

Title page (Original research)

**Examination of knee extensor and valgus moment arms of the patellar tendon in older
individuals with and without knee osteoarthritis**

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Abstract

Background: Joint moment arm is a major element that determines joint torque. This study aimed to investigate factors associated with knee extensor and valgus moment arms of the patellar tendon in older individuals with and without knee osteoarthritis.

Methods: Thirty-six participants with knee osteoarthritis (mean age, 78.1 ± 6.0 years) and 43 healthy controls (mean age, 73.0 ± 6.3 years) were analyzed. Magnetic resonance images (MRI) from the knee joint and thigh were acquired using a 3.0T MRI scanner. The three-dimensional moment arm was defined as the distance between the contact point of the tibiofemoral joint and the patellar tendon line. The three-dimensional moment arm was decomposed into sagittal and coronal components, which were calculated as knee extensor and valgus moment arms, respectively. Quadriceps muscle volume, epicondylar width, bisect offset, Insall–Salvati ratio, and Kellgren–Lawrence grade were assessed. Multiple regression analyses were performed in the healthy control and knee osteoarthritis groups, with knee extensor and valgus moment arms as dependent variables.

Findings: Knee extensor moment arm was significantly associated with epicondylar width and the Insall–Salvati ratio in the healthy control group and with Kellgren–Lawrence grade, epicondylar width, and quadriceps muscle volume in the knee osteoarthritis group. Valgus knee moment arm was significantly associated with bisect offset in both the groups.

48 *Interpretation:* Knee size, osteoarthritis severity, and quadriceps muscle volume affect the knee
49 extensor moment arm in knee osteoarthritis, whereas lateral patellar displacement affects the
50 valgus knee moment arms in older individuals with and without knee osteoarthritis.

51

52 **Keywords**

53 moment arm, patellar tendon, magnetic resonance image, muscle volume, bisect offset

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1. Introduction

Joint torque is the product of muscle force and joint moment arm (MA) (Blazeovich et al., 2009; Miyake et al., 2017). The representative determinant of muscle force is muscle volume (MV), and both MV and MA are major elements of joint torque (Hori et al., 2020). Loss of MV, known as muscle atrophy, is associated with a decline in joint torque, and previous studies (Blazeovich et al., 2009; Miyake et al., 2017) have indicated that joint MA is also associated with joint torque and physical performance. Although most previous studies (Akagi et al., 2009; Mitchell et al., 2012; Monte and Franchi, 2023) investigated the effect of MV on joint torque, focusing on the effect of joint MA length on joint torque is necessary.

Knee extensor torque is a representative physical performance indicator in older individuals, reflecting their ability to perform daily activities and their risk of falls (Moreland et al., 2004; Rantanen et al., 2001). The effect of the patellar tendon MA length on the knee extensor is associated with the quadriceps MV (Miyake et al., 2017; Ueno et al., 2021) and skeletal size, specifically the size of the distal femur (Sheehan, 2007). In contrast, a previous study (Ward et al., 2005) reported that patellar height, known as the Insall–Salvati ratio, was not associated with the patellar tendon MA length. Studies investigating the factors affecting the MA length in young individuals have been conducted. However, no study has investigated the factors associated with patellar tendon MA length in older individuals.

73 Quadriceps muscle atrophy in patients with knee osteoarthritis (OA) progresses with
74 radiographic OA severity (Taniguchi et al., 2015; Yamauchi et al., 2019). Because MV and MA
75 are correlated (Miyake et al., 2017; Ueno et al., 2021), the patellar tendon MA may be relatively
76 shorter in knee OA, considering that the quadriceps MV is smaller in knee OA than in healthy
77 individuals. In addition, the remarkable varus deformity of knee OA results in altered joint
78 biomechanics in the coronal plane. Theoretically, knee deformity in the coronal plane causes
79 patellar displacement (Mizuno et al., 2001), potentially leading to an alteration in the medial-to-
80 lateral alignment of the patellar tendon, that is, a change in the valgus MA. Therefore, the factors
81 associated with patellar tendon MA in knee OA could differ from those in healthy individuals
82 owing to the effects of a decline in quadriceps MV and varus deformity. However, to the best of
83 our knowledge, the factors associated with knee extensor and valgus MAs of the patellar tendon
84 in older individuals with and without knee OA remain unclear.

85 This study aimed to investigate the factors associated with knee extensor and valgus
86 MAs of the patellar tendon in older individuals with and without knee OA. Particularly in patients
87 with knee OA, we hypothesized that knee extensor MA could be associated with quadriceps MV
88 and skeletal size and that valgus knee MA could be associated with patellar displacement due to
89 varus deformity.

2. Methods

2.1. Participants

A total of 84 older individuals aged > 60 years from local communities in Kyoto City participated in the present study. The inclusion criteria were the ability to walk independently without using assistive devices and no general contraindications for magnetic resonance imaging (MRI) scans. The exclusion criteria were surgical history of the lower limb, rheumatoid arthritis, knee osteonecrosis, neuromuscular disorders, and cognitive disorders. After obtaining MRI scans of the right knee joint, an experienced orthopedic surgeon classified the presence or absence of knee OA based on the Kellgren–Lawrence (KL) grade ≥ 2 . Among them, participants with KL0–1 (n=48), those with knee symptoms during walking (numerical rating scale >3) were excluded (Simic et al., 2013). Finally, 36 participants with knee OA (KL2, n=12; KL3, n=7; KL4, n=17) and 43 healthy controls (KL0, n=16; KL1, n=27) were included in the present study. This study was approved by the Ethics Committee of Kyoto University Graduate School and Faculty of Medicine (R1746) and adhered to the Declaration of Helsinki. Before participating in this study, we obtained informed verbal and written consent from the participants after explaining the study procedures.

2.2. MRI acquisition

MRI was performed using a 3.0 T MRI scanner (Magnetom Verio, SIEMENS, Germany). The participants were placed in a relaxed supine position with their knees extended. A handmade apparatus was used to prevent the distal lower extremity from moving during the measurements. The investigator made adjustments by placing a cushion under the knee position when needed, to ensure a comfortable knee extension position for participants during the MRI scan. The three-dimensional (3D) SPACE technique was employed using a proton density-weighted image sequence and spine and body matrix coils to obtain MRIs of the knee joint. The parameters for 3D SPACE (Taniguchi et al., 2023) were set to a slice thickness of 0.7 mm, repetition time of 1000 ms, echo time of 35 ms, field of view of $150 \times 150 \text{ mm}^2$, and voxel size of $0.59 \times 0.59 \times 0.7 \text{ mm}^3$. To measure quadriceps MV, the whole right thigh image was taken using a T1-weighted MRI sequence with the following parameters (Taniguchi et al., 2023): slice thickness, 4 mm; repetition time, 2820 ms; echo time, 16 ms; field of view, $320 \times 240 \text{ mm}^2$; flip angle, 129° ; voxel size, $0.5 \times 0.5 \times 4.0 \text{ mm}^3$.

2.3. Assessment of the knee joint morphology

The assessment of the KL grade using 3D SPACE MRIs was defined as a grading system according to the Noyes classification, considering the status of osteophytes, bone marrow oedema,

and subchondral cysts. This assessment tool was confirmed to be strongly correlated with radiographs (Park et al., 2013). An experienced orthopedic surgeon evaluated all participants' assessments. As an indicator of knee size, epicondylar width was measured by determining the distance between the medial and lateral epicondyles on an axial slice where it appeared the largest (Servien et al., 2008).

2.4. Moment arm measurements

All the imaging analyses were performed by a well-trained examiner. We utilized 3D Slicer version 4.10.2 (Slicer Community, <http://www.slicer.org>) to measure the MA. An investigator used a 3D slicer to identify landmarks for measuring the patellar tendon MA, and spatial coordinates were acquired using a multiplanar reconstruction function (Fedorov et al., 2012). The patellar tendon MA was defined as the distance between the contact point of the tibiofemoral joint and the patellar tendon line (details provided later) (Blazevich et al., 2009; Kellis and Baltzopoulos, 1999). The contact point at the tibiofemoral joint was defined as the midpoint between the distal end of the femur and the proximal end of the tibia on the center of the femoral trochlear groove in the sagittal image (Figure 1a). To specify the midpoint of the patellar tendon, the intersection of the anterior-posterior and medial-lateral margins of the patellar tendon was identified on the transverse image (Figure 1b). After identifying the midpoints of the patellar

tendon in the proximal and distal portions of the transverse plane, the line connecting the midpoints of the proximal and distal portions was defined as the patellar tendon line (Figure 1c). After obtaining the 3D spatial coordinates, a perpendicular line from the contact point of the tibiofemoral joint to the patellar tendon line was drawn, referred to as 3D-MA. The angle (θ) on the transverse plane between the tangent to medial-lateral posterior condyle of the femur and the 3D-MA was then calculated. Finally, the 3D-MA was decomposed into individual plane component. The length (cm) of the sagittal plane component represented knee extensor MA and coronal plane component represented knee valgus MA (Figure 2).

2.5. Patellar alignment measurements

To evaluate patellar alignment, the bisect offset was measured as an index of patellar shift (Pal et al., 2012), whereas the Insall–Salvati ratio was measured as an index of patellar height (Verhulst et al., 2020). Bisect offset was measured as follows. A line tangent to both condyles was drawn on the slice where the posterior femoral condyles were the largest. A perpendicular line passing through the deepest point of the trochlear groove was used. The ratio of medial-to-lateral displacement of the patella relative to the perpendicular line was measured (Figure 3a). A high ratio indicates lateral patellar displacement. The Insall–Salvati ratio was calculated as the ratio of the length of the patellar tendon to the maximum length of the patella on a sagittal plane (Figure

3b). A low ratio indicates downward patellar displacement.

2.6. Muscle volume measurements

The regions of interest in the T1-weighted images were segmented for four individual quadriceps using OsiriX MD software (version 11.0; OsiriX, Switzerland). The regions of interest for the four individual quadriceps were set to include the entire muscle length, and the muscle cross-sectional area (CSA, cm^2) was calculated. The volume (cm^3) of each slice was obtained by multiplying the muscle CSA with a slice thickness of 4 mm, and the MV was calculated by summing the volume of each slice along the entire muscle length.

2.7. Statistical analysis

All statistical analyses were performed using SPSS version 22 (IBM Inc., Japan). The Shapiro–Wilk test confirmed that the data obtained in the present study did not follow a normal distribution. The Mann–Whitney U-test was used to compare the characteristics of the healthy control and knee OA groups. Correlations between knee extensor and valgus MAs, epicondylar width, bisect offset, Insall–Salvati ratio, and quadriceps MV in each group were calculated using Spearman’s correlation coefficients. Multiple regression analyses using the forced-entry method were performed in the healthy control and knee OA groups to investigate the factors associated with

patellar tendon knee extensor and valgus MAs. The dependent variables were knee extensor and valgus MAs, whereas the independent variables were epicondylar width, bisect offset, Insall–Salvati ratio, quadriceps MV, and KL grade. The KL grade was not included as an independent variable in the multiple regression analysis of the healthy control group. Statistical significance was set at $p < 0.05$.

3. Results

Table 1 presents the characteristics of the participants in the healthy control and knee OA groups. Patients in the knee OA group were significantly older, had a higher body mass index, and were significantly shorter than those of patients in the healthy control group. In addition, quadriceps MV was significantly lower in the knee OA group than in the healthy control group. Conversely, there was no difference in the knee extensor and valgus MAs between the groups. The bisect offset was significantly larger in the knee OA group than in the healthy control group; however, there was no significant difference in the Insall–Salvati ratio between the groups.

The correlation coefficients between the knee extensor and valgus MAs, epicondylar width, bisect offset, Insall–Salvati ratio, and quadriceps MV in each group are presented in Tables 2 and 3. Knee extensor MA showed significant positive correlations with epicondylar

width and quadriceps MV in the healthy control and knee OA groups. Additionally, in both the groups, there was a significant positive correlation between epicondylar width and quadriceps MV. Knee valgus MA was positively correlated with bisect offset ($\rho=0.357$, $p<0.05$) and the Insall–Salvati ratio ($\rho=0.312$, $p<0.05$) in the healthy control and bisect offset ($\rho=0.362$, $p<0.05$) in the knee OA group.

Table 4 presents the results of multiple regression analyses in the healthy control group. Knee extensor MA was significantly associated with epicondylar width (beta [B]=3.341, 95% confidence interval [CI]: 1.626–5.056, $p<0.01$) and the Insall–Salvati ratio (B=-7.459, 95% CI: -12.247 to -2.672, $p=0.003$). Knee valgus MA was significantly associated with bisect offset (B=11.965, 95% CI: 1.245–22.685, $p=0.03$).

Table 5 presents the results of multiple regression analyses in the knee OA group. Knee extensor MA was significantly associated with KL grade (B=1.114, 95% CI: 0.262–1.965, $p=0.012$), epicondylar width (B=2.369, 95% CI: 0.801–3.938, $p=0.004$), and quadriceps MV (B=0.005, 95% CI: 0.001–0.008, $p=0.006$), whereas valgus knee MA was significantly associated with bisect offset (B=27.793, 95% CI: 12.119–43.467, $p<0.001$).

4. Discussion

The most important findings of the present study were as follows. Greater epicondylar width and lower patellar height were associated with increased knee extensor MA in the healthy control group. A higher OA severity, greater epicondylar width, and larger quadriceps MV were associated with increased knee extensor MA in the knee OA group. These results support our hypothesis. Valgus knee MA was associated with patellar displacement in the healthy control and knee OA groups. However, no significant association was found between valgus knee MA and knee OA severity, which partially rejected our hypothesis. Among these findings, the association between the quadriceps MV and knee extensor MA in knee OA is clinically significant, implying that quadriceps muscle atrophy is associated with a decrease in knee extensor MA. Considering that quadriceps MV is a variable factor, improving MA and quadriceps MV may enhance knee extensor torque. The present study is the first to investigate the factors associated with knee extensor and valgus MAs in healthy individuals and those with knee OA.

Longer knee extensor MA of the patellar tendon in healthy control was associated with a larger epicondylar width, that is, a larger knee size. This finding is consistent with that of a previous study on healthy young individuals (Sheehan, 2007). Sheehan et al. (Sheehan, 2007) reported that knee extensor MA significantly differed between sexes among young individuals; however, the difference disappeared when corrected for knee size, suggesting that knee extensor MA is affected by knee size. Although quadriceps MV was confirmed as a significant correlation

with knee extensor MA in the healthy control group, it was not selected as a significant variable affecting knee extensor MA in the multiple regression analysis. In addition, epicondylar width was positively correlated with quadriceps MV ($\rho=0.728$, $p<0.01$). Since the epicondylar width ($\rho=0.690$, $p<0.01$) had a relatively stronger association with knee extensor MA than that of quadriceps MV ($\rho=0.516$, $p<0.01$), the epicondylar width was selected as a significant variable. Our findings suggested that knee extensor MA in the healthy control group was determined using knee size. The present study's results indicated that the knee extensor MA of the patellar tendon was longer in the lower patellar position, which contrasted with a previous study's findings (Ward et al., 2005). This discrepancy could be due to differences in MA calculation methods. In a previous study, Ward et al. (Ward et al., 2005) measured knee extensor MA using sagittal MRIs of the knee; however, the present study measured 3D-MA and calculated knee extensor MA by decomposing it into sagittal plane components. In the present study, the patellar tendon was defined by its anterior-posterior and medial-lateral margins, with the advantage of strictly defining the center of the patellar tendon. The center of the knee joint was defined as the intersection of the cruciate ligaments by Ward et al. (Ward et al., 2005), whereas the present study defined it as the contact point of the tibiofemoral joint. The 3D-MA was determined using these reference points in the present study; however, conventional MA methods were calculated two-dimensionally as the tibiofemoral contact point and perpendicular line of the patellar tendon

(Ward et al., 2005). Therefore, differences in patellar height may have been detected in the coronal plane. As the Insall–Salvati ratio decreases, indicating that the patella is positioned below the femoral trochlea (trochlear femur), the patella is displaced anteriorly from the joint center. This structural factor may explain the decrease in knee extensor MA with higher patellar height.

In patients with knee OA, the knee extensor MA of the patellar tendon increased with OA severity. The association between knee extensor MA and OA severity may be influenced by the infrapatellar fat pad (IFP) thickness. The complication rate of patellofemoral OA increases with knee OA severity (Farrokhi et al., 2013), and patellofemoral OA is associated with IFP thickening (Cowan et al., 2015). It was unclear whether the present study’s participants had patellofemoral OA; however, considering the high complication rate of patellofemoral OA in patients with severe knee OA, IFP thickening could be associated with an increase in knee extensor MA. Furthermore, consistent with the findings of a previous study targeting young individuals (Ueno et al., 2021), knee extensor MA in patients with knee OA was significantly associated with quadriceps MV in the present study. Because the quadriceps MV generally decreases with advancing knee OA severity (Taniguchi et al., 2015), shorter knee extensor MA may be due to muscle atrophy-related changes. In contrast, the relationship between knee extensor MA and the Insall–Salvati ratio confirmed in the control group was not evident in the knee OA group. In the case of IFP thickening in knee OA, the length of the patellar tendon would theoretically increase, consequently indicating

a relatively higher Insall-Salvati ratio. The lack of association between knee extension MA and patellar height in knee OA could be as attributed to structural changes caused by the IFP thickening.

Valgus knee MA in the healthy control and knee OA groups was positively associated with bisect offset, indicating an increase in valgus knee MA with lateral patellar displacement. When the patella is displaced laterally, the proximal portion of the patellar tendon also moves laterally, resulting in a larger decomposition vector in the 3D-MA in the coronal plane. Additionally, the bisect offset was significantly greater in the knee OA than in the healthy control group. The patellar tendon has a valgus knee MA, and lateral patellar displacement in knee OA may increase the length of valgus knee MA. Lateral patellar displacement is a risk factor for joint cartilage loss and pain related to patellofemoral OA (Dai et al., 2021; Macri et al., 2017). Therefore, the association between valgus knee MA and lateral patellar displacement in knee OA negatively affects the patellofemoral joint.

Both MA and MV are strong determinants of joint torque; therefore, it is reasonable that the knee extensor MA of the patellar tendon correlates with the knee extensor torque (Blazevich et al., 2009). In particular, knee extensor torque is associated with physical dysfunction in patients with knee OA (Oiestad et al., 2015; Ruhdorfer et al., 2015); therefore, evaluation of knee extension MA and quadriceps MV is important. Among the present study's findings, the relationship

between the knee extensor MA and quadriceps MV in knee OA was clinically important, implying that quadriceps muscle atrophy is associated with a decrease of knee extensor MA. Considering that quadriceps MV is a variable factor, training-induced quadriceps muscle hypertrophy increases knee extensor MA, and the synergistic effect can be expected to enhance knee extensor torque. Future studies are required to verify whether training-induced muscle hypertrophy can increase knee extensor MA.

 This study has some limitations. First, variations in knee angle during the MRI scan might have affected knee MAs. In this study, the MRI was performed in the knee extension position. Because knee MAs of the patellar tendon vary with the knee flexion angle (Buford et al., 1997), the characteristics of knee extensor and valgus MAs in the knee flexion position were unclear. Therefore, the effect of the relationship between quadriceps MV and MA on knee extensor torque and their contribution rates could not be investigated. Additionally, the knee extension angle during the MRI scan was not completely uniform between participants because the knee was extended within a comfortable range during scanning. The results of the present study may not be valid for participants with remarkable knee extension limitations. Second, this study had a cross-sectional design, thus the effects of decreased knee extension MA and quadriceps muscle atrophy on the development of knee OA were not clear. Future longitudinal studies are warranted to determine the causal relationship between knee extensor MA and

quadriceps MV, and how decreased knee extensor MA could influence knee OA development and progression.

5. Conclusions

The knee extensor MA was associated with knee size, especially in patients with knee OA, OA severity, and quadriceps MV, whereas valgus knee MA was associated with lateral patellar displacement in patients with and without knee OA. Among these findings, the association between quadriceps MV, a modifiable factor, and knee extensor MA in knee OA is clinically important.

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Data will be made available on request.

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Figure Captions

Fig. 1 Definition of the contact point at the tibiofemoral joint and the patellar tendon line for measuring the moment arm

Step 1: a) The midpoint between the distal end of the femur and the proximal end of the tibia on the center of the femoral trochlear groove in the sagittal plane was defined as the contact point (white dot) at the tibiofemoral joint.

Step 2: b) The midpoint (white dot) of the patellar tendon was determined at two locations (proximal and distal) by drawing the intersection of the anterior-posterior and medial-lateral margins (black dots) on the transverse plane.

Step 3: c) The midpoint of the patellar tendon (white dots) determined in Step 2 is displayed on the sagittal plane. After the midpoint of the patellar tendon was determined in each proximal and distal portion (Step 2), the line connecting the midpoints was defined as the patellar tendon line (yellow line).

Fig. 2 The determination of knee extensor and valgus moment arms

The 3D-MA (gray line) is drawn as a perpendicular line from the contact point of the tibiofemoral joint to the patellar tendon line. The angle (θ) on the transverse plane between the tangent to the medial-lateral posterior condyle of the femur (white line) and the 3D-MA was measured. The

sagittal plane component of 3D-MA (dotted arrow) was calculated as knee extensor MA, and the frontal plane component (solid arrow) as knee valgus MA.

Fig. 3 Measurement procedure for the bisect offset and the Insall–Salvati ratio

a) The bisect offset; the posterior condylar axis (double line) was drawn tangent to both the posterior femoral condyles at their maximum dorsal in the transverse image. A perpendicular line (solid line) against the posterior condylar axis was drawn passing through the deepest point of the trochlear groove. Then, the line (dotted line) connecting the medial (point-A) to the lateral (point-C) margins of the patella bone was drawn, and the intersection (point-B) of the patellar tendon line and a perpendicular line against the posterior condylar axis was identified. Finally, the ratio of the medial-lateral displacement of the patella relative to the perpendicular line was calculated as length of (B-C) divided by length of (A-C). A higher ratio of bisect offset indicates patella alignment is shifted laterally.

b) The Insall–Salvati ratio; the maximum lengths of the patellar tendon (dotted line) and bone (solid line) were measured in the sagittal plane and calculated as the ratio of the patellar tendon to the patellar bone. The proper range of the Insall–Salvati ratio is 0.8–1.2, and a higher ratio indicates that the patella alignment is shifted upwards.

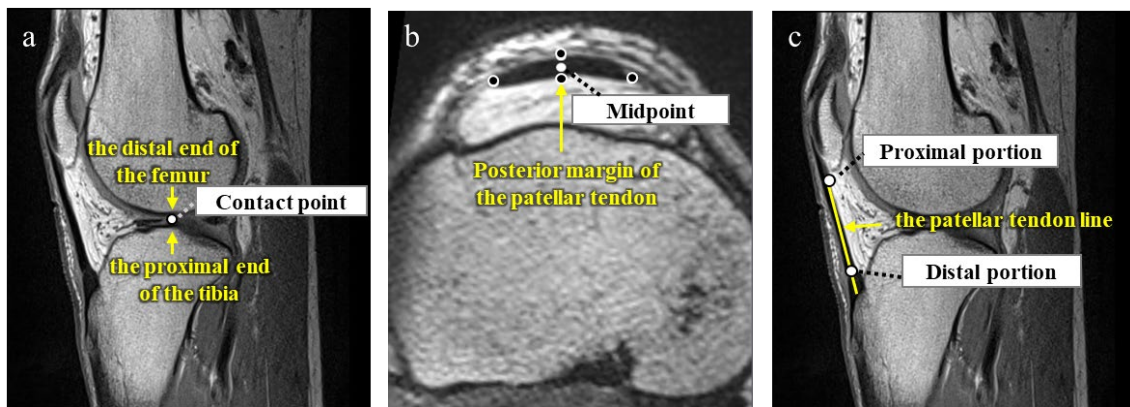


Figure 1

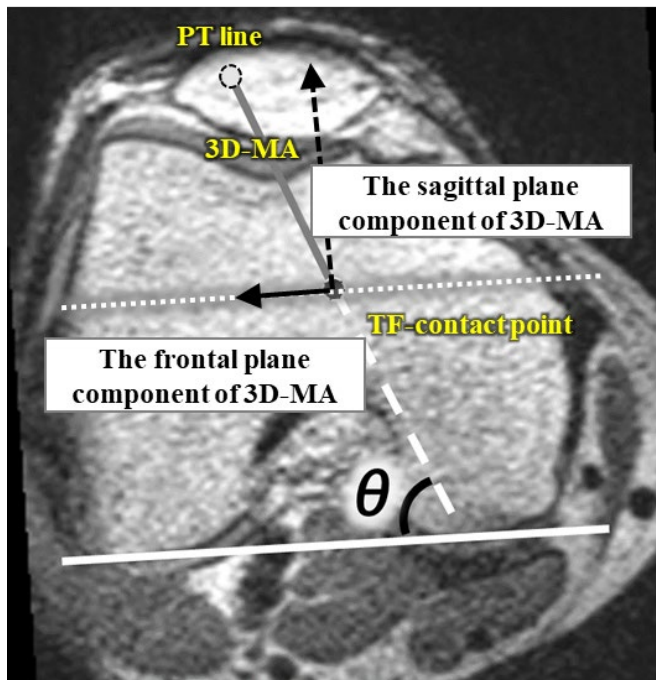


Figure 2

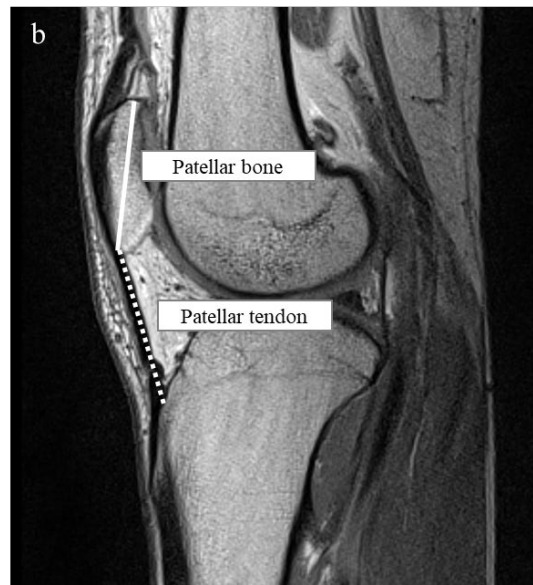
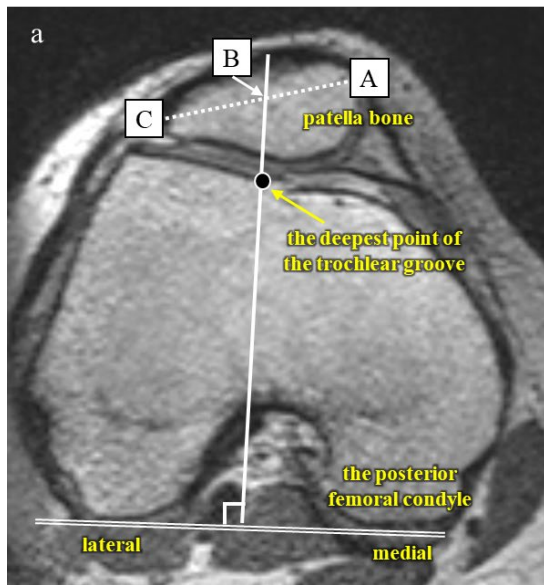


Figure 3

Table 1. Characteristics of participants in the healthy control and knee osteoarthritis groups

	Healthy control group (n=48)	Knee OA group (n=36)	<i>P</i> value
Age (y)	73.0±6.3	78.1±6.0	< 0.01
Height (cm)	160.3±9.3	154.6±7.8	0.010
Weight (kg)	54.0±8.9	53.6±8.3	0.716
Body mass index (kg/m ²)	20.9±2.3	22.4±2.6	0.023
Knee extensor MA (cm)	2.90±0.30	2.81±2.79	0.330
Knee valgus MA (cm)	0.82±0.25	0.77±0.29	0.238
Epicondylar width (cm)	7.72±0.61	7.57±0.55	0.266
Bisect offset	0.50±0.07	0.54±0.05	0.038
Insall-Salvati ratio	0.94±0.14	0.92±0.13	0.701
Quadriceps MV (cm ³)	1124.7±267.2	972.2±294.0	0.012

Values are expressed as the mean ± standard deviation.

OA, osteoarthritis; MA, moment arm; MV, muscle volume.

Table 2. Results of Spearman's correlation coefficients in the healthy control group

	Knee extensor MA	Knee valgus MA	Epicondyla r width	Bisect offset	Insall- Salvati ratio	Quadriceps MV
Knee extensor MA	—	-0.143	0.690**	-0.020	-0.300	0.516**
Knee valgus MA		—	0.030	0.357*	0.312*	0.203
Epicondyla r width			—	-0.097	0.058	0.728**
Bisect offset				—	0.197	0.055
Insall- Salvati ratio					—	0.127
Quadriceps MV						—

MA, moment arm; MV, muscle volume.

Statistical significance: * $p < 0.05$, ** $p < 0.01$

Table 3. Results of Spearman's correlation coefficients in the knee OA group

	Knee extensor MA	Knee valgus MA	Epicondyla r width	Bisect offset	Insall- Salvati ratio	Quadriceps MV
Knee extensor MA	—	0.092	0.716**	0.002	-0.189	0.586**
Knee valgus MA		—	0.324	0.362*	-0.217	0.285
Epicondyla r width			—	0.115	-0.293	0.636**
Bisect offset				—	0.097	0.035
Insall- Salvati ratio					—	-0.194
Quadriceps MV						—

MA, moment arm; MV, muscle volume.

Statistical significance: * $p < 0.05$, ** $p < 0.01$

Table 4. Coefficient of multiple linear regression analyses for knee extensor and valgus moment arm in the healthy control group

Independent variables	Unstandardized coefficient (B)	Standardized coefficient (β)	P value	95% coefficient interval for B	R ²	Adjusted R ²
Knee extensor MA					0.583	0.539
Epicondylar width	3.341	0.668	<0.001	1.626, 5.056		
Bisect offset	4.157	0.094	0.399	-5.701, 14.015		
Insall-Salvati ratio	-7.459	-0.343	0.003	-12.247, -2.672		
Quadriceps MV	0.001	0.042	0.809	-0.003, 0.004		
Knee valgus MA					0.284	0.209
Epicondylar width	-0.670	-0.728	0.471	-2.535, 1.194		
Bisect offset	11.965	0.325	0.030	1.245, 22.685		
Insall-Salvati ratio	4.826	0.268	0.068	-0.380, 10.033		
Quadriceps MV	0.002	0.263	0.248	-0.002, 0.007		

Bolded values are statistically significant (p<0.05).

MA, moment arm; MV, muscle volume.

Table 5. Coefficient of multiple linear regression analyses for knee extensor and valgus moment arm of knee osteoarthritis group

Independent variables	Unstandardized coefficient (B)	Standardized coefficient (β)	<i>P</i> value	95% coefficient interval for B	R^2	Adjusted R^2
Knee extensor MA					0.639	0.579
KL grade	1.114	0.354	0.012	0.262, 1.965		
Epicondylar width	2.369	0.470	0.004	0.801, 3.938		
Bisect offset	-3.717	-0.070	0.535	-15.802, 8.367		
Insall-Salvati ratio	-1.687	-0.078	0.507	-6.825, 3.450		
Quadriceps MV	0.005	0.497	0.006	0.001, 0.008		
Knee valgus MA					0.432	0.337
KL grade	-0.791	-0.243	0.154	-1.895, 0.313		
Epicondylar width	-1.399	-0.269	0.170	-0.635, 3.434		
Bisect offset	27.793	0.504	< 0.001	12.119, 43.467		
Insall-Salvati ratio	-1.269	-0.057	0.700	-7.932, 5.395		
Quadriceps MV	0.000	-0.033	0.876	-0.005, 0.004		

Bolded values are statistically significant ($p < 0.05$).

MA, moment arm; OA, osteoarthritis; KL, Kellgren-Lawrence; MV, muscle volume.