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ORIGINAL ARTICLE

Association of leg muscle symmetry with knee osteoarthritis

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Abstract

Objectives This study aimed to evaluate the relationship of leg muscle symmetry to the prevalence, radiographic grade, and symptoms of knee osteoarthritis (OA).

Method We conducted a cross-sectional study using data from the Korean National Health and Nutrition Examination Survey (KNHANES), collected in 2010 and 2011. Men and women aged 60 years or older were included. Leg muscle mass was measured using dual-energy X-ray absorptiometry, and the muscle asymmetry index was defined as $|(\text{left leg muscle mass})/(\text{left and right leg muscle mass}) \times 100 - 50|$. Statistical analyses were performed to examine the relationships between the muscle asymmetry index and the radiographic grade and knee symptoms.

Results A total of 2548 subjects were included in the analysis. The muscle asymmetry index was positively associated with radiographic knee OA grade and knee pain, especially in men. Men with knee OA and the highest quartile of muscle asymmetry index were 3.3 times more likely to have knee pain compared with those in the lowest quartile. When subjects were divided into four groups by body mass index (BMI) and muscle asymmetry index, subjects with asymmetric obese and men with asymmetric normal BMI had worse grade of radiographic knee OA.

Conclusions Leg muscle asymmetry in men, irrespective of obesity, was associated with significantly higher grade of radiographic knee OA and prevalent knee pain. Longitudinal studies will be needed to determine the cause-and-effect relationship and to determine whether the higher or lower mass, beyond the asymmetry, is associated with radiographic severity or symptomatic knee OA.

Key Points
•Leg muscle asymmetry was related to prevalence and radiographic severity of knee OA, especially in men.
•Leg muscle asymmetry was associated with knee pain.
•Those with both leg muscle asymmetry and obesity showed higher prevalence of knee pain and worse radiographic knee OA.

Keywords Knee osteoarthritis · Knee pain · Leg muscle · Muscle mass · Muscle symmetry

Introduction

Osteoarthritis (OA) is the most common type of arthritis, and it has a significant impact on quality of life, morbidity, and health-care costs. OA has been recognized as a progressive disease that results from stress in synovial joint tissues including periarticular muscles [1]. Recently, studies have reported the important roles of periarticular muscles in OA pathogenesis. In knee OA, the mass and strength of the quadriceps muscle were shown to be associated with symptoms [2–4], prevalence, and progression [5–8].

As one of the measures to evaluate periarticular muscles in knee OA, leg muscle symmetry has not been investigated. Muscle symmetry is determined by how each side of the muscle mass is distributed by comparison to its opposite. Leg muscle asymmetry represents imbalance of muscle mass in both sides. Clinically, knee OA patients are often observed to have asymmetrical leg muscle mass, but so far, there have been no study reporting the relationship between leg muscle asymmetry and knee symptoms. Leg muscle symmetry may be an easy, indirect measurement of periarticular muscle

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integrity, which could be related to knee OA severity and knee symptoms.

Therefore, in this study, we examined if deranged leg muscle symmetry is related to higher prevalence of knee OA and its radiographic grade as well as knee symptoms using data from a nationwide survey in Korea. We hypothesized that (i) those with greater leg muscle asymmetry have higher prevalence of knee OA, (ii) those with greater leg muscle asymmetry have worse radiographic knee grade of OA and more severe pain, and (iii) leg muscle asymmetry is an important factor for knee OA as much as obesity, which is a common and well-known risk factor for OA. We examined these hypotheses separately in each sex because women and men have different OA prevalence and severity [9, 10] as well as quadriceps strength, mass [11] and the degree of symptoms [12], and likely, different degree of leg muscle asymmetry.

Materials and methods

Study participants

We conducted a cross-sectional study using data from the Fifth Korean National Health and Nutrition Examination Survey (KNHANES V) collected in 2010 and 2011. KNHANES is a nationally representative, cross-sectional survey that has been conducted by the Korean Centers for Disease Control and Prevention since 1998. It is designed to assess the health and nutritional status of non-institutionalized civilian population in Korea and comprises a health interview, a health examination, and a nutrition survey. KNHANES used a stratified, multistage, clustered probability sampling method to select a representative sample of the civilian Korean population. Among the subjects in KNHANES V, we included men or women 60 years or older who underwent both knee radiographs and dual-energy X-ray absorptiometry (DXA) scans. Of 17,476 subjects included in the KNHANES V, 2717 subjects were 60 years or older. Of the 2717 subjects, 169 subjects did not have knee X-rays or DXA scans and were excluded. Therefore, 2548 subjects were included in the analysis. All participants in KNHANES V provided written informed consent for participation in the survey and use of data for research purposes. As this study used de-identified national survey data from KNHANES V, it has been granted an exemption from requiring ethics approval by Institutional Review Board of Catholic University of Korea (KC14EISI0096).

Variables

Study participants completed a questionnaire that included basic demographics, medical history, social history, and lifestyle habits. The medical history inquired about the presence of hypertension, diabetes mellitus, or osteoporosis. Social history included inquiry about cigarette smoking (ever smokers, i.e., those who have history of smoking more than five packs of cigarettes in their life in the past or presently smoking), alcohol consumption (percentage of number of months consuming alcohol once or more over the last 12 months), and physical activity (regular exercisers, i.e., those who perform mildly fatiguing exercise for 30 min or more at least 5 days/week or very fatiguing exercise for 20 min or more at least 3 days/week). Body mass index (BMI) was defined as body weight/height^2 (kg/m^2). Waist circumference was measured at the midpoint between the bottom of the rib cage and the top of the lateral border of the iliac crest with full expiration.

Radiographic examination of knee OA

Bilateral standing anteroposterior and lateral plain radiographs of the knees were obtained using SD3000 Synchro Stand (Accele Ray, Shinyoung Co., Seoul, South Korea). Radiographs were carefully monitored and evaluated by a group of radiographic technicians. The average score of the X-ray quality was 82.09 of 100. Two independent radiologists graded the degree of knee OA according to the Kellgren-Lawrence (KL) grade. The higher grade between the two was taken if a discrepancy was noted. However, if the discrepancy was equal or more than two grades, a third radiologist adjudicated to arrive at a consensus. After grading both knee joints, the higher grade was determined as the KL grade of each patient. The concordance rate of KL grades between the two radiologists was 94.76%. The inter-rater agreement, kappa coefficient, for the KL grading was 0.65. The radiologists had no knowledge about any participant's knee symptoms. Radiographic knee OA was defined as KL grade ≥ 2.

Measurement of body composition

DXA scans were performed using Hologic® (Marlborough, MA) Discovery-W, which generated the lean mass, fat mass, bone mineral contents, and bone mineral density of whole body by regions. The leg region of interest was defined as the area demarcated as proximally from the line crossing femoral neck just proximal to the intertrochanteric line and distally to the foot. Muscle mass was obtained from subtracting bone mineral content from lean mass. We defined the muscle asymmetry index as $|(\text{left leg muscle mass})/(\text{both leg muscle mass}) \times 100 - 50|$. The index value was designed as the absolute value to show the degree of asymmetry and ranged non-directionally from 0 to 50, with 0 indicating perfect symmetry and 50 indicating the greatest asymmetry in both sides of leg muscles. Similarly, the fat asymmetry index was defined as $|(\text{left leg fat mass})/(\text{both legs fat mass}) \times 100 - 50|$.

Measurement of knee symptoms

Symptomatic knee OA was defined as the presence of pain or stiffness among those with radiographic knee OA. The presence of knee pain was a dichotomous variable in which a person experienced or did not experience knee joint pain for more than 30 days over the last 3 months. The degree of knee pain was obtained on a scale of 1 to 10 by numeric rating scale, with 10 being the worst. The presence of knee stiffness was defined as the presence of knee joint morning stiffness for more than 30 days over the last 3 months.

Statistical analyses

Subjects were grouped by sex, and the characteristics were compared using *t* test, chi-square test, and analysis of variance depending on the variable characteristics. Analyses of covariance were performed to examine the muscle asymmetry index by KL grade and knee symptoms with and without adjustment. Trend tests were performed using general linear models adjusted for age, smoking, alcohol consumption, physical activity, and waist circumference. The muscle asymmetry index was categorized into quartiles, with Q1 being the lowest 25 percentile and Q4 being the highest 25 percentile. Univariate and multivariable logistic regression models were used to generate odds ratios and 95% confidence intervals (CIs) for having radiographic knee OA and knee symptoms by the different quartiles of the muscle asymmetry index. The analyses were repeated for the subgroups of subjects who have radiographic knee OA to generate odds ratios and 95% CIs for presence of knee symptoms by the different quartiles of the muscle asymmetry index. Subjects were divided into normal or obese by BMI cutoff of 25 kg/m^2 by 2014 Clinical Practice Guidelines for Overweight and Obesity in Korea [13]. Using the muscle asymmetry index, subjects were classified as asymmetric if they were within the fourth quartile (Q4) and symmetric if they were within the rest of quartiles (Q1–Q3). Based on these categories, subjects were divided into four groups: symmetric normal, symmetric obese, asymmetric normal, and asymmetric obese. Odds ratios and 95% CIs were obtained for the prevalence of radiographic knee OA and knee pain by the different groups. Statistical analyses were conducted with SAS version 9.3 (SAS Institute, Cary, NC, USA).

Results

A total of 2548 patients (1126 men and 1422 women) were included in the analysis. The characteristics of men and women were significantly different (Table 1). Men were younger, had lower BMI but with more muscle mass and less fat mass in both legs, were more likely to be ever smoker, were more likely to consume alcohol, were more physically active, and were more likely to have hypertension than women. Osteoporosis was much more prevalent in women. The average muscle asymmetry index was significantly higher in women. Women were more likely to have radiographic knee OA, defined by KL grade ≥ 2, than men ($p < .0001$). Knee pain and stiffness were more prevalent in women than in men ($p < .0001$).

When the muscle asymmetry index was stratified by radiographic knee grade (KL grade) or symptoms (pain or stiffness), it showed different findings in men and women (Table 2). Men showed a significant trend of having a higher muscle asymmetry index as the radiographic grade increased,

Table 1 Subject characteristics

	Men $N = 1126$	Women $N = 1422$	p
Age (years)	68.6 ± 0.2	70.3 ± 0.3	< .0001
BMI (kg/m^2)	23.5 ± 0.1	24.2 ± 0.1	< .0001
Waist circumference (cm)	85.9 ± 0.4	83.7 ± 0.3	< .0001
Muscle mass, left leg (g)	7419.6 ± 50.2	5138.9 ± 31	< .0001
Muscle mass, right leg (g)	7521.2 ± 49.7	5245.9 ± 28.6	< .0001
Fat mass, left leg (g)	1944.5 ± 37	2778.5 ± 35.7	< .0001
Fat mass, right leg (g)	2020.9 ± 36.4	2857.3 ± 39.6	< .0001
Muscle asymmetry index	0.94 ± 0.03	1.04 ± 0.03	.0137
Fat asymmetry index	1.9 ± 0.1	1.5 ± 0.1	.0476
Obesity and muscle asymmetry index (*n*)			
Symmetric normal	577	655	
Symmetric obese	267	411	
Asymmetric normal	205	212	
Asymmetric obese	76	143	
Ever smoker (%)	86.1 (86.7)	9.9 (13.3)	< .0001
Alcohol consumption (%)	65.9 (72.2)	19 (27.8)	< .0001
Physical activity (%)	19.3 (49.2)	14.9 (50.8)	.0143
Hypertension (%)	18 (51.5)	12.7 (48.5)	.002
Diabetes mellitus (%)	18.9 (41.4)	20.8 (58.6)	.3363
DXA (%)			< .0001
Normal	39.1 (83.4)	6.5 (16.6)	
Osteopenia	50.3 (49.8)	42.5 (50.2)	
Osteoporosis	10.6 (14.8)	50.9 (85.2)	
Osteoarthritis (%)			
KL grade			< .0001
0	26.1 (2.0)	17.3 (1.1)	
1	35.2 (1.9)	18.8 (1.3)	
2	22.2 (1.8)	13.3 (1.1)	
3	12.0 (1.4)	30.0 (2.0)	
4	4.5 (0.6)	20.5 (1.4)	
Knee pain (%)	15.6 (1.4)	42.1 (1.5)	< .0001
Knee stiffness (%)	7.7 (1.1)	23.8 (1.4)	< .0001

Values are the mean ± standard error (SE) or mean% (SE%)

BMI body mass index, *DXA* dual-energy X-ray absorptiometry, *KL* Kellgren-Lawrence

Table 2 Muscle asymmetry index by radiographic grade (Kellgren-Lawrence grade) and knee symptoms

	Kellgren-Lawrence grade						Knee pain			Knee stiffness		
	0	1	2	3	4	*p*	No	Yes	*p*	No	Yes	*p*
Model 1												
Men	0.81 ± 0.04	0.85 ± 0.05	1.03 ± 0.07	1.04 ± 0.09	1.68 ± 0.24	< .0001	0.9 ± 0.03	1.14 ± 0.08	< .01	0.94 ± 0.03	0.89 ± 0.09	.62
Women	1.06 ± 0.07	0.94 ± 0.07	1.04 ± 0.07	1.04 ± 0.05	1.12 ± 0.07	.46	1.01 ± 0.04	1.09 ± 0.05	.21	1.05 ± 0.04	1.02 ± 0.05	.68
Model 2												
Men	0.82 ± 0.05	0.85 ± 0.05	1.02 ± 0.07	1.04 ± 0.09	1.66 ± 0.24	< .001	0.91 ± 0.03	1.14 ± 0.07	< .01	0.95 ± 0.03	0.89 ± 0.09	.58
Women	1.07 ± 0.07	0.95 ± 0.07	1.04 ± 0.07	1.03 ± 0.05	1.09 ± 0.07	.54	1.01 ± 0.04	1.07 ± 0.06	.33	1.05 ± 0.04	1 ± 0.06	.41
Model 3												
Men	0.81 ± 0.05	0.85 ± 0.05	1.03 ± 0.07	1.05 ± 0.09	1.68 ± 0.24	< .001	0.91 ± 0.03	1.14 ± 0.08	< .01	0.95 ± 0.03	0.88 ± 0.09	.5
Women	1.08 ± 0.07	0.95 ± 0.07	1.04 ± 0.07	1.03 ± 0.05	1.09 ± 0.07	.54	1.01 ± 0.04	1.07 ± 0.06	.39	1.05 ± 0.04	1 ± 0.06	.41
Model 4												
Men	0.82 ± 0.05	0.84 ± 0.05	1.02 ± 0.07	1.05 ± 0.09	1.67 ± 0.24	< .001	0.9 ± 0.03	1.14 ± 0.08	< .01	0.95 ± 0.03	0.88 ± 0.09	.51
Women	1.08 ± 0.07	0.96 ± 0.07	1.04 ± 0.07	1 ± 0.05	1.08 ± 0.07	.44	1 ± 0.04	1.07 ± 0.06	.28	1.04 ± 0.04	1 ± 0.06	.54

Model 1: unadjusted; model 2: adjusted for age; model 3:adjusted for age and waist circumference; model 4:adjusted for age, waist circumference, smoker, alcohol consumption, and physical activity

whereas women did not show such a trend. Men with knee pain had a higher asymmetry index compared with men without knee pain. Women also showed similar finding, but it did not reach statistical significance. However, the prevalence of knee stiffness did not show any difference in the muscle asymmetry index. It was also noted that women without radiographic knee OA (those with KL grade 0) had higher muscle asymmetry than those with mild radiographic knee OA.

When subjects were divided into quartiles based on the asymmetry index, men in the third or fourth quartile were more likely to have significantly higher radiographic knee grade (Table 3). The most asymmetric group (those in the fourth quartile) had 2.3 times higher radiographic grade than the least asymmetric group in men adjusted for age, waist circumference, smoking, drinking, and physical activity. In addition, men in the fourth quartile had 2.8 times more likely to have knee pain than men in the first quartile.

When the analysis was limited to those with radiographic knee OA (KL grade ≥ 2), increased muscle asymmetry index was significantly associated with frequent knee pain in men. Men in the fourth quartile were 3.3 times more likely to have pain compared with men in the first quartile. Women with higher muscle asymmetry index also showed a trend of prevalent knee pain, but it did not reach statistical significance (Fig. 1).

Lastly, when we divided the subjects into four groups by BMI and muscle asymmetry index, the prevalence of radiographic knee OA was highest in the asymmetric obese group in both men and women. Those in the asymmetric obese group were 1.8 times (95% CI 1.02, 3.31) or 3.6 times (95% CI 1.76, 7.18) more likely to have radiographic knee OA in men and women, respectively (Fig. 2). In addition, men in the asymmetric normal group were 1.8 times (95% CI 1.12, 2.77) more likely to have higher radiographic grade compared with men in the symmetric normal group, whereas men in the symmetric obese group did not have significantly higher radiographic grade compared with men in the symmetric normal group. In men, being asymmetric was a remarkably important factor related to the degree of radiographic knee OA, irrespective of obesity. Meanwhile, in women, obesity or asymmetry alone did not affect the degree of radiographic grade or knee pain; however, having both obesity and asymmetry was related to 3.6 times (95% CI 1.76, 7.18) higher degree of radiographic grade (Fig. 2). In terms of knee pain, men in the asymmetric obese group were 2.7 times (95% CI 1.12, 6.60) more likely to have pain in their knees, whereas other groups were not significantly related to the prevalence of knee pain. In women, none of the groups were related to knee pain. In terms of knee stiffness, women in the asymmetric obese group were 1.7 times (95% CI 1.06, 2.85) more likely to have stiffness compared with those in the symmetric normal group.

Table 3 Odds ratios of radiographic grade (Kellgren-Lawrence grade), presence of knee pain and stiffness by quartiles of muscle asymmetry index

	Kellgren-Lawrence grade		Knee pain		Knee stiffness	
	Men	Women	Men	Women	Men	Women
Model 1						
Q1	1	1	1	1	1	1
Q2	1.39 (0.93, 2.07)	0.94 (0.65, 1.36)	1.75 (0.84, 3.63)	0.98 (0.68, 1.41)	2.21 (0.98, 4.97)	1.20 (0.8, 1.80)
Q3	1.77 (1.12, 2.80)	1.16 (0.81, 1.67)	1.62 (0.84, 3.14)	1.07 (0.74, 1.54)	0.51 (0.21, 1.26)	0.99 (0.65, 1.52)
Q4	2.19 (1.33, 3.61)	1.11 (0.72, 1.72)	2.86 (1.56, 5.24)	1.26 (0.82, 1.96)	1.32 (0.61, 2.85)	1.06 (0.68, 1.65)
p	.02	.62	.005	.68	.01	.80
Model 2						
Q1	1	1	1	1	1	1
Q2	1.5 (1.02, 2.22)	0.84 (0.56, 1.24)	1.71 (0.85, 3.46)	0.92 (0.63, 1.34)	2.13 (0.97, 4.65)	1.18 (0.78, 1.77)
Q3	1.85 (1.17, 2.93)	1.11 (0.76, 1.61)	1.59 (0.82, 3.07)	1.04 (0.72, 1.51)	0.50 (0.20, 1.25)	1.00 (0.66, 1.53)
Q4	2.31 (1.40, 3.80)	1.04 (0.66, 1.63)	2.81 (1.53, 5.17)	1.22 (0.77, 1.92)	1.25 (0.57, 2.77)	1.05 (0.67, 1.64)
p	.01	.46	.006	.67	.01	.86
Model 3						
Q1	1	1	1	1	1	1
Q2	1.46 (0.99, 2.15)	0.82 (0.55, 1.23)	1.66 (0.81, 3.38)	0.94 (0.63, 1.39)	2.07 (0.94, 4.56)	1.24 (0.81, 1.88)
Q3	1.88 (1.21, 2.94)	1.04 (0.72, 1.51)	1.61 (0.82, 3.13)	1 (0.69, 1.46)	0.51 (0.21, 1.26)	1.01 (0.65, 1.56)
Q4	2.26 (1.37, 3.71)	0.98 (0.62, 1.53)	2.82 (1.54, 5.18)	1.28 (0.80, 2.04)	1.25 (0.56, 2.80)	1.09 (0.69, 1.74)
p	.01	.62	.01	.64	.02	.75

Model 1: adjusted for age; model 2: adjusted for age and waist circumference; model 3:adjusted for age, waist circumference, smoker, alcohol consumption, and physical activity

Q1 indicates the most symmetric quartile; Q4 indicates the most asymmetric quartile

Discussion

In Korean subjects 60 years or older, leg muscle asymmetry was associated with both prevalence and radiographic severity of knee OA, especially in men. Furthermore, leg muscle asymmetry was also associated with prevalent knee pain. These relationships were particularly significant in men. When men and women were classified by the degree of both muscle asymmetry index and obesity, those in the asymmetric obese group had 1.8 and 3.6 times higher radiographic knee OA grade, respectively. In men, leg muscle asymmetry was a highly significant factor associated with knee radiographic grade and knee pain irrespective of obesity.

The finding in our study differed significantly by sex. Women also showed the trend of having higher radiographic grade and knee pain in those with muscle asymmetry, but it was not as significant as in men. The reason why the relationship was more significant in men remains unclear. It should be noted that muscle asymmetry was more severe in women than in men even those without radiographic knee OA, as shown in Table 2 (see KL grade 0). Based on these findings, we suspect that men's knee symptoms are more solely related to leg

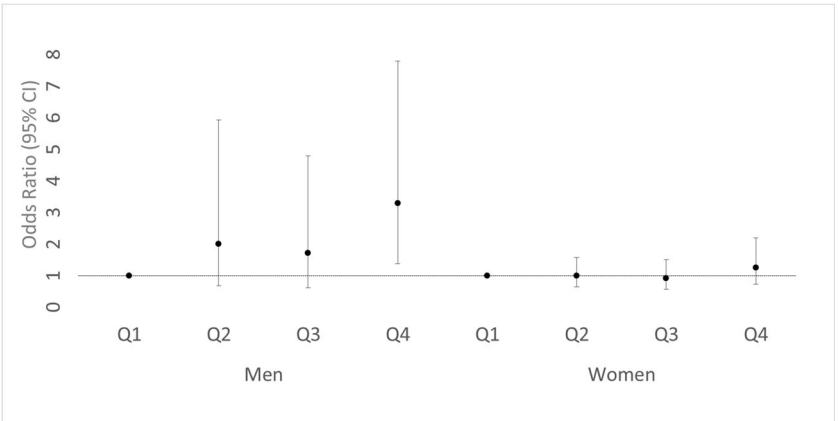

Fig. 1 Risk of knee pain by muscle asymmetry index in those with radiographic knee OA. The odds ratios of knee pain prevalence by muscle asymmetry index are shown. Muscle asymmetry index was categorized into quartiles; Q1 indicates the most symmetric quartile, and Q4 indicates the most asymmetric quartile

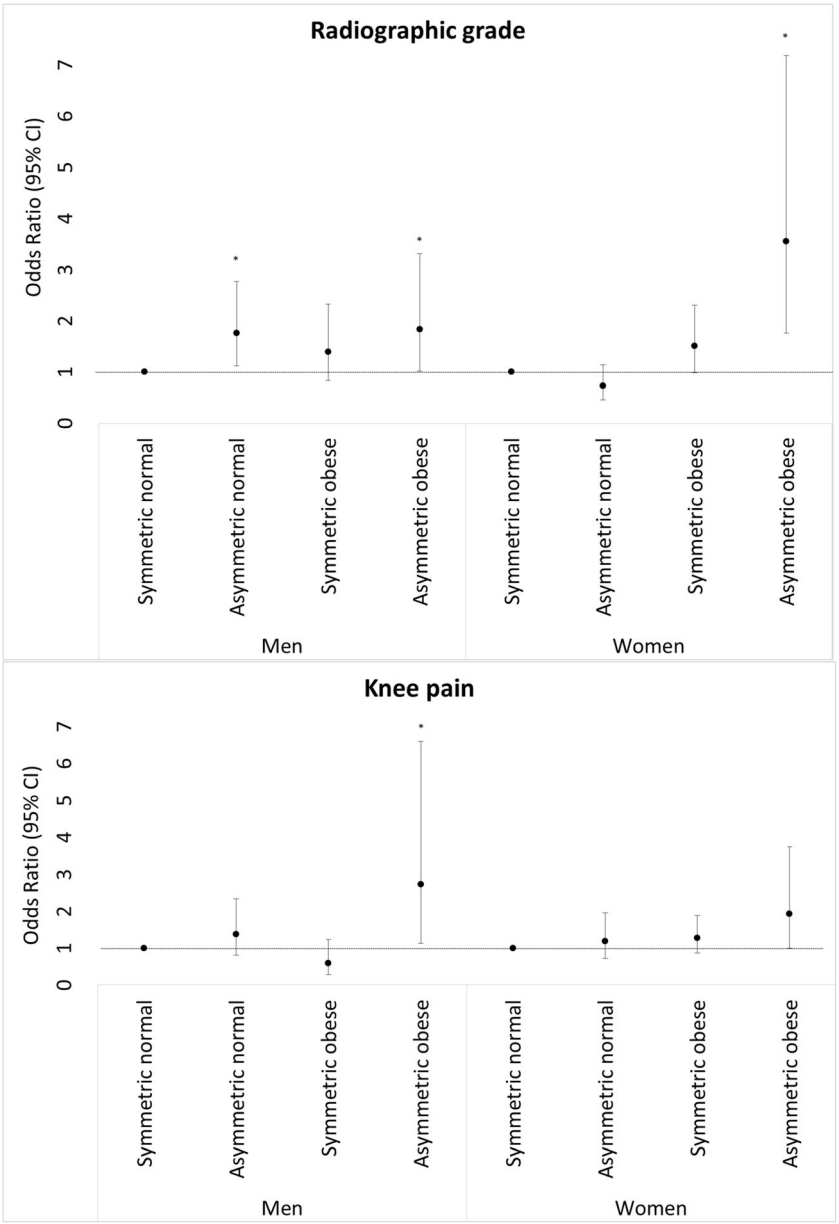

Fig. 2 Risk of radiographic severity and knee pain by obesity with muscle asymmetry index. The odds ratios of radiographic grade and prevalent knee pain by obesity with muscle asymmetry index are shown. Those with asymmetry had higher risk of worse radiographic grade and knee pain, especially in men. Men with asymmetry regardless of obesity were significantly related to worse radiographic knee OA. Asterisk indicates statistical significance

muscle asymmetry, whereas women's symptoms are more multifactorial. Studies have reported sex differences in OA characteristics [10]. Men have higher muscle strength in the quadriceps and hamstrings than women. Muscle mass or strength may have a more important role in the development or symptoms in men, whereas more complicated factors may be involved in women [12, 14].

Obesity is a known risk factor for the prevalence of knee OA and knee symptoms. Our study showed that leg muscle asymmetry was an even more important factor related to radiographic knee OA than obesity, especially in men. Despite the presence of obesity, the prevalence of knee OA in subjects with lower muscle asymmetry index was lower than in those with higher index. In men with fairly maintained muscle symmetry, obesity was not related to significantly higher radiographic grade compared with normal BMI. Our findings emphasize the importance of skeletal muscles and their balance in OA pathogenesis. Loss of skeletal muscles, sarcopenia, has been reported to be associated with knee OA [15, 16], but to the best of our knowledge, no study has examined muscle mass discrepancy in both legs and its effect on symptoms and disease severity. Our findings can be partially explained by biomechanics. It is expected that having knee OA or pain in one of the knee joints could cause disuse in leg muscles and abnormal loading [17], resulting in asymmetric muscle volume in both legs. However, on the other hand, muscle asymmetry in legs could generate instability and different loading to both knee joints and may result in degeneration or pain. As this was a cross-sectional study, longitudinal studies will be needed to determine the cause-and-effect

relationship between muscle asymmetry and radiographic severity or symptomatic knee OA.

Our study has limitations. We obtained leg muscle asymmetry index from body composition measured by DXA. There are other methods of measuring muscle mass including MRI, CT, ultrasonography, and bioelectrical impedance analysis, and DXA can be considered to be less precise compared with other methods. Nevertheless, DXA is a less labor-intensive, less operator-dependent and is a quick and easy method to obtain muscle mass from a large number of participants like ours. Also, its accuracy probably had little effect on our study findings given that we used ratio instead of the measured amount itself. We were also unable to find out if the association was from the discrepancy of the radiographic degree of both sides as the data was limited to examine this possibility. Although our study was not designed to study the relationship of the leg muscle asymmetry and side differences of knee joints, we think future study should be done to see if the finding is stronger in those with greater side differences as the side differences of knee cartilage volume were reported to be positively correlated with side differences of muscle mass [18]. However, we do not believe our study finding was driven by those with severe side differences of knee OA because almost 84% of the male subjects had mild or no radiographic OA (KL grade 0 to 2) at their worse knee joint.

Leg muscle symmetry is a factor that has not been explored in knee OA, but our cross-sectional study using KNHANES data showed association with radiographic severity and pain of knee OA, especially in men. Our study also suggested that asymmetry may be more significant factor than obesity for radiographic knee OA and knee pain in men. Longitudinal studies will be needed to determine the cause-and-effect relationship between muscle asymmetry and radiographic severity or symptomatic knee OA, and to determine whether the higher or lower mass, beyond the asymmetry, is associated with radiographic severity or symptomatic knee OA.

Compliance with ethical standards

All participants in KNHANES V provided written informed consent for participation in the survey and use of data for research purposes. As this study used de-identified national survey data from KNHANES V, it has been granted an exemption from requiring ethics approval by Institutional Review Board of Catholic University of Korea (KC14EISI0096).

Disclosures None.

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