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Association between Relative Handgrip Strength and Osteoporosis in Older Women: The Korea National Health and Nutrition Examination Survey 2014–2018

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Background: While handgrip strength is associated with osteoporosis in the older population and muscle weakness is related to a reduction in bone mineral density, no study has yet assessed the association between relative hand grip strength (RHGS) and osteoporosis in the older Korean population. This study assessed the associations between RHGS and osteoporosis in Korean older women aged over 60 years. **Methods:** We used data of 4,179 older women from the Korea National Health and Nutrition Examination Survey (KNHANES) from 2014 to 2018. We applied binomial logistic regression to identify an association between RHGS and osteoporosis while controlling for other covariates such as age; socioeconomic status; smoking behavior; alcohol consumption, laboratory test results; and the prevalence of hypertension, diabetes mellitus, thyroid disease, and obesity. **Results:** RHGS was significantly associated with osteoporosis of the left hand in older Korean women. RHGS levels 2 and 4 of the left hand showed an inverse association with the prevalence of osteoporosis in female participants aged 60–69 years (odds ratio [OR]=0.637; 95% confidence interval [CI], 0.452–0.898; p=0.010; and OR=0.496; 95% CI, 0.258–0.956; p=0.036, respectively) but not in those aged over 70 years and in the right hand. **Conclusion:** osteoporosis was significantly associated with left-hand RHGS in 60–69-year-old women, and the osteoporosis risks decreased by approximately 36.3% and 50.4% in women with RHGS levels 2 and 4, respectively. RHGS may be used to predict osteoporosis in pre-clinical settings such as public health care institutes.

Key Words: Aged, Hand strength, Osteoporosis

INTRODUCTION

Osteoporosis is a musculoskeletal disease characterized by decreasing bone mineral density (BMD) and mass that can result in damaged bone structure. BMD can be decreased by losing too much bone or generating too little bone. The consequent reduction in bone strength is clinically evidenced by bone fractures. Aging, genetics, nutrition, vitamin and mineral deficiencies, lifestyle choices, smoking history, hormonal production, and medications reportedly contribute to skeletal fragility. An imbalance in bone

metabolism is a cause of osteoporosis.[1] Moreover, the risk of osteoporosis resulted in osteoporosis-related fractures (in the hip, spine, distal radius, and humerus), which could be a leading cause of significant morbidity and disability in the older adult population and one of the factors increasing the economic burden on the healthcare system.[2] While the incidence of osteoporosis and its related fractures varied worldwide, it is not enough to compare incidence rates among countries owing to the lack of studies and insufficient information. Recently, the Korean Nationwide-database Osteoporosis Study (KNOS) was conducted with the Korean Society of Bone and Mineral Research and Health Insurance Review and Assessments.[3] The KNOS included data from the Korean National Claim Registry using International Classification of Disease-10 codes. The KNOS reported that there were 1.23 million osteoporosis patients aged over 50 years in 2007, of whom approximately 89.9% were female patients. Among osteoporosis patients, 58.5% were prescribed anti-osteoporosis drugs for 6 months or more, with a mean of 70 days of drug therapy.[3]

Osteoporosis often leads to musculoskeletal disorders that cause hip, spine, and wrist fractures that decrease the quality of life of patients. Moreover, it can increase the risk of mortality.[4] With increasing life expectancy in the population, osteoporosis is becoming a global public health issue, with more than 200 million people globally experiencing osteoporosis.

Moreover, the International Osteoporosis Foundation reported that over 30% of women older than 50 years experienced osteoporotic fractures.[5,6] In the future, more populations will develop osteoporosis; furthermore, the rates of diseases related to osteoporosis will also increase because they develop without specific symptoms in the initial stage of osteoporosis and therefore remain undiagnosed.[7]

Osteoporosis is more common in postmenopausal women owing to estrogen, which plays a critical role in bone remodeling by controlling osteoclastogenesis[1] and acts directly on osteoblasts and osteoclasts, protecting both cortical and trabecular bones.

Postmenopausal osteoporosis occurs because the ovarian functions stop and the interactions with bone materials do not occur naturally because of a decrease in estrogen secretion. Osteoporotic bones are reportedly susceptible to breaks owing to their porosity and sparsity. In particular, the older population experiences frequent falls due to muscle weakness, senescence of vascular functions, and other critical conditions such as visual impairment or Parkinson disease, for which patients have a very high risk of osteoporotic fractures[8] and which can lead to serious morbidity and mortality.[1] Therefore, osteoporosis prediction and prevention are essential, especially for older female individuals.

Handgrip strength (HGS) is a common assessment tool used to evaluate physical function, such as the maximum voluntary force of both hands, which is measured in a seated or a standing position to reflect muscle strengths of the upper limbs or lower limbs and core muscles, respectively.[9] HGS is a simple, reliable, and inexpensive assessment tool with demonstrated prognostic utility. HGS is also a predictor for future disability, frailty, metabolic syndrome, and diabetes mellitus (DM) and is a particularly useful and quick tool to assess muscle strength.[10] Therefore, this tool can be used to predict osteoporosis in pre-clinical settings such as public healthcare institutes.

Guidelines including, the European Working Group on Sarcopenia in Older People, have accepted HGS as a recommended tool in the diagnostic algorithm for sarcopenia.[11] Moreover, lower HGS was associated with osteoporosis in the older population, and muscle weakness was also related to a reduction of BMD.[12] Cheung et al.[13] reported that HGS was a predictor of osteoporotic fracture risk and could be applied in addition to BMD as a diagnostic tool for assessing the risk of fracture. According to their research, the HGS T-score was associated with an increased risk of osteoporotic fracture, although the presence of prevalent fractures may lead to physical disability and subsequently reduced muscle mass and strength. Several studies reported significant associations between HGS and vertebral fracture and hip fracture risk.[14,15] However, forearm fracture risk was not significantly associated with low HGS.[14] In postmenopausal Japanese women, low HGS was associated with increased risks of vertebral fracture in a 15-year period and distal forearm fracture in a 10-year period.[16]

Lee et al.[17] reported that relative HGS (RHGS) is associated with HGS and body size, and they proposed its use as a better assessment tool to capture conceptual concomitant health as a simple, inexpensive, and easy method to target cardiovascular health at the public health level. Comparison of muscle strength after correcting for body mass showed a higher level of absolute muscle strength in obese women,[17] and obese women had a lower RHGS after adjusting for body mass index (BMI). Therefore, in clinical practice, RHGS may be a convenient tool to identify older participants with reduced physical function or loss of independent daily living capacity.[18] There are differences between using absolute HGS and RHGS. Absolute HGS indicated the strengths of the small muscle group in the upper body and the lower arm, leg, and core muscle;[19] however, BMI was not calculated despite its close correlation to BMD. Recent studies have reported that RHGS was negatively correlated with cardiometabolic risk, including the metabolic profile of fasting glucose, high-density lipoprotein (HDL) cholesterol, and triglyceride levels.[20] Li et al.[20] reported that RHGS measurement was a more reasonable factor to predict metabolic profile and metabolic disease than absolute HGS.

However, no study has assessed the association between RHGS (HGS divided by the BMI) and osteoporosis in the older Korean population. Hence, this cross-sectional study investigated the association between RHGS and osteoporosis in older Korean adults aged 60–69 and 70+ years.

MATERIALS AND METHODS

Study Population

This study was conducted using data from the Korea National Health and Nutrition Examination Survey (KNHANES) from 2014 to 2018. This survey has been performed since 1998 by the Korea Center for Disease Control and Prevention (KCDC). The KNHANES involves a multistage stratified cluster sampling of 4,600 households and 10,000–12,000 individuals annually. Details of the survey design and data source are described elsewhere.[21] The study protocols, with written informed consent obtained from all participants, were approved by the Institutional Review Board of the KCDC (No. 2015-01-02-6C).

The dataset in the present study included survey results on health conditions obtained from general health examinations and nutritional assessments. This study included participants aged 60 years or older who completed assessments for osteoporosis and underwent HGS tests of both hands. We divided the participants into two groups based on age (60–69 years and 70+ years).

Main Variables

Osteroporosis

Dual-energy X-ray absorptiometry (DXA, QDR 4500A; Hologic Inc., Waltham, MA, USA) was used to measure bone mineral content and BMD in the KNHANES. The manufacturer (DEX) provided the criteria for the diagnosis of osteoporosis[22] using the T-scores of the whole femur, femoral neck, and lumbar spine based on the World Health Organization criteria (T-score > -1, normal; -2.5 < T-score ≤ -1, osteopenia; and T-score ≤ -2.5, osteoporosis).[23]

RHGS

HGS was measured in each hand three times using a digital grip strength dynamometer (Model T.K.K 5401; Takei Scientific Instruments Co., Tokyo, Japan). The participants were instructed to hold the dynamometer with the second proximal interphalangeal joint of the hand flexed at 90° to the handle and squeeze the handle as hard as they could in the standing position (elbow extension status). After each measurement, the participants rested for at least 30 seconds.[24] The maximum value of the three measurements was used.

A recent study suggested the use of BMI for adjusting HGS as a muscle quality index.[5] Therefore, HGS, which is the maximum grip strength, was used to evaluate the independent contribution of body composition and strength. RHGS was calculated for each hand as the maximum absolute HGS divided by BMI.[25]

We categorized RHGS in women into four levels according to the quartiles as previously described:[26] level 1, Q1 (< 25th percentile); level 2, Q2 (25–49th percentiles); level 3, Q3 (50–74th percentiles); and level 4, Q4 (≥ 75th percentile).[26]

Covariates

The covariates included in this study were identified by referring to previously reported factors associated with decreased HGS.[27]

This study included the following baseline sociodemographic characteristics: age (60–69 and ≥ 70 years), income level (in quartiles), and education status (below elementary school, middle school graduate, high school graduate, and college graduate or above). There were also several variables related to health-related behaviors, including alcohol consumption classified into six categories (none, < 1/month, about 1/month, 2–4/month, 2–3/week or ≥ 4/week); smoking behavior classified into four categories (never, past smoking, smoking sometimes, or smoking daily); walking exercise indicated by three categories (never, 1–6 days/week, or daily); muscle exercise divided into three categories (never, 1–4 days/week or ≥ 5 days/week); aerobic activity classified into two categories (yes or no); DM prevalence (yes or no); family medical history of hypertension (HTN) in the father, mother, brother, or sister (yes or no); and results of laboratory tests such as those of systolic blood pressure (SBP), diastolic blood pressure (DBP), and fasting blood sugar (FBS), cholesterol, triglyceride (TG), aspartate aminotransferase (AST), and alanine aminotransferase (ALT).

Statistical analysis

The KNHANES is a complex, stratified, multistage, probability-cluster survey of a representative sample of the non-institutionalized civilian population in Korea.[28] Therefore, we performed a complex sample analysis by considering the weights, stratification, and clustering not used in ordinary statistical work.

The results are presented as numbers and percentages for the general characteristics of the participants. Chi-square tests were used to compare percentages to describe the general characteristics of the participants. Independent t-tests were used to assess differences in clinical variables. We performed multiple logistic regression analysis to identify associations between RHGS and osteoporosis in older participants by controlling for other covariates and determining the odds ratios (ORs) and 95% confidence intervals

(CIs). The significance level was set at $p < 0.05$. We performed these analyses using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp, Armonk, NY, USA).

RESULTS

Sample Characteristics

The mean age of the 4,179 older women included in this study using KNHANES 2014–2018 data was 70.0 ± 6.6 years. This study included 490 (23.5%) participants with osteoporosis and 1,596 (76.5%) participants without osteoporosis in the 60–69-year group and 758 (35.8%) and 1,357 (64.2%) participants, respectively, in the 70+-year group (Table 1).

We observed a significant association between right and left RHGS in the two age groups ($p < 0.05$). The dominant hand was not significantly associated between the two groups (94.8% and 94.3% of subjects had right-hand dominance in the 60–69-and 70+-year groups, respectively). There was no association between the groups with respect to income levels. Education levels showed a significant association in both groups ($p < 0.05$). We observed significant associations between alcohol consumption ($p < 0.05$) and smoking behavior ($p < 0.05$) in both groups. The prevalence of HTN, DM, and thyroid diseases showed significant associations in both groups ($p < 0.05$) (Table 1).

Comparisons of Clinical Variables between the Presence and Absence of osteoporosis in the 60–69- and 70+-Year Groups

We observed significant differences between participants with and without osteoporosis in the 60–69-year group ($p < 0.05$) but not in the 70+-year group (Table 2). SBP differed significantly between the participants with and without osteoporosis in the 60–69-year group ($p < 0.05$), while DBP did not. The total cholesterol level did not differ significantly between participants with and without osteoporosis in the 60–69-year group. FBS levels differed significantly between participants with and without osteoporosis in the 60–69-year group; however, TG, AST, and ALT levels did not. In the 70+-year group, only BMI, SBP, and total cholesterol level differed significantly between participants with and without osteoporosis ($p < 0.05$).

Associations between RHGS and osteoporosis in the 60–69- and 70+-Year Groups

The OR of the prevalence of osteoporosis in the 60–69-year group was 0.696 (95% CI, 0.500–0.970; $p < 0.05$) in only RHGS level 2 of the left hand; however, we observed no significant association between the prevalence of osteoporosis and RHGS in other levels of the right hand (Table 3). In the 70+-year group, the RHGS of

Table 1. Characteristics of the subjects included in this study according to age group

Characteristic	60–69 years	70+ years	p-value
Osteoporosis			< 0.001**
No	1,596 (76.5)	1,357 (64.2)	
Yes	490 (23.5)	758 (35.8)	
Right RHGS			< 0.001**
Level 1	666 (34.6)	1,203 (64.7)	
Level 2	633 (32.9)	461 (24.8)	
Level 3	444 (23.1)	155 (8.3)	
Level 4	182 (9.5)	41 (2.2)	
Left RHGS			< 0.001**
Level 1	675 (34.9)	1,227 (65.6)	
Level 2	619 (32.0)	432 (23.1)	
Level 3	453 (23.4)	163 (8.7)	
Level 4	186 (9.6)	49 (2.6)	
Dominant hand			0.261
Right	1,978 (94.8)	1,995 (94.3)	
Left	108 (5.2)	120 (5.7)	
Income level			0.873
1st	520 (25.0)	521 (24.8)	
2nd	515 (24.8)	534 (25.4)	
3rd	506 (24.3)	522 (24.9)	
4th	538 (25.9)	523 (24.9)	
Education level			< 0.001**
Elementary	1,015 (48.9)	1,664 (80.1)	
Middle school	464 (22.3)	183 (8.8)	
High school	398 (19.2)	161 (7.8)	
University	200 (9.6)	69 (3.3)	
Alcohol consumption			< 0.001**
None	975 (47.0)	1,419 (68.3)	
< 1/month	524 (25.2)	356 (17.1)	
About 1/month	196 (9.4)	95 (4.6)	
2–4/month	241 (11.6)	119 (5.7)	
2–3/week	105 (5.1)	51 (2.5)	
> 4/week	35 (1.7)	38 (1.8)	
Smoking			0.038*
Never	1,944 (93.7)	1,949 (93.9)	
Past	66 (3.2)	80 (3.9)	
Sometimes	11 (0.5)	2 (0.1)	
Daily	53 (2.6)	44 (2.1)	
Hypertension			< 0.001**
No	1,274 (61.1)	793 (37.5)	
Yes	812 (38.9)	1,322 (62.5)	
Diabetes mellitus			< 0.001**
No	1,801 (86.3)	1,613 (76.3)	
Yes	285 (13.7)	502 (23.7)	
Thyroid disease			< 0.001**
No	1,973 (94.6)	2,054 (97.2)	
Yes	112 (5.4)	60 (2.8)	

Values are presented as number (%).
RHGS, relative hand grip strength.
*p<0.05, **p<0.01.

Table 2. Comparisons of clinical outcomes with respect to the presence of osteoporosis according to age groups

Item	60–69 years			70+ years		
	Without osteoporosis	With osteoporosis	p-value	Without osteoporosis	With osteoporosis	p-value
Age (y)	64.0 ± 2.9	65.1 ± 2.8	< 0.001**	75.8 ± 3.5	75.5 ± 3.5	0.092
BMI (kg/m^2)	24.6 ± 3.4	24.2 ± 3.2	0.015*	24.7 ± 3.4	24.1 ± 3.3	< 0.001**
SBP (mmHg)	126.0 ± 17.1	124.0 ± 15.9	0.027*	132.4 ± 18.4	129.7 ± 18.1	0.001**
DBP (mmHg)	75.7 ± 9.4	74.9 ± 8.6	0.090	71.2 ± 10.1	71.3 ± 9.7	0.839
Cholesterol (mg/dL)	104.4 ± 24.0	104.5 ± 26.1	0.893	108.7 ± 26.8	105.5 ± 25.5	0.009**
FBS (mg/dL)	199.3 ± 39.6	194.5 ± 38.7	0.021*	187.6 ± 40.1	186.9 ± 37.6	0.716
TG (mg/dL)	134.7 ± 82.5	127.2 ± 67.7	0.072	135.2 ± 76.7	135.4 ± 101.7	0.978
AST (U/L)	23.8 ± 9.1	23.9 ± 10.7	0.817	24.1 ± 9.8	24.0 ± 9.7	0.859
ALT (U/L)	21.3 ± 13.8	20.9 ± 13.2	0.523	19.2 ± 11.4	18.7 ± 11.3	0.362

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBS, fasting blood sugar; TG, triglyceride; AST, aspartate aminotransferase; ALT, alanine aminotransferase.
*p<0.05, **p<0.01.

Table 3. Associations between RHGS and osteoporosis according to age groups: unadjusted model

RHGS	60–69 years				70+ years			
	OR	95% CI		p-value	OR	95% CI		p-value
		LL	UL			LL	UL	
Right RHGS								
Level 1	1.000			0.680	1.000			0.821
Level 2	1.042	0.751	1.446	0.806	0.934	0.703	1.241	0.639
Level 3	0.867	0.558	1.348	0.527	0.820	0.496	1.356	0.439
Level 4	1.079	0.588	1.979	0.807	0.670	0.262	1.715	0.404
Left RHGS								
Level 1	1.000			0.073	1.000			0.509
Level 2	0.696	0.500	0.970	0.032*	1.057	0.792	1.410	0.707
Level 3	0.869	0.567	1.330	0.517	1.370	0.848	2.211	0.198
Level 4	0.597	0.319	1.119	0.107	1.756	0.726	4.245	0.211

OR, odds ratio, CI, confidence interval; RHGS, relative handgrip strength; LL, lower limit; UL, upper limit.
*p<0.05.

both hands was not significantly associated with the prevalence of osteoporosis.

After controlling for covariates such as socioeconomic status; smoking behavior; alcohol consumption; laboratory test results; and prevalence of HTN, DM, and thyroid disease, the prevalence of osteoporosis was significantly associated with RHGS level 2 (OR = 0.637; 95% CI, 0.452–0.898; p = 0.010) and level 4 (OR = 0.496; 95% CI, 0.258–0.956; p = 0.036) of the left hand in the 60– 69-year group (Table 4). We observed no significant association between the prevalence of osteoporosis and RHGS level 3 of the left hand and all RHGS levels of the right hand. In the 70+-year group, RHGS of both the hands was not significantly associated with the prevalence of osteoporosis.

DISCUSSION

In this study, RHGS was significantly associated with osteoporosis in the left hand of older Korean women. RHGS levels 2 and 4 of the left hand were inversely associated with the prevalence of osteoporosis in female participants aged 60–69 years but not in those aged 70+ years and in the right hand.

Our finding of an association between RHGS and osteoporosis was similar to that of four previous studies. Karkkainen et al.[14] reported results consistent with our findings based on the Osteoporosis Risk Factor and Prevention Study, which began in Kuopio, Finland, in 1989. The authors performed a prospective population-based cohort study to determine the association between vertebral fracture and hip fracture risk and HGS in 2,298 postmenopausal women with an 8-year follow-up. They reported that de-

Table 4. Associations between RHGS and osteoporosis according to age groups: adjusted model

RHGS	60–69 years				70+ years			
	OR	95% CI		p-value	OR	95% CI		p-value
		LL	UL			LL	UL	
Right RHGS								
Level 1	1.000			0.789	1.000			0.800
Level 2	0.947	0.673	1.331	0.753	0.892	0.656	1.212	0.464
Level 3	0.803	0.505	1.276	0.352	0.816	0.474	1.403	0.462
Level 4	0.898	0.477	1.694	0.741	0.667	0.251	1.775	0.418
Left RHGS								
Level 1	1.000			0.022*	1.000			0.664
Level 2	0.637	0.452	0.898	0.010*	0.953	0.698	1.302	0.763
Level 3	0.790	0.506	1.232	0.298	1.272	0.757	2.136	0.363
Level 4	0.496	0.258	0.956	0.036*	1.390	0.535	3.613	0.500

OR, odds ratio, CI, confidence interval; RHGS, relative handgrip strength; LL, lower limit; UL, upper limit.
*$p<0.05$.

creasing HGS was associated with a 1.05-fold (1.01–1.09) increased risk of hip fractures.[14] Similarly, Dixon et al.[15] performed a multi-center study to assess the association between HGS and BMD in women. Their study recruited middle-aged and older European men and women (aged over 50 years, 1,265 men and 1,380 women) for a screening survey of vertebral osteoporosis. The authors measured HGS using a dynamometer, similar to our research process. They reported that female participants with low grip strength (< 231 mmHg) had significantly lower bone masses at the spine and femoral neck after adjusting for age. Their main outcome was not the same as that of our study (OS), but they also showed that HGS was related to bone mass. Kim et al.[29] reported an association between HGS and BMD of the spine, femur neck, and total hip and fragility fractures in 337 healthy postmenopausal Korean women. Moreover, low HGS was associated with low BMD of the spine, femur neck, and total hip, with an increased risk of previous fragility fractures. This result is consistent with our findings. In the Japanese Population-based Osteoporosis Cohort Study (median follow-up time, 15.2 years) on the association between HGS and site-specific risks of on the association between HGS and site-specific (distal forearm, vertebrae, and hip) risks of major osteoporotic fracture in 1,342 postmenopausal women aged over 50 years, Kamiya et al.[16] reported associations between low HGS and increased risks of fracture at the distal forearm, vertebrae, and hip. The vertebral fracture risk was increased after adjusting for BMI, history of DM, and calcium intake.[16] HGS was associated with the risk of distal forearm fractures during the 10-year follow-up period and vertebral fractures within 15 years or more. Although this study did not employ the study design as that in the present study as it was a long-term follow-up longitudinal study with a median follow-up period of 15 years, the results of the study showing an association between HGS and fracture risk are similar. Sui et al.[30] reported a relationship between HGS and muscle quality in Australian women, with the mean HGS and muscle quality decreasing with age in older women. The relationship between HGS and osteoporotic fracture differed according to the subject's age, similar to the results of our study.

In addition, previous studies have reported an association between HGS and several chronic diseases. Ilich et al.[31] reported the association between osteosarcopenic obesity and HGS, walking abilities, and balance in postmenopausal women, wherein women with osteosarcopenic obesity presented the lowest handgrip scores, slowest usual and brisk walking speeds, and shortest time for each leg stance. Jang et al.[32] reported an association between RHGS and cardiovascular disease in participants aged > 45 years in the Korean Longitudinal Study of Aging. They observed a significant association between RHGS and cardiovascular disease in both women and men. Previous studies have reported negative associations between RHGS and cardiometabolic risk, including the metabolic profile of fasting glucose, HDL cholesterol, and triglyceride levels.[20] The risk of adverse cardiometabolic health was approximately 24% lower in participants with higher HGS than in those with lower muscular strength.[17,20] Hong et al.[24] assessed the relationship between RHGS and metabolic syndrome in subjects aged over 65 years, reporting a significantly lower prevalence of metabolic syndrome for the highest quartile of RHGS. Moreover, the OR of metabolic syndrome was lower in the highest HGS group than in the lowest HGS group.[24] These results suggest that HGS is related to chronic diseases, including cardiovascular disease, metabolic syndrome, and HTN.

In this study, only RHGS of the left hand was significantly associated with the prevalence of osteoporosis in female subjects aged

60–69 years. This study included an analysis based on the dominant hand in using RHGS to predict osteoporosis diagnosis. Recent studies have reported that left key-pinch strength is less than the right key-pinch strength in right-hand-dominant subjects.[33] Lee et al.[34] reported a relationship between HGS and the prevalence of rheumatoid arthritis and DM in 4,186 participants aged over 65 years. In their study, higher HGS was significantly associated with a reduced prevalence of rheumatoid arthritis. The ORs for the right and left hands also differed (right hand: 0.29; 95% CI, 0.16–0.52; $p < 0.05$; left hand: 0.20; 95% CI, 0.10–0.38, $p < 0.05$) and also for diabetes (right hand: OR = 0.71; 95% CI, 0.57–0.89; $p < 0.05$; left hand: OR = 0.71; 95% CI, 0.58–0.88; $p < 0.05$). This result indicated the different effects of left and right HGS on the prevalence risk of rheumatoid arthritis. In particular, the risk of disease prevalence was significantly reduced for higher left HGS compared with right HGS.[34] In our study, increasing RHGS of the left hand was associated with a decreased prevalence of osteoporosis in female participants aged 60–69 years. Although there are differences in disease, our results are is similar to those of previous studies reporting a significant association only in the left hand. In their observational, cross-sectional study of the differences in BMD, T-score, Z-score at distal forearm regions of both arms and handgrip isometric strength between dominant versus non-dominant hands in 162 subjects aged 40–65 years,[35] the authors reported significantly higher BMD, T-score, Z-score, and handgrip isometric strength in the dominant hand than those in the non-dominant hand among women aged 40–65 years ($p < 0.05$). This finding suggests that there is also a significant difference in baseline values between non-dominant and dominant hands.[35] Similarly, we tried to compare HGS by dividing the participants according to their dominant and non-dominant hands. However, over 94% of subjects were right-handed. Due to the small proportion of participants with a dominant left hand, it was difficult to investigate the difference of hand dominance in this group.

In our study, RHGS was not significantly associated with the prevalence of osteoporosis in female subjects aged 70 years or older. Recently, Kwak et al.[36] reported the results of a cohort study assessing sex-specific factors related to HGS in older subjects aged 65 years or older. The cohort comprised 1,197 men and 1,384 women from the KNHANES, which was the same source of data as that in our study. The authors reported no significant association between low and normal HGS and the prevalence of osteoarthritis and osteoporosis in women ($p = 0.074$ and $p = 0.149$, respectively). Although this finding was observed in their analysis of subjects aged over 65 years, it is similar to the results in our study of the lack of association between the prevalence of osteoarthritis and osteoporosis and HGS in older adults.

It is challenging to compare this study to previous studies on osteoporosis because few have reported the association between osteoporosis and HGS; while several studies showed the relationship between osteoporotic fracture and HGS,[14-16,35] they did not use RHGS by applying BMI; therefore, they did not completely prove the role of HGS. Moreover, they used only HGS without considering the dominant hand.[14,16,31] However, in this study, we considered the dominant hands in the logistic regression model controlled for other covariates and found that left-hand RHGS was a better index to identify osteoporosis diagnosis status. RHGS was divided into left and right hands and compared, and the dominant side was included in the analysis of the association with osteoporosis as a covariate. The left hand was dominant in 5.2% of subjects in the 60–60-year group and 5.7% of the 70+-year group. To control for the dominant hand as a covariate, they were all included in the analysis.

Several limitations should be considered when interpreting the results of this study. First, the cross-sectional nature of our study prevented us in demonstrating any causal relationships between RHGS and osteoporosis prevalence. Second, we could not determine whether the participants received treatment for osteoporosis. Finally, we did not consider surgical or natural menopause. In the future, a more comprehensive study to overcome these limitations is needed. Moreover, additional studies are needed to identify causes for the differences in results between the 60–69-year and 70+-year groups as the present study did not document the causality-making differences among those results. RHGS has been reported as a significant predictor of frailty, metabolic syndrome, DM, and other musculoskeletal diseases. Moreover, it is a particularly good and quick tool to assess muscle strength.[27]

In this study, the prevalence of osteoporosis was significantly associated with left-hand RHGS in women aged 60–69 years after adjusting for sociodemographic characteristics, lifestyle behaviors, and other health-related variables in the KNHANES data from 2014 to 2018. Furthermore, the osteoporosis risks were decreased by approximately 36.3% and 50.4% in levels 2 and 4, respectively. In contrast, RHGS was not significantly associated with osteoporosis in women aged > 70 years and in the right hand.

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CONFLICT OF INTEREST

The researchers claim no conflicts of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, KHA, MR; Methodology, YL; Software, SL, HG; Validation, HG; Formal Analysis, SL, HG; Investigation,

DYK; Writing – Original Draft Preparation, KHA; Writing – Review & Editing, YL, TYS; Supervision, MR; Project Administration, SL.

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