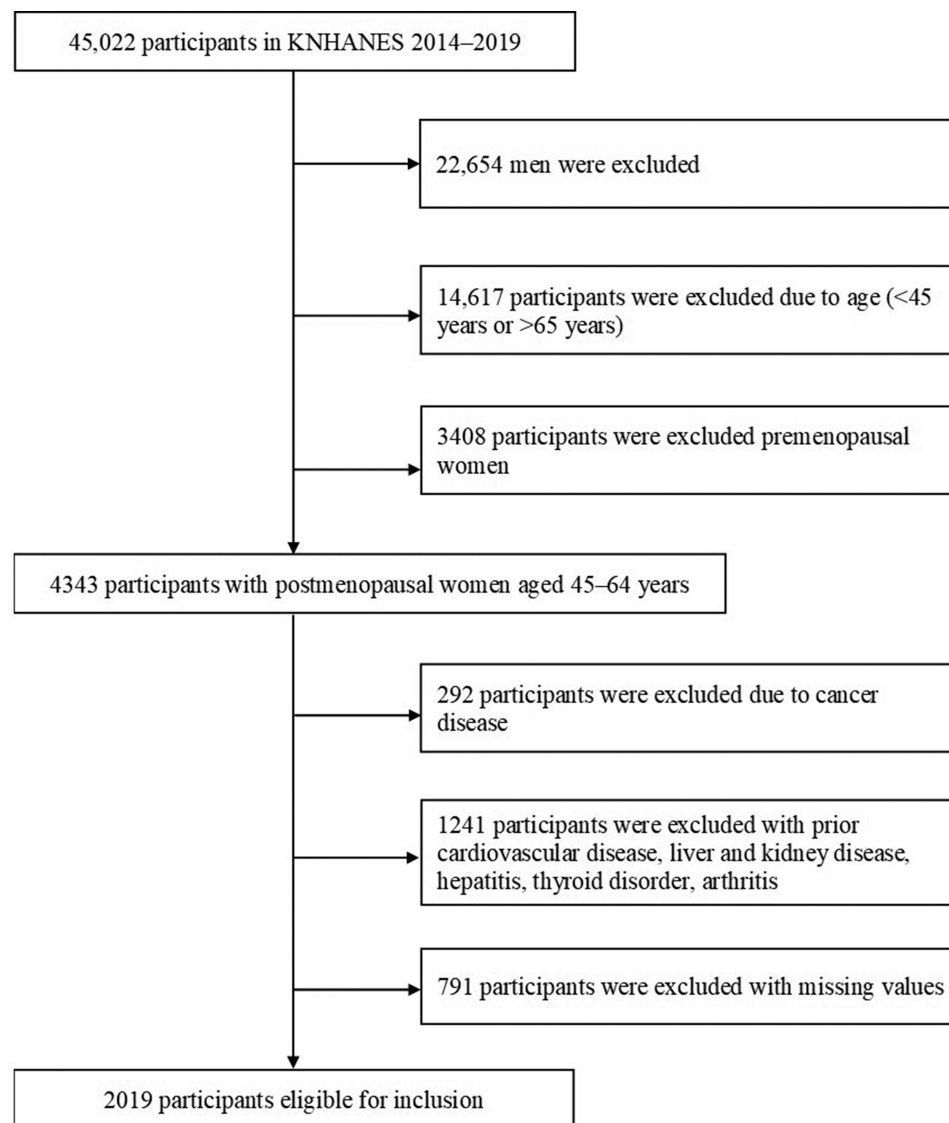
### Estimated ASCVD Risk/Dependent Variable

We calculated the 10-year risk of a first hard ASCVD event using the pooled cohort equations for non-Hispanic Whites. Following the ACC/AHA (American College of Cardiology/American Heart Association) guidelines, the nine variables included in the 10-year ASCVD risk calculation are race, sex, age, total cholesterol, high-density lipoprotein cholesterol, blood pressure, diabetes diagnosis, treatment for hypertension, and smoking status. [Table 1](#) presents relevant data for the subjects in this study, extracted from the KNHANES. Results were categorized into low-risk (less than 7.5% risk) and high-risk (greater than 7.5% risk) groups.<sup>31</sup>

Measurements and surveys were conducted following a minimum of 8 hours of fasting. Blood pressure readings were obtained using a sphygmomanometer; three measurements were taken, with the mean of the second and third readings constituting the examination blood pressure. We assessed serum glucose levels (using the hexokinase ultraviolet method) and hemoglobin A1C (using the high-performance liquid chromatography method). Diabetes mellitus was defined as a serum fasting glucose level  $\geq 126$  mg/dL, a hemoglobin A1C level  $\geq 6.5\%$ , the use of diabetes medication, the use of insulin injections, or a physician diagnosis. Total cholesterol and high-density lipoprotein cholesterol levels were determined using a standard enzymatic method. Cigarette smoking status was self-reported, and the use of antihypertensive medication was verified by research assistants. The pooled cohort equations for non-Hispanic Whites have demonstrated good discrimination for ASCVD prediction in Korean male and female subjects.<sup>32</sup>

### Measurement of Grip Strength

We measured grip strength using a digital hand dynamometer (Digital grip strength dynamometer, T.K.K. 5401, Takei Scientific Instruments Co., Ltd., Tokyo, Japan), a tool with proven reliability and validity.<sup>33</sup> Measurements were performed in accordance with the Southampton protocol for adult grip strength assessment. Subjects were seated with



**Figure 1** Flowchart of the study participant selection process.

their forearms resting neutrally on the arms of a chair. We obtained three grip strength measurements for each hand, selecting the maximum strength for analysis. Participants were given a minimum of 30 seconds of rest between measurements. Grip strength was defined as the maximum measurement obtained from the dominant hand.<sup>34</sup> Relative grip strength was calculated by dividing absolute grip strength by body mass index.<sup>35,36</sup>

## Covariates

We evaluated covariates including individual sociodemographic characteristics and health-related factors. Individual sociodemographic variables were education (categorized as elementary school, middle school, high school, and college) and socioeconomic status (divided into quintiles). Health-related factors included alcohol consumption (dichotomized as yes/no for drinking at least once a month in the past year) and physical activity (dichotomized as yes/no for engaging in high-intensity activity for >75 min/week, moderate-intensity activity for >150 min/week, or a combination of both). Based on the guidance of previous studies, we also selected the duration of breastfeeding and age at menarche as covariates.<sup>37–40</sup>

**Table 1** General Characteristics of the Study Population According to the 2014–2019 KNHANES Survey

Variables*	Participants (N=2019)		Overall Population	
	(N, Weighted %)	(Mean, SE)	(N, weighted %)	(Mean, SE)
Age (years)	56.82	0.11	40.68	0.18
Education				
≤ elementary school	437	20.8%	14,515	26.2%
Middle school graduate	446	21.5%	4670	10.8%
High school graduate	772	39.8%	11,134	30.1%
College graduate+	364	18.0%	12,036	33.0%
Household income				
1st quartile	229	10.9%	7856	14.6%
2nd quartile	516	25.4%	11,289	24.7%
3rd quartile	574	28.9%	12,804	30.1%
4th quartile	700	34.7%	12,868	30.6%
Alcohol consumption				
No	1278	61.9%	19,076	45.5%
Yes	741	38.1%	19,112	54.5%
Physical activity <sup>†</sup>				
No	1128	54.2%	18,849	50.4%
Yes	891	45.8%	16,198	49.6%
Smoking				
No	1951	96.3%	38,629	82.5%
Yes	68	3.7%	6393	17.5%
Diabetes diagnosis				
No	352	17.5%	16,871	36.1%
Yes	1667	82.5%	28,151	63.9%
Treatment for hypertension				
No	1559	77.9%	36,295	84.5%
Yes	460	22.1%	8727	15.5%
Total cholesterol (mg/dL)	206.86	1.00	187.91	0.26
HDL cholesterol (mg/dL)	54.62	0.33	51.30	0.09
LDL cholesterol (mg/dL)	124.33	1.56	114.36	0.44
Triglycerides (mg/dL)	125.36	1.88	133.16	0.82
Systolic blood pressure (mmHg)	119.49	0.43	116.53	0.14
AST (IU/L)	23.27	0.22	22.81	0.09
ALT (IU/L)	20.88	0.33	22.33	0.13
Hemoglobin (g/dL)	13.43	0.02	14.27	0.01
Hematocrit (%)	40.90	0.07	43.15	0.04
Fasting glucose (mg/dL)	100.60	0.55	99.14	0.16
HbA1c (%)	5.80	0.20	5.63	0.01
TSH (uU/mL)	3.16	0.20	2.74	0.05
Free thyroxine (ng/dL)	1.15	0.01	1.27	0.01
Height (cm)	156.43	0.14	160.36	0.11
Weight (kg)	58.21	0.20	60.81	0.11
Waist circumference (cm)	80.27	0.22	79.07	0.10
Body mass index (kg/□)	23.79	0.08	23.02	0.03
Age at menarche(years)	14.48	0.05	13.63	0.02
Age at menopause (years)	50.40	0.09	49.09	0.61
Duration of breastfeeding	21.92	0.44	29.41	0.40
< 12 months	495	25.0%	3312	27.9%
≥ 12 months	1524	75.0%	10,185	72.1%

(Continued)

Table 1 (Continued).

Variables*	Participants (N=2019)		Overall Population	
	(N, Weighted %)	(Mean, SE)	(N, weighted %)	(Mean, SE)
Handgrip strength	24.78	0.11	32.29	0.76
< 18Kg ‡	106	5.2%	3338	3.9%
≥ 18Kg	1913	94.8%	34,913	93.1%
Relative Handgrip Strength				
1st quartile	504	25.2%	7082	14.7%
2nd quartile	505	24.8%	5038	11.6%
3rd quartile	505	24.4%	5276	12.8%
4th quartile	505	25.6%	20,763	60.9%
ASCVD 10-year risk	5.07	0.09	6.19	0.30
Low risk (< 7.5%)	1553	79.0%	23,146	68.5%
High risk (≥ 7.5%)	466	21.0%	14,565	31.5%

**Notes:** \*Properties included in the dependent variable were excluded from the independent variable. †Physical activity was considered adequate if the participant engaged in any of the following for at least 1 week: moderate-intensity physical activity for at least 2 hours and 30 minutes, vigorous-intensity physical activity for at least 1 hour and 15 minutes, or a combination of both. ‡Considered for sarcopenia.

**Abbreviations:** ALT, alanine aminotransferase; AST, aspartate aminotransferase; ASCVD, atherosclerotic cardiovascular disease; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TSH, thyroid-stimulating hormone.

## Statistical Analysis

The KNHANES dataset was designed using complex, stratified, multistage, and probability-cluster sampling, certified as appropriate for generating representative statistics. Given these characteristics, we employed a complex sampling method to analyze the KNHANES data. We calculated descriptive statistics, including means and standard deviations for continuous variables, and relative frequencies for categorical variables. Chi-square tests were used for categorical variables and *t*-tests for continuous variables to analyze associations between demographic characteristics and 10-year ASCVD risk. We performed logistic regression analysis (considering the complex sampling design) to identify the association between relative grip strength quartiles and 10-year ASCVD risk, controlling for education, income, alcohol consumption, physical activity, breastfeeding duration, and age at menarche. All statistical analyses were conducted using SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA), with a significance level of  $p < 0.05$ .

## Results

### Participant Characteristics

Table 1 presents the sociodemographic and clinical characteristics of the 2014–2019 KNHANES survey population alongside those of the postmenopausal, middle-aged women included in this study.

The mean age of the overall population was 40.68 years, whereas the mean age of the postmenopausal, middle-aged women in our study was 56.82 years. In the study cohort, 39.8% had completed high school, while 33.0% of the overall population had attained a college education or higher. The distribution across household income quartiles was fairly even, though the fourth quartile was most prominently represented. In contrast to the overall population, postmenopausal, middle-aged women were less active (less likely to participate in moderate to vigorous physical activity) and less likely to smoke. Notably, the postmenopausal, middle-aged women had slightly higher mean ages at menarche (14.48 years) and menopause (50.4 years) relative to the overall population. Furthermore, 75% of these women had breastfed for longer than 12 months. Regarding handgrip strength, 5.2% of the postmenopausal, middle-aged women fell into the  $\leq 18$  kg category, indicative of sarcopenia. This percentage was higher than that of the overall population. To examine whether relative grip strength affects ASCVD risk, we categorized the participants into quartiles and presented the characteristics of each group (Supplementary Table 1). The 10-year ASCVD risk was 31.5% in the overall population, compared with 21.0% among the postmenopausal, middle-aged women.

## Differences in Characteristics According to 10-Year ASCVD Risk

Table 2 shows the differences in baseline characteristics between subjects with high versus low 10-year ASCVD risk. There was a statistically significant difference between the high- and low-ASCVD-risk groups according to education levels ( $p < 0.001$ ). There was also significant variation in 10-year ASCVD risk by household income quartile ( $p < 0.001$ ) and alcohol consumption status ( $p = 0.009$ ). Age at menarche ( $p = 0.002$ ) and breastfeeding duration ( $p < 0.001$ ) were also significant determinants influencing the 10-year ASCVD risk. The relative grip strength quartile groups also varied significantly in terms of their associations with 10-year ASCVD risk ( $p < 0.001$ ).

## Factors Associated with Relative Grip Strength

Table 3, derived from a multiple logistic regression analysis, highlights the variables independently associated with relative grip strength. Relative to subjects with elementary education or below, participants who had completed middle school, high school, or college had odds ratios of 2.187, 2.551, and 3.440 respectively, signifying a diminished 10-year ASCVD risk. This suggests that higher educational attainment corresponded with a reduced 10-year ASCVD risk ( $p < 0.001$ ).

Relative to the lowest income bracket, the subsequent higher income quartiles—lower-middle, upper-middle, and upper—had odds ratios of 1.189, 1.480, and 2.536, respectively, all suggesting a decreased 10-year ASCVD risk. In other words, higher household income was associated with lower ASCVD risk ( $p < 0.001$ ). Subjects who consumed alcohol at least once a month had 1.536 times the odds of lower 10-year ASCVD risk relative to non-drinkers. Those who breastfed for more than 12 months had 0.588 times the odds of lower 10-year ASCVD risk than their counterparts who breastfed

**Table 2** Relationship Between Participant Characteristics and the 10-Year ASCVD Risk

Variables*	ASCVD 10-Year Risk (Weighted %)		Design-Based p-value
	Low-Risk (<7.5%)	High-Risk (≥ 7.5%)	
Education			<0.001
≤ elementary school	59.3%	40.7%	
Middle school graduate	79.5%	20.5%	
High school graduate	84.2%	15.8%	
College graduate+	89.5%	10.5%	
Household income			<0.001
1st quartile	64.8%	35.2%	
2nd quartile	71.7%	28.3%	
3rd quartile	79.0%	21.0%	
4th quartile	88.7%	11.3%	
Alcohol consumption			0.009
No	76.8%	23.2%	
Yes	82.5%	17.5%	
Physical activity <sup>†</sup>			0.042
No	77.0%	23.0%	
Yes	81.2%	18.8%	
Duration of breastfeeding			<0.001
< 12 months	88.3%	11.7%	
≥ 12 months	75.8%	24.2%	
Age at menarche	14.42±0.05	14.73±0.09	0.002
Relative Grip Strength			<0.001
1st quartile	71.7%	28.3%	
2nd quartile	74.5%	25.5%	
3rd quartile	82.6%	17.4%	
4th quartile	86.9%	13.1%	

**Notes:** \* Properties included in the dependent variable were excluded from the independent variable. <sup>†</sup>Physical activity was considered adequate if the participant engaged in any of the following for at least 1 week: moderate-intensity physical activity for at least 2 hours and 30 minutes, vigorous-intensity physical activity for at least 1 hour and 15 minutes, or a combination of both.

**Table 3** Weighted Logistic Regression Analysis of Factors Affecting the 10-Year ASCVD Risk (N = 2019)

Variables	OR (Exp $\beta$ )*	95% CI	p-value
Education			
≤Elementary school <sup>†</sup>	–	–	–
Middle school graduate	2.187	1.587–3.015	<0.001
High school graduate	2.554	1.827–3.561	<0.001
College graduate	3.440	2.188–5.406	<0.001
Household income			
First quartile <sup>‡</sup>	–	–	–
Second quartile	1.189	0.815–1.735	0.370
Third quartile	1.480	0.986–2.223	0.059
Fourth quartile	2.536	1.654–3.887	<0.001
Alcohol consumption			
No <sup>†</sup>	–	–	–
Yes	1.536	1.153–2.046	0.003
Physical activity <sup>‡</sup>			
No <sup>†</sup>	–	–	–
Yes	1.111	0.851–1.450	0.438
Duration of breastfeeding			
<12 months <sup>†</sup>	–	–	–
≥12 months	0.588	0.422–0.820	0.002
Age at menarche	1.004	0.933–1.080	0.923
Relative grip strength			
First quartile <sup>†</sup>	–	–	–
Second quartile	0.994	0.711–1.388	0.970
Third quartile	1.534	1.092–2.155	0.014
Fourth quartile	1.926	1.304–2.843	0.001

**Notes:** \* Odds ratio of low risk group (<7.5% 10-year ASCVD risk) compared to high risk group (≥ 7.5% 10-year ASCVD risk). <sup>†</sup>Reference group. <sup>‡</sup>The amount of physical activity was considered adequate if one engaged in moderate-intensity physical activity for at least 2 hours and 30 minutes, vigorous-intensity physical activity for more than one hour and 15 minutes, or a combination thereof for one week.

**Abbreviation:** ASCVD atherosclerotic cardiovascular disease, OR odds ratio.

for less than 12 months. Relative to the low-relative-grip-strength category, the other grip strength quartiles—lower-middle, upper-middle, and high—had odds ratios of 0.994, 1.534, and 1.926, respectively, indicative of their association with a lower 10-year ASCVD risk.

## Discussion

This study examined the association between relative grip strength and CVD risk among middle-aged, postmenopausal women using national population-based data from South Korea. To our knowledge, this was the first study to focus exclusively on middle-aged, postmenopausal women and to reveal the relationship between relative grip strength and 10-year cardiovascular disease risk after adjusting for socioeconomic factors, health-related behaviors, comorbidities, and reproductive factors.

The results showed that higher household income and education were associated with significantly lower CVD risk. Notably, a previous study found education and income to be key socioeconomic determinants that negatively impacted CVD outcomes among women, consistent with our findings.<sup>41</sup> Additionally, previous studies, including systematic reviews and meta-analyses of gender differences in CVD and socioeconomic status, have found socioeconomic status to be inversely associated with cardiovascular risk. Recent European cardiovascular disease statistics show an increased risk of CVD in lower-income groups.<sup>42</sup> A meta-analysis found that lower levels of education and living in low-income,

disadvantaged neighborhoods were significantly associated with cardiovascular risk in women.<sup>42</sup> Additionally, previous studies have consistently found increased cardiovascular risk among poorer women compared with their wealthier counterparts.<sup>43</sup> In a study of African Americans, the age-adjusted hazard ratio for low versus high wealth was 1.06 (95% CI 0.62–1.81) in men but 2.14 (95% CI 0.62–1.81) in women.<sup>44</sup> These socioeconomic factors contribute to disparities in women's cardiovascular health. Compared with men, women of lower socioeconomic status have less time to seek medical care and preventive care<sup>45</sup> and are reported to have inadequate healthcare and healthcare coverage.<sup>46</sup> Moreover, low-income women often work long hours or temporary jobs for economic reasons, such as family support and childcare, which exposes them to high levels of stress, leaves them with less time to care for themselves, and reduces their time for exercise and other leisure activities.<sup>14,15</sup> Therefore, reducing socioeconomic inequalities associated with coronary heart disease and CVD outcomes may require differing approaches for men and women.<sup>47</sup>

In this study, physical activity was not significantly associated with 10-year ASCVD risk. A recent study found that the middle-aged population (35–65 years) faces a higher risk of developing cardiovascular disease due to a predominantly sedentary lifestyle.<sup>48</sup> In general, regular physical activity plays a positive role as a modifiable factor in preventing CVD. A previous study has shown the benefits of physical activity in middle-aged women, with moderate physical activity being associated with a lower risk of coronary heart disease, venous thromboembolic events, and cerebrovascular disease than inactivity.<sup>49</sup> The insignificant association between physical activity and ASCVD in this study may be due to the dichotomous use of “physical activity (yes/no)” as a categorization criterion, a variable provided in the KNHANES raw data user guideline. Therefore, future studies should further examine cardiovascular risk in middle-aged postmenopausal women by subdividing physical activity into light, moderate, and vigorous intensity categories, for example.

This study found that breastfeeding for more than 12 months was associated with an increased risk of CVD, somewhat contradicting previous research. Breastfeeding is protective against many maternal cardiovascular risk factors and outcomes, and there is evidence that longer breastfeeding duration may have a protective effect,<sup>50–52</sup> but this remains unclear. Some studies found no clear associations between breastfeeding and CVD.<sup>53</sup> A recent study on the association between reproductive factors and CVD in postmenopausal women in Korea found that the longer the duration of breastfeeding, the higher the risk of CVD, consistent with our findings.<sup>54</sup> These inconsistent findings regarding breastfeeding and cardiovascular risk may be due to differences in the selection of subjects and differences in the duration and intensity of breastfeeding.<sup>54–56</sup> Overall, these factors should be considered when conducting future large-scale studies of breastfeeding and CVD in postmenopausal women.

This study evaluated the association between relative grip strength and 10-year ASCVD risk and found that those with higher relative grip strength had a significantly lower risk of ASCVD compared with those with lower relative grip strength. These findings are consistent with a growing body of evidence suggesting that relative grip strength may be an important marker of overall health, including cardiovascular health. Relative grip strength is used as a more objective marker than absolute handgrip strength, as it can reflect both muscle strength and obesity by taking into account body mass index.<sup>57</sup> Previous studies have also reported that it provides the most consistent results.<sup>15</sup> Laukkanen et al<sup>58</sup> found inverse associations between relative grip strength and cardiovascular events and all-cause mortality. A cohort study in Taiwan identified associations between CVD risk factors by distinguishing between relative and dominant grip strength and found that relative grip strength was significantly associated with cardiometabolic disease risk, with a stronger association than dominant grip strength.<sup>17</sup> Leong et al<sup>21</sup> examined the relationship between relative grip strength and mortality risk according to sex in different populations. They found that the inverse relationship between relative grip strength and mortality was stronger among women than among men, highlighting the potential importance of grip strength in assessing cardiovascular risk in women. A study using the Framingham Risk Score to determine the 10-year risk of CVD among middle-aged women found that increasing relative grip strength was associated with a decreased 10-year risk of cardiovascular events.<sup>59</sup>

Menopause is an important life stage for women characterized by hormonal changes and changes in cardiovascular risk factors. Additionally, monitoring relative grip strength could be a simple and cost-effective way to identify individuals at higher risk of CVD. Understanding the complex interplay between relative grip strength and cardiovascular health in middle-aged, postmenopausal women has important implications for prevention strategies and personalized

healthcare interventions. Incorporating relative grip strength measurement into routine health assessments may help mitigate cardiovascular risk through early detection and tailored interventions. This study emphasized the potential importance of relative grip strength in assessing cardiovascular risk in middle-aged postmenopausal women.

## Conclusion

This study found that low relative grip strength was associated with increased CVD risk. Relative grip strength was determined to be an independent predictor of CVD risk in middle-aged, postmenopausal women. Given that postmenopausal women are a high-risk group for CVD and experience progressive muscle weakness, relative grip strength has potential value as a simple, useful, and accessible screening tool for community CVD risk prevention and health promotion. These findings provide a rationale for designing and expanding future intervention programs aimed at promoting health behaviors to prevent CVD in middle-aged, postmenopausal women.

## Ethics Approval and Informed Consent

The study design was approved and exempted by the Institutional Review Board of Konyang University (KYU IRB-2023-10-011). This study was analyzed using data from KNHANES, an annual survey conducted by the Korean Ministry of Health and Welfare. This survey was approved by the Institutional Review Board of the Korea Health and Nutrition Service, the KCDC discloses only de-identified data on its website so that individuals cannot be extrapolated from the survey data in accordance with the Personal Information Protection Act and the Statistics Act. The data accessed for this study was in compliance with applicable data protection and privacy regulations.

## Author Contributions

All authors made significant contributions to the work reported, whether that was in the conception, study design, execution, acquisition of data, analysis, or interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors report no conflicts of interest in this work.

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