Original Article

Ultrasonographic Morphological Changes in the Prefemoral Fat Pad Associated with Knee Osteoarthritis

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Abstract

Background: In normal knees, quadriceps contraction changes the shape of the prefemoral fat pad (PFP). However, in persons with knee osteoarthritis (OA), the functional or morphological changes of the PFP are unclear. This study aimed to clarify the morphological changes in the PFP in individuals with knee OA through ultrasonography. **Materials and Methods:** Participants were divided into the OA (36 knees; mean age, 74 years), elderly (31 knees; mean age, 70 years), and young (26 knees; mean age, 21 years) groups. The anteroposterior (AP) length of the PFP before and during isometric quadriceps contraction at 0°, 30°, 60°, and 90° knee flexion was measured ultrasonographically. The difference between the maximum and minimum length values, change in length, was also measured. These parameters were compared among the three groups. In the OA group, correlations between the parameters and clinical features (knee pain; visual analog scale, knee range of motion [ROM], Kellgren and Lawrence (K/L) grade, and intercondylar distance) were examined by Spearman and Pearson's correlation coefficient tests. **Results:** The AP lengths of the PFP before contraction were significantly lower in the OA group than in elderly group and young group at 30° (6.9 ± 2.5 vs. 12.0 ± 3.6 or 11.1 ± 2.7 mm, respectively; in order $P = 0.014$, $P = 0.006$) and 60° (6.5 ± 2.0 vs. 9.7 ± 2.5 or 9.1 ± 2.7 mm, respectively; both $P < 0.001$). The AP lengths of the PFP during contraction were significantly lower in the OA group than in elderly group and young group at 0° (6.7 ± 2.3 vs. 8.8 ± 3.7 or 9.1 ± 1.6 mm, respectively; both $P < 0.001$), 30° (7.9 ± 2.6 vs. 12.9 ± 3.7 or 13.0 ± 2.6 mm, respectively; both $P < 0.001$), and 60° (7.1 ± 2.5 vs. 13.5 ± 2.6 or 13.6 ± 3.0 mm, respectively; both $P < 0.001$). The change in length before maximum isometric quadriceps contraction was significantly lower in the knee OA group than in both elderly and young groups (3.3 ± 1.9 vs. 8.4 ± 2.5 or 6.8 ± 3.0 mm, respectively; both $P < 0.001$). The change in length during contraction was also significantly lower in the knee OA group than in both the elderly and young groups (3.9 ± 2.3 vs. 8.7 ± 2.3 or 8.9 ± 2.0 mm, respectively; both $P < 0.001$). In the OA group, change in length during contraction was significantly associated with knee pain ($r = -0.476$, $P = 0.007$), knee ROM ($r = 0.388$, $P = 0.019$), and Kellgren and Lawrence grade ($r = -0.357$, $P = 0.045$). **Conclusions:** In knee OA, movement of PFP was decreased more than healthy participants. In the knee OA group, the decrease of the morphological change of the PFP showed the relationship between VAS score, knee extension ROM, intercondylar distance (ICD), and K/L grade. An evaluation to the PFP may be required in individuals with knee OA.

Keywords: Adipose tissue, osteoarthritis, knee, ultrasonography

Introduction

Osteoarthritis (OA) is a common musculoskeletal disease in the elderly. Pain and quadriceps weakness are well-known characteristics of knee OA[1] and affect walking ability and activity of daily living.[2] In persons aged above 40 years in Japan, the prevalence of knee OA is 42.6% in men and 62.4% in women, respectively, and a total of 25.3 million people (8.6 million men and 16.7 million women) are possibly affected by this condition.[3]

Many causes of knee OA have been considered in the literature.[4-7] Distel *et al*.[8] and Ballegaard *et al*.[9] implicated

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fat pads as one of the causes. There are three fat pads in the knee joint, the infrapatellar fat pad (IFP), quadriceps fat pad, and prefemoral fat pad (PFP). Of these, the IFP has been widely investigated by several authors.[10-13] The chemical effects of IFP were also recently noted.[8,9]

PFP supports the sliding of the suprapatellar bursa (SB) during the isometric contraction of the quadriceps[14] since it is located between the SB and femur.

However, the relationship between PFP and knee OA is unclear. The purpose of the present study was to clarify the morphological changes in the PFP in individuals with knee OA and elderly persons without knee OA and to examine any correlations between PFP motion change and clinical or physical features of knee OA.

Participants

Twenty-five participants with knee OA were enrolled in the present study (9 men, 16 women, mean age 74 years, mean body mass index [BMI] 26.6 kg/m^2; 95% confidence interval [CI] 24.8–28.5). They were diagnosed as having knee OA based on clinical knee symptoms and knee radiography, namely, knee pain, swelling, poor range of motion (ROM), lost joint space, deformities, and osteophyte. In the radiographic findings, cases graded as 2, 3, or 4 on the Kellgren and Lawrence (K/L) grade[15] were included. Among the 25 participants, 11 had bilateral knee OA and 14 had unilateral knee OA. Consequently, 36 knees were examined as the knee OA group.

Thirty-one knees of 18 healthy elderly individuals (5 men, 13 women, mean age 70 years, mean BMI 22.3 kg/m^2; 95% CI 21.0–23.5) were classified as the elderly group. Twenty-six knees of 14 young and healthy participants (8 men, 6 women, mean age 21 years, mean BMI 21.5 kg/m^2; 95% CI 20.6–22.3) were classified as the young group. In the elderly and the young groups, persons having any symptom or deformity around the knees, knee pain, obvious deformity, orthopedic or neuromuscular disorder in the lower limb, and wear or irregularity of the femoral cartilage discovered through ultrasonographic survey[16] were excluded. This study was carried out based on the "Helsinki Declaration" (October 2008, Seoul, revised). In addition, personal information was handled according to the Personal Information Protection Law and participant privacy was protected. We confirmed that participants understood the study's purpose and obtained written informed consent. This study received the approval of the Municipal Akita City Hospital Ethical Review Board in 2014 (approval number 12).

Materials and Methods

Ultrasound image recording

We used a B-mode ultrasound device (HI VISION Noblus, Hitachi Aloka Medical, Mitaka city, Tokyo, Japan) and a 13-4 MHz transducer. The long axial view was obtained by placing the transducer on the line from the anterosuperior iliac spine to the center of the patella.[14,17] In the sitting position, the participants' knees were fixed at 0°, 30°, 60°, and 90° flexion using an isometric knee musculometer (Hydromusculator GT160, OG Giken, Okayama city, Okayama, Japan). PFP was examined before and during maximum isometric quadriceps contraction at each knee flexion position [Figure 1].

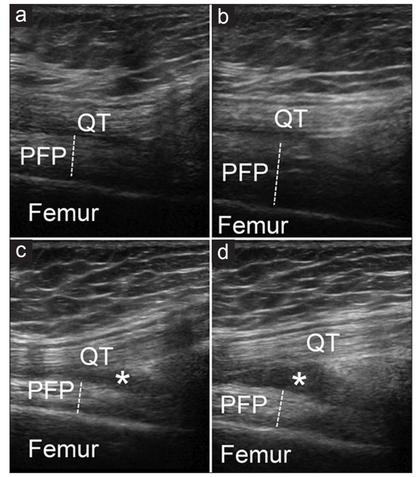

Figure 1: Ultrasound images showing the prefemoral fat pad and suprapatellar bursa (knee extension position). A: Healthy elderly person at rest, B: Healthy elderly person during isometric quadriceps contraction, C: Knee OA at rest, D: Knee OA during isometric quadriceps contraction. OA: Osteoarthritis, QT: Quadriceps tendon. *In knee OA, knee effusion in the suprapatellar bursa was observed

Ultrasound image analysis

The anteroposterior (AP) lengths of the PFP and the SB before and during maximum isometric quadriceps contraction were measured from the ultrasound images. The PFP was observed between the surface of the femur and deep layer of the SB. From the PFP length, before the contraction at 0°, 30°, 60°, and 90° flexed position, the maximum and the minimum AP lengths were selected. Afterward, the difference between the maximum value and minimum value AP length was calculated and expressed as the "change in length." Similarly, the change in length was calculated from PF*P* values during the maximum isometric quadriceps contraction. The change in length indicates that how much AP length was changed due to the change in knee angle.

The existence of knee effusion was defined as when the AP length of the SB from the ultrasound images exceeded 2 mm,[18] and the knee OA group was further divided into the effusion and the no-effusion groups. The AP length and change in PFP length were compared between the knee OA, elderly, and young groups. These parameters were also compared between the effusion and no-effusion groups in the knee OA group.

Clinical and physical assessments

Knee pain was evaluated using the 100-mm visual analog scale (VAS).[19] The participants marked the point on the scale which indicated the maximum intensity of knee pain they felt recently. The distance, in the standing position, between the medial femoral condyles on both limbs was measured as the ICD.[20] Maximum knee flexion and extension angles were measured in the supine position using a standard goniometer (OG giken, Okayama city, Okayama, Japan).

Statistical analysis

Statistical analyses were performed using SPSS Statistics version 21 (IBM, Chuo Ward, Tokyo, Japan). The assumption of normality was assessed by the Shapiro–Wilk test.

The AP length of the PFP before and during the quadriceps contraction, length change, and AP length of the SB was analyzed using one-way ANOVA and Tukey's multiple comparison tests among the knee OA, elderly, and young groups. The AP length of the PFP was compared between before and during the quadriceps contraction using paired *t*-tests. In the knee OA group, the parameters were compared between the knee effusion and no-knee effusion groups using student's *t*-tests.

Spearman and Pearson's correlation coefficient tests were used to assess the relationship between parameters of PFP and knee effusion and for other clinical and physical assessments. The level of significance was set at $P < 0.05$.

Results

The anteroposterior length of the prefemoral fat pad

The AP length of the PFP before maximum isometric quadriceps contraction was significantly lower in the knee OA group than in the elderly or the young groups at 30° (6.9; 95% CI 6.0–7.7 vs. 12.0; 95% CI 10.7–13.4 or 11.1; 95% CI 10.0–12.2 mm, respectively; in order $P = 0.014$, $P = 0.006$) and 60° (6.5; 95% CI 5.8–7.2 vs. 9.7; 95% CI 8.7–10.6 or 9.1; 95% CI 8.0–10.2 mm, respectively; both $P < 0.001$). There was no difference between the elderly and young groups regarding any knee angles. The AP length of the PFP during contraction was significantly lower in the knee OA group than in the elderly or young groups at 0° (6.7; 95% CI 5.7–7.6 vs. 8.8; 95% CI 7.5–10.2 or 9.1; 95% CI 8.5–9.8 mm, respectively; both $P < 0.001$), 30° (7.9; 95% CI 7.0–8.8 vs.

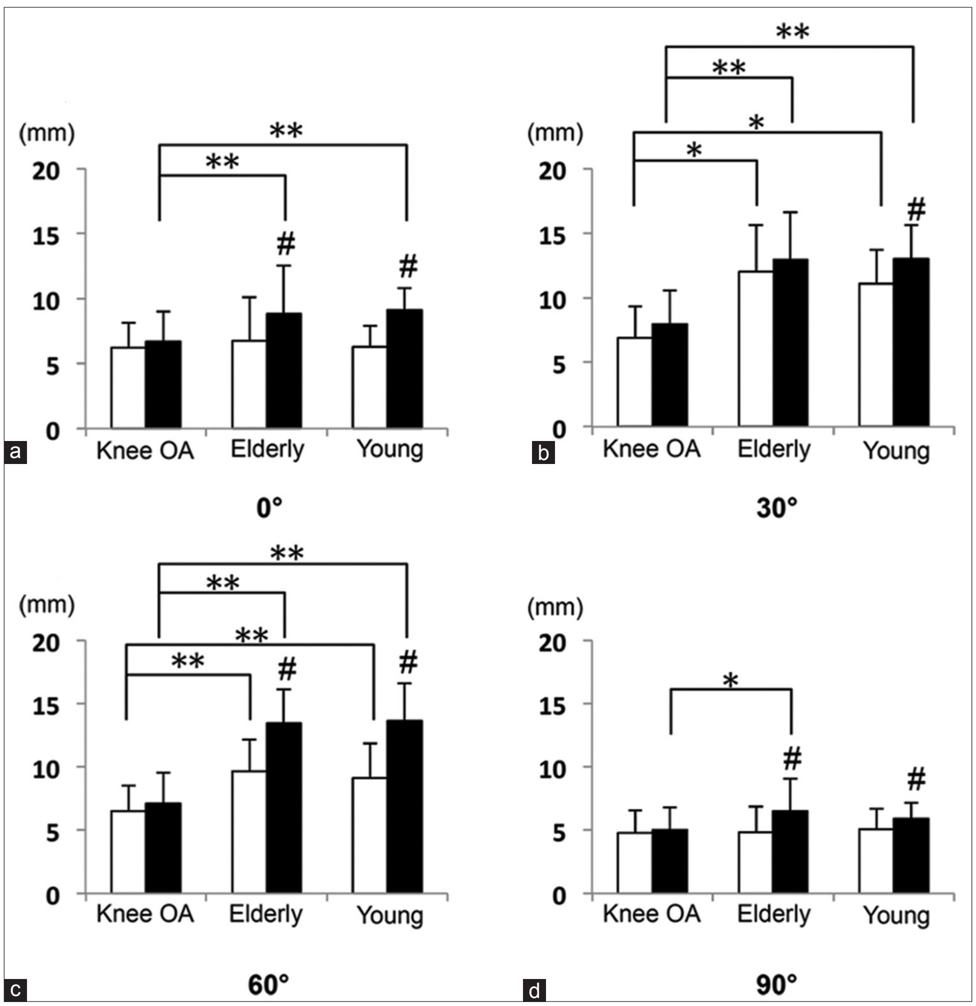

Figure 2: Anteroposterior length of the prefemoral fat pad (mean values ± standard deviation) at each knee flexion angle for (a) 0°, (b) 30°, (c) 60°, and (d) 90°. Anteroposterior length of the prefemoral fat pad was lower in the knee osteoarthritis group than in both the elderly or young groups at 0°, 30°, and 60°. There was a significant difference in anteroposterior length of the prefemoral fat pad between before and during the contraction in both the elderly and the young groups. White bar, before maximum isometric quadriceps contraction; black bar, during the contraction. *$P < 0.05$, **$P < 0.001$, #Significant difference between before and during the contraction at $P < 0.01$. OA: Osteoarthritis

12.9; 95% CI 11.6–14.3 or 13.0; 95% CI 12.0–14.1 mm, respectively; both $P < 0.001$), and 60° (7.1; 95% CI 6.2–7.9 vs. 13.5; 95% CI 12.5–14.5 or 13.6; 95% CI 12.4–14.8 mm, respectively; both $P < 0.001$). There was no difference between the elderly and young groups regarding any knee angles. In the young group, the AP length of the PFP before contraction was significantly lower than during the contraction for each knee angle. Similarly, in the elderly group, these differences were observed at 0°, 60°, and 90° knee flexion. In the knee OA group, there was no significant difference in AP length between before and during contraction at any knee angles [Figure 2].

Change in length

The change in length before maximum isometric quadriceps contraction was significantly lower in the knee OA group than in both elderly and young groups (3.3; 95% CI 2.6–3.9 vs. 8.4; 95% CI 7.5–9.3 or 6.8; 95% CI 5.6–8.0 mm, respectively; both $P < 0.001$). Length change during contraction was also significantly lower in the knee OA group than in both the elderly and young groups (3.9; 95% CI 3.1–4.7 vs. 8.7; 95% CI 7.8–9.5 or 8.9; 95% CI 8.1–9.8 mm, respectively; both $P < 0.001$). There was no significant difference in length change between the elderly and the young groups [Figure 3].

The anteroposterior length of the suprapatellar bursa

The AP length of the SB was significantly higher in the knee OA group than in the elderly and young groups (4.3; 95% CI 3.1–4.7 vs. 1.1; 95% CI 0.8–1.5 or 1.1; 95% CI 0.9–1.3 mm, respectively; both $P < 0.001$). No significant difference was found between the elderly and the young groups. The knee OA group was further divided into the effusion (26 knees, mean age 73 years) and no-effusion (10 knees, mean age 77 years) groups. The AP length of the PFP before and during the contraction was not significantly different between the effusion and no-effusion groups. The length change of the PFP before and during the contraction was significantly lower in the effusion group than in the no-effusion group (2.7; 95% CI 2.0–3.5 mm vs. 4.7; 95% CI 3.7–5.6 mm, 3.4; 95% CI 2.4–4.4 mm vs. 5.3; 95% CI 4.2–6.3 mm, respectively, in order $P = 0.006$, $P = 0.008$) [Figure 4].

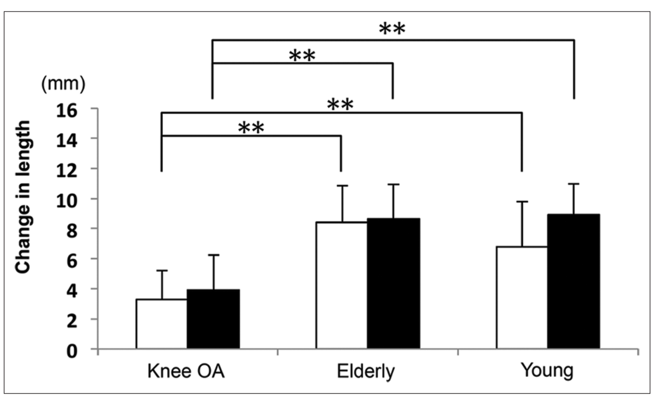

Figure 3: Change in prefemoral fat pad length in the knee osteoarthritis, elderly, and young groups. Change in length before the maximum isometric contraction (white bar) and during the contraction (black bar) was significantly lower in the knee Osteoarthritis group than in the elderly or young groups. $^{**}P < 0.001$ (one-way ANOVA and Tukey's multiple comparison tests). OA: Osteoarthritis

Correlations between prefemoral fat pad parameters and physical assessments in the knee osteoarthritis group

There was no significant correlation between AP length of the PFP before or during the contraction and physical assessments, namely, VAS score, knee ROM, ICD, and K/L grade. The change in PFP length before the contraction was significantly associated with ICD. The change in PFP length during the contraction was significantly associated with VAS score, knee ROM, and K/L grade [Table 1].

Discussion

The anteroposterior length of the prefemoral fat pad

Many reports have shown that white adipose tissue secretes inflammatory substances such as cytokines[21] in addition to its role as the storehouse of extra calories. Hoffa first reported a syndrome of infrapatellar fat pad (IFP) impingement in 1904.[11] The inflamed fat pad may be hypertrophied predisposing it to crushing or impingement between the femur and tibia and to further injury and inflammation.[12] Bohnsack *et al*.[22]

Table 1: Correlations between prefemoral fat pad parameters and clinical features

	Change in PFP length			
	At rest		During contraction	
	r	*P*	*r*	*P*
ICD	−0.459	0.016*	−0.365	0.061
VAS	−0.273	0.138	−0.476	0.007*
K/L grade	−0.183	0.315	−0.357	0.045*
ROM of knee extension	0.300	0.076	0.388	0.019*

$^{*}P<0.05$. *r*: Correlation coefficient, PFP: Prefemoral fat pad, ICD: Intercondylar distance, VAS: Visual analog scale, K/L grade: Kellgren and Lawrence grade, ROM: Range of motion

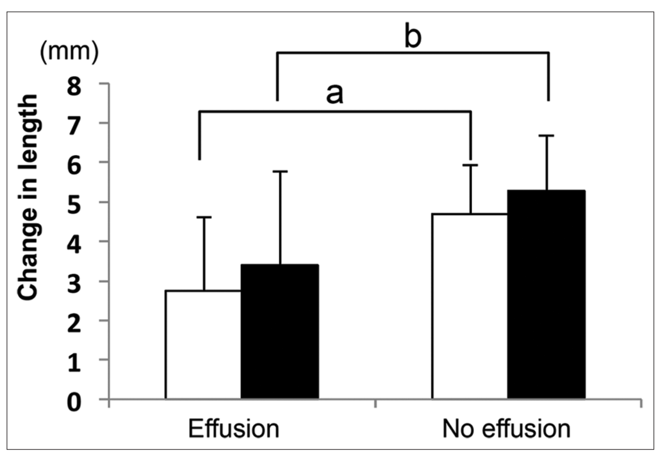

Figure 4: Change in prefemoral fat pad length in the effusion and no-effusion groups. Changes before maximum isometric quadriceps contraction (white bar) and during the contraction (black bar) were significantly lower in the effusion group than in the no-effusion group (a: $P = 0.006$, b: $P = 0.008$; respectively). OA: Osteoarthritis

suggested that the IFP played a role in stabilizing the patella in the extremes of knee motion. Subhawong *et al*.[23] reported that edema in IFP may be an important indicator of underlying patellofemoral maltracking or impingement, and there was a statistically significant association between the presence of IFP edema and PFP edema. Regarding PFP, Kim *et al*.[24] reported in their magnetic resonance imaging study that PFP could show an impingement between the anterior aspect of the distal femur and the patella undersurface and a mass-like fatty tissue protrusion from the PFP on the lateral femoral condyle caused mechanical symptoms. Dynamic motions of the PFP during isometric contraction of the quadriceps have been well described through ultrasonography.[14] The PFP may support the sliding of the SB during quadriceps contraction and knee flexion or extension since it is located between SB and femur. However, a correlation between PFP and knee disorders including knee OA has not been reported.

The present study showed that, in individuals with knee OA, AP length of the PFP did not change before and during maximum isometric quadriceps contraction for any knee angles from 0° to 90°. In contrast, in individuals without knee symptoms or deformity, the length significantly increased as the knee angle increased both before and during the contraction. Since these abnormal patterns of the length were observed only in the OA group, they are considered to cause by knee OA, and not aging. Since quadriceps weakness is occasionally present in individuals with knee OA,[25] quadriceps weakness may be related to decreased movement of PFP. In addition, the morphological change of PFP was also considered to be a cause of the decreased movement due to OA changes.

Change in length

Change in PFP length during knee motion from 0° to 90° was significantly lower in the OA group than in the elderly and young groups. Since the normal change in PFP length with passive motion was confirmed in the elderly group, the small length change in the OA group was related to knee OA. PFP is a fat pad within the knee joint, and its surrounding structures including the quadriceps muscle passively change its shape. Ultrasonography imaging could assess the fibrosis or atrophy of musculoskeletal structures.[26-28] Moreover, the decreased movement of the PFP may be associated with a longstanding limitation of ROM and/or pain in the OA group.

The anteroposterior length of the suprapatellar bursa

Effusion in the SB is one of the symptoms of knee OA. Ike *et al*.[29] found a significant correlation between the volumes of synovial fluid obtained in the knee joint and maximum depth (AP length) of the SB measured through ultrasound. Fahrer *et al*.[30] found that knee effusion reduced maximum isometric muscle strength because of reflex inhibition. Since the bursa exists adjacent to the PFP, effusion of the bursa might be associated with the motion and change of PFP. Actually, change in PFP length before and during the contraction was significantly lower in the effusion group than in the no-effusion group. Saavedra *et al*.[31] reported that the pressure exerted on the effusion by the quadriceps and patella pushes the fluid in knee flexion. This mechanism might be associated with a decrease in length change in the OA group. Inflammatory cytokine density in the synovial fluid is high in individuals with knee OA.[32,33] Direct pressure and/or chemical agents from the effusion of the SB might affect PFP, resulting in the decreased change in length.

Correlations between prefemoral fat pad parameters and physical assessments in the knee osteoarthritis group

Change in length was significantly correlated with ICD representing varus deformity of the knee OA, although there was no significant correlation between the AP length of the PFP and several clinical features. Since knee varus deformity is a result of OA progression associated with the change of the soft tissue around the knee,[34-36] not only varus deformity but also changes in the PFP itself, might affect the decreased movement of the PFP. Moreover, the change in length was also related to the VAS score, knee ROM, and K/L grade. IFP has substance – P-containing fibers and their close relationship to its posterior synovial lining implicates IFP pathologies as a source of infrapatellar knee pain.[37] Clockaerts *et al*.[38] reported that adipose tissue secreting inflammatory agents in the IFP, which are in close contact with the synovial layers and articulating cartilage, play an important role in the etiopathogenesis of OA. IFP probably plays important roles in the development of knee disorders. However, there has not been any report mentioning PFP.

Study limitations

The present study had several limitations. First, the influence of muscle strength was not investigated and since PFP is adipose tissue, its movement or change of shape depends on muscle contraction. Muscle strength and its influences on the PFP are important. Furthermore, quantitative evaluation of PFP elasticity was not performed. Ultrasonography including echo intensity and/or elastographic measurement may be useful for analyzing PFP elasticity.

This study included bilateral knee OA; they were same participants in knee OA group. There may be a bias in the statistical analysis relationship between each knee and the individual characteristics such as age, BMI, and ICD.

Conclusions

As a result of quantitative evaluation of PFP using ultrasonography, the AP length of the PFP was lower in the knee OA than in the elderly and the young groups. The PFP of the knee OA was not able to confirm the morphological change of the PFP by knee joint movement and quadriceps contraction like as found in the elderly and the young groups. In the knee OA group, the decrease of the morphological change of the PFP showed the relationship between VAS score, knee extension ROM, ICD, and K/L grade. In addition, the existence of knee effusion was thought to reduce the change in length of the PFP by knee joint movement. Although these causal relationships should be further investigated, PFP evaluation seems important in clinical practice.

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Conflicts of interest

There are no conflicts of interest.

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