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Original Article

Functional status of the articularis genus muscle in individuals with knee osteoarthritis

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Abstract

Objectives: To clarify the functional status of the articularis genus muscle (AGM) in individuals with knee osteoarthritis (OA) and to analyze the muscle's relationship with knee OA. **Methods:** Fifty-two individuals with knee OA (mean age, 73.4 years), 50 elderly individuals without knee OA changes (mean age, 71.2 years) and 75 young individuals (mean age, 20.2 years) were observed the AGM using ultrasonography. The thickness of the AGM, the anteroposterior distance of the suprapatellar bursa, and moving distance of the muscle insertion were measured both at rest and during isometric contraction, and values during contraction were expressed as percentages of the values at rest (%Muscle-Increase, %Bursa-Increase). **Results:** Muscle thickness at rest, %Muscle-Increase, %Bursa-Increase, and moving distance of the muscle insertion were significantly lower and anteroposterior distance of the suprapatellar bursa was significantly higher in the OA group than in the controls ($p < 0.001$, all). In the OA group, these values for the AGM were significantly correlated with knee range of motion, knee pain, and Kellgren and Lawrence grade. **Conclusions:** Individuals with knee OA exhibited atrophic changes and dysfunctions of the AGM, and these were associated with symptoms. Atrophic changes and dysfunctions of the AGM may be specific changes associated with knee OA.

Keywords: Articularis Genus Muscle, Osteoarthritis, Knee, Ultrasound Imaging, Muscle Function

Introduction

The articularis genus muscle (AGM) is a small muscle located between the vastus intermedius muscle and the prefemoral fat pad. It originates from the anterior surface of the femur and inserts into the suprapatellar bursa[1-4]. It may be regarded as the fifth head of the quadriceps femoris muscle or as a distal fiber of the vastus intermedius muscle[5]. The function of the AGM is assumed to be to retract and elevate the suprapatellar bursa during knee extension, preventing entrapment of the bursa between the patella and the femur[1,3,4,6]. Therefore, dysfunction of the AGM is considered to be a cause of knee pain and of patella infera[4,7]. However, no previous study has directly and dynamically measured the functional status of the AGM.

Knee osteoarthritis (OA) is a chronic degenerative disease of the knee joint. Various factors, such as age[8,9], sex[10,11], obesity[8,10,12], alignment[13,14], and bone metabolism[15,16], are related to its symptoms and/or development. Weakness of the quadriceps muscle is one of the risk factors associated with the symptoms and development of knee OA. Ding et al.[17] showed that quadriceps and hip flexor weakness was associated with a loss of medial femoral cartilage volume on magnetic resonance imaging (MRI). As a result of their systematic review and meta-analysis, Øiestad et al.[18] suggested that knee extensor weakness was related to an increased risk of developing knee OA in both men and women. Although the AGM is also assumed to influence knee OA, no mechanism or causal relationship has been clarified.

The authors have no conflict of interest.

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The purposes of this study were to clarify the functional status of the AGM in individuals with knee OA and to analyze the relationship between its functional status and knee OA.

Methods

Participants

The study consisted of three groups, one group of patients with knee OA (the OA group) and two control groups. The OA group consisted of 52 individuals with medial knee OA who were treated at the Ugo Municipal Hospital or the Sannoh Orthopedic Clinic in Japan (12 men, 40 women; mean age, 73.4 years; mean body mass index, 26.5 kg/m^2). Of the 52 individuals in the OA group, 22 had bilateral lesions, while the other 30 had unilateral lesions. Consequently, the data set for the OA group referred to 74 OA knees. OA severity was scored based on knee radiographs, according to the grading scale proposed by Kellgren and Lawrence (KL grade)[19]. Individuals who had a history of hip surgery, knee surgery, or rheumatoid arthritis were excluded from the OA group. The first control group consisted of 50 community-dwelling elderly individuals (elderly group: 6 men, 44 women; mean age, 71.2 years; mean body mass index, 23.5 kg/m^2; 100 knees) without any knee pain, knee OA changes, or history of knee surgery. Individuals who had OA changes of the femoral trochlear or osteophyte on ultrasonography were excluded from the elderly group[20]. The second control group consisted of 75 young, healthy individuals (young group: 25 men, 50 women; mean age, 20.2 years; mean body mass index, 21.0 kg/m^2; 150 knees). The weekly frequency of physical activity was 0-1, 1-2, and >2 times for the OA, elderly, and young groups, respectively. Finally, 15 further individuals with unilateral knee OA who were treated at the Sannoh Orthopedic Clinic in Japan (4 men, 11 women; mean age, 70.6 years; mean body mass index, 25.8 kg/m^2) were examined, to investigate the differences between affected and non-affected knees while accounting for life-style factors. The study was approved by the Ethics Committee of Akita University Graduate School of Health Sciences (approval No. 1035), and written informed consent for the collection and use of the information was obtained from all respondents in accordance with the Declaration of Helsinki.

Experimental procedure

The AGM was examined on ultrasonography (HI VISION Avius, Hitachi Aloka Medical, Japan) using a linear-array transducer with a frequency of 10MHz (EUP-L65, Hitachi Aloka Medical, Japan). A long-axis image of the AGM was obtained while participants were in a seated position on the test chair (Musculator GT30, OG Giken, Japan). The trunk, pelvis, and distal part of the lower leg were fixed by belts during the procedure (Figure 1). The transducer was placed 3 cm above the superior border of the patella, on the line between the anterior superior iliac spine and the center of the superior border of the patella, according to the anatomic location and the imaging protocol for the vastus intermedius muscle[4,21].

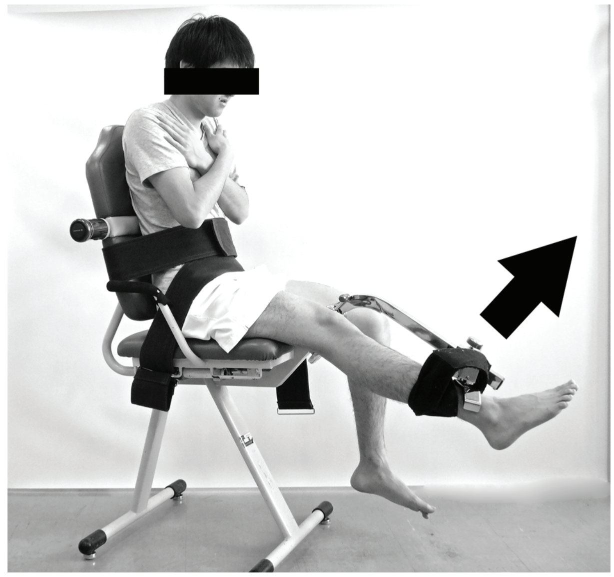

Figure 1. Positioning of the participants during isometric knee extension.

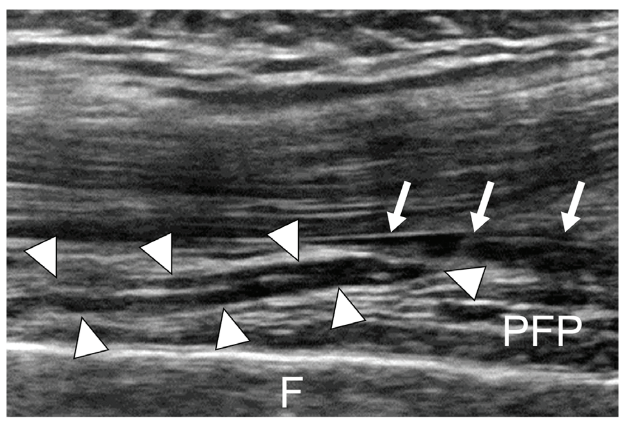

Figure 2. Long-axis image of the AGM (arrowheads). The AGM was identified as the thin muscle located on the prefemoral fat pad inserting into the inferior aspect of the suprapatellar bursa (arrows). F: Femur, PFP: Prefemoral fat pad.

During the examination, the transducer was held perpendicularly to the skin surface, with minimum pressure, so as to maintain contact with the skin but not to affect the thickness of the AGM. The participants were instructed to perform isometric knee extension starting at 30° knee flexion, maintaining maximum extension for three seconds. The exercise was repeated three times without a rest. All ultrasonography examinations were performed in the afternoon, and partici-

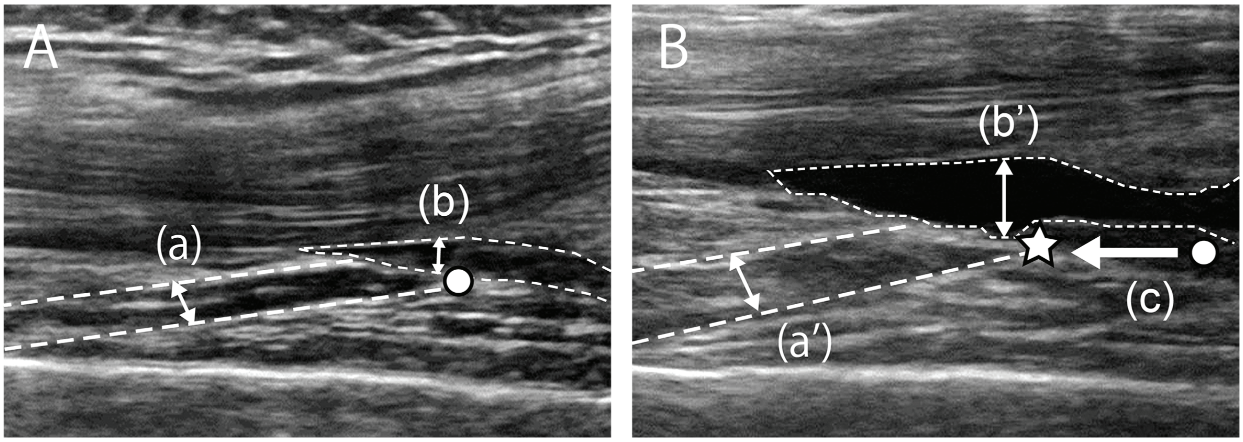

Figure 3A, B. Analysis of the AGM. **A.** Long-axis image at rest. **B.** Long-axis image during isometric contraction. (a) or (a') showed muscle thickness of the AGM. Increased muscle thickness during isometric contraction was expressed as a percentage of the thickness at rest (%Muscle-Increase = (a' − a) / a). (b) or (b') showed the anteroposterior distance of the suprapatellar bursa. The increased anteroposterior distance during contraction was expressed as a percentage of the distance at rest (%Bursa-Increase = (b' − b) / b). The moving distance of the muscle insertion (c) was measured as the distance between points at rest (○) and during isometric contraction (☆).

pants were instructed to enough rest for at least 15 minutes before the examination. The AGM was identified as the thin muscle located on the prefemoral fat pad inserting into the inferior aspect of the suprapatellar bursa[1,2] (Figure 2). The images of the AGM and suprapatellar bursa during maximum isometric knee extension were recorded and stored into the ultrasonography equipment for further analysis. The following parameters were measured on the images using the caliper function provided by the ultrasonography equipment. The thickness of the AGM was measured as the maximum distance between the fascia, both at rest and during isometric contraction. The increase in muscle thickness during contraction was expressed as a percentage of the thickness at rest (%Muscle-Increase, Figure 3-A). The anteroposterior distance of the suprapatellar bursa was measured as the length perpendicular to the inserted position of the AGM, both at rest and during isometric contraction. The increase in length of the suprapatellar bursa during contraction was expressed as a percentage of the length at rest (%Bursa-Increase, Figure 3-A). The moving distance of the muscle insertion was measured as the distance between points at rest and during isometric contraction (Figure 3-B). The values obtained were averaged over three measurements. All ultrasonography measurements were performed by the same investigator (A. S.), who had 5 years of experience in musculoskeletal sonography at the time of the investigation.

In the OA group, knee flexion/extension range of motion (ROM) was measured with a standard goniometer using the greater trochanter, lateral condyle of the femur, head of the fibula, and lateral malleolus as bony landmarks[22]. Knee pain was assessed by the visual analogue scale (VAS pain, 0-100 mm)[23].

Statistical analysis

Muscle thickness at rest, %Muscle-Increase, anteroposterior distance of the bursa at rest, %Bursa-Increase, and moving distance of the muscle insertion were compared among the OA, elderly, and young groups using a one-way analysis of variance (ANOVA) with post-hoc Tukey tests. In addition, a paired t-test was applied to compared the values of these parameters between the affected and non-affected knees in individuals with unilateral knee OA (N = 15). The relationships between muscle thickness of the AGM and body mass index and between ultrasonography-derived measurements and clinical features (knee ROM, VAS pain, and KL grade) in the OA group were examined using the Pearson correlation coefficient or Spearman rank correlation coefficient.

To assess the test-retest reliability of the ultrasonography measurement, 12 healthy individuals who selected randomly from the young group (6 men, 6 women; mean age, 21.4 years; 12 knees) were measured twice, at an interval of at least 1 week. Intraclass correlation coefficients (ICCs) with their 95% confidence intervals (CIs) were calculated. All statistical analyses were performed using SPSS 22.0 (IBM Corp, Armonk, NY). The level of significance was set at $P < 0.05$.

Results

Test-retest reliability

The ICCs (1, 1) for muscle thickness at rest and %Muscle-Increase were 0.881 (95% CI; 0.605 - 0.965) and 0.805 (95% CI; 0.491 - 0.939), respectively. The ICCs (1, 1) for the anteroposterior distance of the bursa at rest and the %Bursa-Increase were 0.788 (95% CI; 0.434 - 0.933) and 0.729

Table 1. Comparison of the functional status of the articularis genus muscle in each group.

Variables	OA Group	Elderly Group	Young Group
Muscle thickness			
- Rest (mm)	1.91 ± 0.16[ab]	2.02 ± 0.11[b]	2.38 ± 0.20
- %Muscle-Increase (%)	37.00 ± 20.26[ab]	72.42 ± 12.27[b]	92.60 ± 15.86
Anteroposterior distance of the bursa			
- Rest (mm)	3.58 ± 2.07[ab]	0.94 ± 0.26[b]	0.69 ± 0.18
- %Bursa-Increase (%)	61.10 ± 46.12[ab]	216.89 ± 85.47[b]	411.21 ± 141.74
Moving distance of the insertion (mm)	5.25 ± 2.40[ab]	9.67 ± 2.74[b]	11.16 ± 2.13

Values are mean ± SD. [a] Significantly different from the elderly group (p < 0.001). [b] Significantly different from the young group (p < 0.001).

Table 2. Comparison of the functional status of the articularis genus muscle between the affected and non-affected knees in individuals with unilateral knee OA (N=15).

Variables	Affected knee	Non-affected knee	P-value
Muscle thickness			
- Rest (mm)	1.99 ± 0.10	2.11 ± 0.15	< 0.001
- %Muscle-Increase (%)	49.55 ± 18.75	74.20 ± 12.21	< 0.001
Anteroposterior distance of the bursa			
- Rest (mm)	2.98 ± 1.92	0.98 ± 0.43	< 0.001
- %Bursa-Increase (%)	68.70 ± 31.45	222.02 ± 71.80	< 0.001
Moving distance of the insertion (mm)	6.20 ± 1.85	9.06 ± 2.00	< 0.001

Values are mean ± SD.

(95% CI; 0.316 - 0.913), respectively. The ICC (1, 1) for the moving distance of the muscle insertion was 0.834 (95% CI; 0.538 - 0.949).

Muscle thickness of the AGM

Muscle thickness at rest was significantly lower in the OA group than in the elderly and young groups (both $p < 0.001$) and was significantly lower in the elderly group than in the young group ($p < 0.001$) (Table 1). Similarly, %Muscle-Increase was significantly lower in the OA group than in the elderly and young groups (both $p < 0.001$) and was significantly lower in the elderly group than in the young group ($p < 0.001$) (Table 1).

Anteroposterior distance of the suprapatellar bursa

The anteroposterior distance of the suprapatellar bursa at rest was significantly higher in the OA group than in the elderly and young groups (both $p < 0.001$) and was significantly higher in the elderly group than in the young group ($p < 0.001$) (Table 1). The %Bursa-Increase was significantly lower in the OA group than in the elderly and young groups (both $p < 0.001$) and was significantly lower in the elderly group than in the young group ($p < 0.001$) (Table 1).

Moving distance of the muscle insertion

The moving distance of the muscle insertion was significantly lower in the OA group than in the elderly and young groups (both $p < 0.001$) and was significantly lower in the elderly group than in the young group ($p < 0.001$) (Table 1).

Comparison between affected and non-affected knees in unilateral knee OA

A total of 15 further individuals (i.e., not from the OA group) with unilateral knee OA were included in this analysis. Of the 15 affected knees, 10 were KL grade II, and 5 were KL grade III. Muscle thickness at rest and %Muscle-Increase were significantly lower in the affected knees than in the non-affected knees (both $p < 0.001$) (Table 2). On the other hand, the anteroposterior distance of the suprapatellar bursa at rest was significantly higher in the affected knees ($p < 0.001$), while the %Bursa-Increase and the moving distance of the muscle insertion were significantly lower (both $p < 0.001$) (Table 2).

Table 3. Correlations between functional status of the muscle and symptoms in the OA group.

Variables	Extension ROM (°)	Flexion ROM (°)	VAS pain (mm)	KL grade
Muscle thickness				
- Rest (mm)	0.464[b]	0.019	-0.356[b]	-0.169
- %Muscle-Increase (%)	0.643[b]	0.269	-0.509[b]	-0.535[b]
Anteroposterior distance of the bursa				
- Rest (mm)	-0.520[b]	-0.391[b]	0.236	0.325[b]
- %Bursa-Increase (%)	0.532[b]	0.249	-0.351[a]	-0.489[b]
Moving distance of the insertion (mm)	0.838[b]	0.458[b]	-0.557[b]	-0.592[b]

ROM, VAS pain: Pearson correlation coefficient. KL grade: Spearman rank correlation coefficient. [a]$p < 0.05$, [b]$p < 0.01$.

Relationship between functional status of the muscle and clinical features in the OA group

Among the 74 knees in the OA group, 27 were KL grade II, 42 were grade III, and 5 were grade IV. The knee extension ROM was -10.22 ± 5.25°, and the knee flexion ROM was 135.00 ± 11.73°. VAS pain was 43.99 ± 23.07 mm. The correlation coefficients between the functional status of the AGM and clinical features in individuals with knee OA are listed in Table 3. Knee extension ROM was highly correlated with the moving distance of the muscle insertion ($r = 0.838$) and moderately correlated with %Muscle-Increase and %Bursa-Increase. VAS pain and KL grade were moderately correlated with %Muscle-Increase and %Bursa-Increase. On the other hand, muscle thickness at rest was not correlated with body mass index ($r = -0.06$, $p = 0.572$).

Discussion

The ICCs (1, 1) for measurements of the functional status of the AGM in this study were 0.729 - 0.881. ICCs greater than 0.7 were considered good and ICCs over 0.9 were considered excellent[24,25]. Therefore, the test-retest reliability of the present study's methods for measuring the functional status of the AGM (using ultrasonography) was confirmed. Ultrasonography has been widely used to measure muscle thickness because it is non-invasive and safe. In addition, previous studies have indicated that muscle thickness measured by ultrasonography was associated with skeletal muscle mass[26] and activation[27,28].

Generally, muscle thickness of the lower extremities declines with ageing. Strasser et al.[29] and Ikezoe et al.[30] reported that the quadriceps muscle is thinner in the elderly than in the young. In our study, the AGM similarly showed age-related atrophic changes and dysfunctions. Muscle thickness and %Muscle-Increase of the AGM were significantly lower in the OA and elderly groups than in the young group. However, these changes were more prominent in the OA group than in the elderly group. Furthermore, such changes were evident in the affected knee of individuals with unilateral OA even after accounting for lifestyle-related factors by comparing the affected and non-affected knees. Moreover, although the difference in muscle thickness between the OA and the elderly groups was approximately 0.1 mm, which may be considered small, a similar difference was observed when comparing the affected and non-affected knees in individuals with unilateral OA. Therefore, these results indicate that atrophic changes and dysfunction in the AGM are related to knee OA. However, several authors have reported that atrophic changes and/or dysfunction of muscles around the knee were not apparent in individuals with knee OA. Liikavainio et al.[31] reported that the thickness of the rectus femoris, vastus lateralis, and vastus intermedius muscles showed no significant difference between patients with knee OA and age-matched controls or among groups divided by KL grade. Ruhdorfer et al.[32] reported that there was no significant difference in the anatomic cross-sectional areas of the quadriceps muscle between patients with knee OA and the controls. Therefore, the atrophic changes and dysfunction of the AGM in the present study may have been specific changes in individuals with knee OA, in contrast to the quadriceps muscle.

Effusion within the suprapatellar bursa is a common clinical finding in individuals with knee OA[33,34]. On ultrasonographic examination, effusion has been defined as anteroposterior distention larger than 2 mm on a longitudinal scan with the knee flexed to 30°[35]. Our results indicated that effusions in the suprapatellar bursa were frequent in the OA group, and the %Bursa-Increase was significantly lower in the OA group than in the controls. Since the AGM retracts back toward the suprapatellar bursa[3,6], the lower %Bursa-Increase in the OA group was likely a result of dysfunction in the AGM and/or a lack of compliance in the suprapatellar bursa. In addition, Spencer et al.[36] and Palmieri et al.[37] reported that effusions in the knee joint led to a decrease in quadriceps activation, known as arthrogenic muscle inhibition (AMI). Ike et al.[38] reported that quadriceps contraction increased the suprapatellar bursal fluid because the intraarticular pressure increased. Therefore, the lower %Bursa-Increase in the OA group might be associated with quadriceps AMI. Similarly, the moving distance of the muscle insertion was significantly lower in the

OA group than in the controls. We defined this distance as the retracted distance of the suprapatellar bursa by the AGM. This finding reflects dysfunction of the AGM, and it may cause entrapment of the suprapatellar bursa during knee extension in individuals with knee OA.

Functional status of the AGM was significantly correlated with several clinical features of knee OA in this study. Specifically, knee extension ROM was highly correlated with the moving distance of the muscle insertion and was moderately correlated with %Muscle-Increase and %Bursa-Increase. Kimura et al.[3] indicated that good flexibility of the knee joint was related to a well-developed joint cavity and good action in the AGM, and that the AGM plays a role in coordination with the suprapatellar bursa during knee extension and flexion. Limitation of knee extension ROM may cause a lack of coordination between the AGM and the suprapatellar bursa and is considered to lead to dysfunction of the AGM. Furthermore, dysfunction of the AGM and loss of motion of the suprapatellar bursa may influence knee pain and development of knee OA.

Our study has some limitations. Since the present study was cross-sectional, the degrees of influence on knee OA between other factors and the progression of knee OA was unclear. Well-designed prospective studies are needed to determine a causative or contributing factor of knee OA and the relationship between the functional status of the AGM and progression of knee OA.

The second limitation is related to the measurement during maximum knee extension. There is continuing controversy as to the relationship between muscle thickness and a higher level of maximum voluntary contraction (MVC)[28,39]. However, the AGM does not act on knee extension, and we observed in this study that the suprapatellar bursa was retracted by the AGM. In addition, in the elderly, a lower level of MVC (e.g., 20% MVC, 50% MVC, etc.) was difficult to perform. Therefore, we only measured muscle thicknesses at MVC. Moreover, as voluntary activation was not assessed, we were unable to measure whether the knee extensors performed MVC in the OA group. Further investigation to assess voluntary activation of the knee extensors via the twitch interpolation technique[40,41] is necessary to completely elucidate this aspect.

As the third limitation, no comparison between the results of ultrasonography and those of other imaging techniques was performed in the present study. It would be useful to compare the thickness and cross sectional area of the AGM measured by ultrasonography and MRI. In particular, the relationship between the AGM and deep-seated structures would be visible on MRI. Although the observation area is limited, we would like to stress the usefulness of ultrasonography for dynamic observations and analysis of the functional status of the muscle.

Conclusions

Atrophic changes and dysfunctions in the AGM were observed in the OA group in addition to age-related changes and were associated with limited knee ROM, knee pain, and stage of knee OA. These findings may be specific to changes occurring in individuals with knee OA. The AGM is an important therapeutic target in individuals with knee OA, whereby improvement in its contraction may contribute to improvement of symptoms.

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