# Relationship of Patellofemoral Angles and Tibiofemoral Rotational Angles With Jumper's Knee in Professional Dancers

## An MRI Analysis

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**Background:** Jumper's knee is a type of tendinopathy affecting the distal insertion of the quadriceps tendon (25% of cases) or the patellar tendon. It has been shown that frontal-plane measurements, such as genu valgum, genu varum, an increased quadriceps angle, a protuberant tibial tuberosity, patella alta, and short hamstring muscles, may be related to jumper's knee.

**Purpose:** To investigate the effects of tibiofemoral rotational angles and patellofemoral (PF) angles on the development of jumper's knee in professional folk dancers.

**Study Design:** Case-control study; Level of evidence, 3.

**Methods:** We examined 26 dancers (16 male, 10 female) with knee pain using magnetic resonance imaging (MRI), for a total of 32 knees. Of the knees, 21 with quadriceps tendinopathy (QT) and 7 with patellar tendinopathy (PT) were detected. Using MRI scans, we measured PF angles (PF sulcus angle, lateral PF angle, patellar tilt angle, lateral trochlear inclination angle, lateral patellar tilt angle, and PF congruence angle) and tibiofemoral rotational angles (condylar twist angle, posterior condylar angle, femoral Insall angle, tibial Insall angle, posterior tibiofemoral angle, and angle between the Whiteside line and posterior femoral condylar line) and noted specifics such as patella alta, patella baja, and the Wiberg classification of the patellar shape between the patients with versus without QT and between patients with versus without PT to understand if there was any relationship with tendinopathy.

**Results:** No statistically significant difference was observed in age, sex, patella alta, or the Wiberg classification between the QT groups (with vs without) and between the PT groups (with vs without) ($P > .05$). Having QT was found to be significantly associated with the PF sulcus angle ($P = .009$), and having PT was found to be significantly associated with the femoral Insall angle ($P = .029$).

**Conclusion:** Jumper's knee was found to be associated with anatomic variations of the PF sulcus angle and rotation of the patellar tendon in relation to the femur (femoral Insall angle) on axial MRI scans in professional dancers. Unlike those of other athletes, dancers' knees are exposed more to external rotation forces because of turnout, and this can be the cause of jumper's knee.

**Keywords:** jumper's knee; patellofemoral angles; tibiofemoral rotation angles; dancer injury; turnout; patellar tendinopathy; quadriceps tendinopathy

Jumper's knee is a degenerative condition of the knee extensor mechanism caused by overuse.[20] While sometimes used synonymously for patellar tendinopathy (PT) alone, it is actually a tendinopathy affecting the distal insertion of the quadriceps tendon (25% of cases) or the patellar tendon.[20]

The literature has suggested that PT is associated with factors related to horizontal landing more so than take-off, which may raise the question of whether a more appropriate label for this injury might be "lander's knee" rather than "jumper's knee."[37] A typical 1.5-hour ballet class will often incorporate more than 200 jumps, with greater than 50% involving single-leg landings.[24] Likewise, folk dancers practice fast and repetitive jumps with fast squats and forced knee extensions.

The most commonly accepted theory is that PT is caused by an interplay of extrinsic and intrinsic factors.[13] Extrinsic factors are those outside of a person, including training volume, types of conditioning activities, specific sport activity, vertical jump performance, training surface, shoes, and environmental conditions.[7,32,34,37-39] Intrinsic factors are those contained within a person, including a high body

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mass index, bone structure, malalignment, abnormal patellar laxity, muscular tightness and imbalance, leg-length differences, arch height of the foot, decreased quadriceps flexibility and hamstring flexibility, quadriceps strength, and flat feet.[13,32,37] It has been shown that anthropometric properties of the knee, such as genu valgum, genu varum, a protuberant tibial tuberosity, external tibial torsion, patella alta, and an increased quadriceps angle, may be related to jumper's knee.[7,32,37,40]

There is no study in the literature on axial magnetic resonance imaging (MRI) findings of the cause of jumper's knee. In this study, we investigated the relationship of tibiofemoral rotational angles and patellofemoral (PF) angles on axial MRI scans to the development of jumper's knee in professional folk dancers. Axial angle variables may be associated with the likelihood of exposure to patellar and/or quadriceps knee tendinopathies in dancers. If alignment of the patellar and quadriceps tendons in relation to the femur and tibia differs, then tendinopathies can occur.

## METHODS

This study was approved by the ethics committee of our institution. We evaluated 32 knees (13 right, 19 left) in 26 performers (16 male, 10 female) of an 82-member folk dance group. All of the patients presented to our clinic with nontraumatic knee pain between February 2009 and February 2019. They all had MRI scans of their knees. Informed consent forms were obtained from all patients.

### Clinical Examination

All 26 dancers had constant knee pain. In patients with quadriceps tendinopathy (QT), pain was located at the proximal pole of the patella, whereas in those with PT, it was localized at the distal pole. Pain was exacerbated with jumping, sprinting, and landing in all of these dancers with jumper's knee. Their function and role-playing ability gradually declined, creating job-threatening disabilities. There were no neurological deficits.

### MRI Diagnosis

Quantitative analysis was conducted using a workstation with dedicated software (AW VolumeShare 4; GE Healthcare). The index measurements were performed by the senior orthopaedic surgeon (N.A.) and senior radiologist (I.K.), and the measurements were cross-checked by another orthopaedic surgeon (T.A.) and an independent radiologist at the same clinic. Intraobserver and interobserver measurement reliabilities were evaluated using the intraclass correlation coefficient (ICC). For measurement reliability, the researchers made 2 measurements on different days. We used the guidelines for kappa or ICC interrater agreement measures: below 0.50: poor; between 0.50 and 0.75: moderate; between 0.75 and 0.90: good; above 0.90: excellent.

The following tibiofemoral rotational angle and PF angle protocols were used to construct axes and perform measurements at the workstation. MRI scans were acquired via a dedicated nonweightbearing knee coil using a 1.5-T system (Magnetom Symphony; Siemens). Coronal, axial, and sagittal proton density–weighted images were obtained using the following imaging parameters: repetition time, 5960 milliseconds; echo time, 45 milliseconds; matrix, $252 \times 512$; field of view, $150 \times 240$ mm; and slice thickness/intersection gap, 3 mm/1 mm. On T2-weighted and proton density fat-saturated images, QT manifests as a thickening of more than 8 mm[31] and increased signal intensity in the distal portion of the tendon, as seen in our patients' scans.[29] PT typically manifests on T1-weighted images as an intermediate signal area and on T2-weighted images as a higher signal area within the tendon.[29] Most commonly, the posterior part of the tendon connecting to the lower pole of the patella is involved.[29] An alteration in patellar tendon thickness of more than 7 mm[43] was accepted as a confirmation of tendinopathy.[23]

### Outcome Measures

For all patients, we noted age and sex as well as patellar characteristics: patella alta and patella baja using the Insall-Salvati[16] method and the Wiberg classification of the patellar shape.[26] In our study, the posterior tibiofemoral angle (PTFA) refers to internal rotation of the tibia in relation to the femur, the tibial Insall angle refers to external rotation of the patellar tendon in relation to the tibia, and the femoral Insall angle refers to external rotation of the patellar tendon in relation to the femur.

*Tibiofemoral Rotational Angles.* The condylar twist angle, posterior condylar angle, femoral Insall angle, tibial Insall angle, PTFA, and angle between the Whiteside line[42] and posterior femoral condylar line (PFCL) were measured on MRI scans (Figure 1 and Table 1). The transepicondylar axis of the distal femur is a useful reference axis to determine the rotational alignment of the femoral component of

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Ethical approval for this study was obtained from Demiroglu Bilim University (approval No. 12.03.2019/2019-06-06).

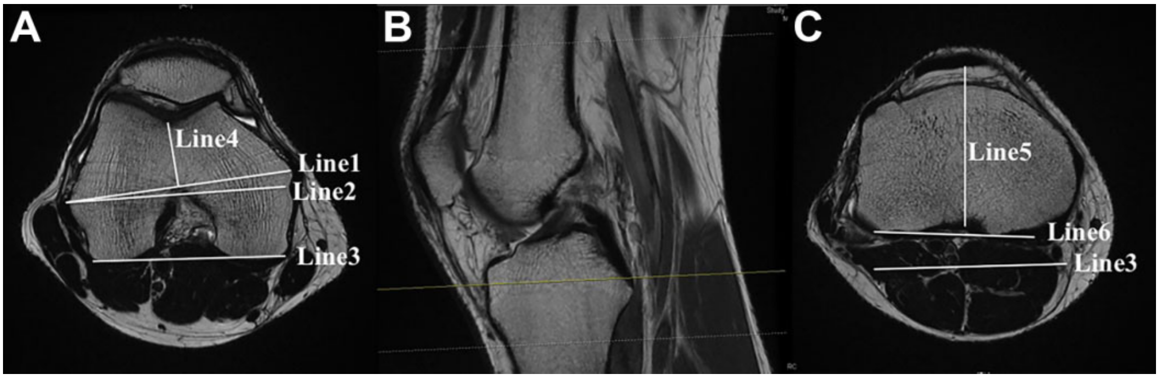


**Figure 1.** Tibiofemoral rotational angles. (A) Distal femoral rotational axes are shown on an axial magnetic resonance imaging scan. Line 1: the clinical (anatomic) epicondylar axis (lateral epicondyle to prominence of medial epicondyle). Line 2: the surgical epicondylar axis (lateral epicondyle to sulcus of medial epicondyle). Line 3: the posterior femoral condylar line (PFCL). Line 4: the Whiteside line was drawn from the apex of the intercondylar notch to the deepest point of the patellar groove. (B) The posterior cruciate ligament insertion site is marked. (C) Line 3 (PFCL) is shifted to the posterior cruciate ligament insertion site on the axial view. Line 5: the Insall axis was drawn from the junction of the medial and middle thirds of the tibial tubercle to the posterior cruciate ligament attachment of the tibia. Line 6: the posterior tibial base line.

TABLE 1
Descriptions of Tibiofemoral Rotational Angles[a]

| Angle | Description of the Lines Forming Angles on Axial MRI Scan |
|---|---|
| Condylar twist angle | Between the anatomic transepicondylar axis (line 1) and the PFCL (line 3)[4] |
| Posterior condylar angle | Between the surgical transepicondylar axis (line 2) and the PFCL (line 3) |
| Femoral Insall angle | Between the line perpendicular to the PFCL (line 3) and the Insall axis (line 5)[17,41] |
| Tibial Insall angle | Between the line perpendicular to the posterior tibial base line (line 6)[15,41] and the Insall axis (line 5) |
| Posterior tibiofemoral angle | Between the PFCL (line 3) and the posterior tibial base line (line 6) |
| Whiteside line–PFCL angle | Between the Whiteside line (line 4) and the PFCL (line 3) |

[a]MRI, magnetic resonance imaging; PFCL, posterior femoral condylar line.

the knee.[4,6] There are 2 transepicondylar axes that have been identified by Berger at al.[6] First, the clinical (anatomic) epicondylar axis (line 1) is a line connecting the prominence of the medial epicondyle, which is the attachment of the superficial fibers of the medial collateral ligament, with the lateral epicondylar prominence. Second, the surgical epicondylar axis (line 2) is a line connecting the sulcus of the medial epicondyle, which is the attachment of the deep fibers of the medial collateral ligament, with the lateral epicondylar prominence (Figure 1A). The PFCL is a tangential line to both posterior condyles of the femur (line 3). The Whiteside line (line 4) runs from the center of the intercondylar notch to the deepest point of the trochlear groove anteriorly (Figure 1A). The PFCL (line 3) was moved to the axial sections, where the posterior cruciate ligament insertion site was spotted (Figure 1B). Figure 1C shows the Insall axis[17,41] (line 5) and the posterior tibial base line (line 6).

*PF Angles.* On the patellar side, we measured the lateral PF angle, PF sulcus angle, PF congruence angle, patellar tilt angle, lateral patellar tilt angle, and lateral trochlear inclination angle (Figure 2).

### Statistical Analysis

Descriptive statistical methods (mean ± SD) as well as the *t* test were used for the independent assessment of variables with a normal distribution in a comparison of paired groups. The Mann-Whitney *U* test was used for a comparison of binary groups with a nonnormal distribution, and the chi-square test was used for a comparison of qualitative data. Statistical analysis was performed using NCSS 2007 Statistical Software (NCSS). Significance was assessed at $P < .05$.

## RESULTS

Of the 32 knees with nontraumatic knee pain, we diagnosed QT in 21 knees (65.6%) and PT in 7 knees (21.9%). There were 16 knees with only QT, 2 knees with only PT, and 5 knees with both conditions (QT and PT). Thus, over the 10-year period of this study, 23 knees of 26 dancers (88.4%) were diagnosed with jumper's knee clinically and using MRI. There were 25 knees with a normal patella, 7 knees with patella alta (no patella baja in our sample), 21 knees with a Wiberg type 1 patella, and 11 knees with a Wiberg type 2 patella. The mean follow-up of the cohort was 40.3 ± 20.3 months (range, 23-97 months).

### Measurement Reliability

The reliability evaluation indicated that the ICC of both measurements of the first investigator was between 0.829 (95% CI, 0.833-0.943) and 0.924 (95% CI, 0.865-0.953). The

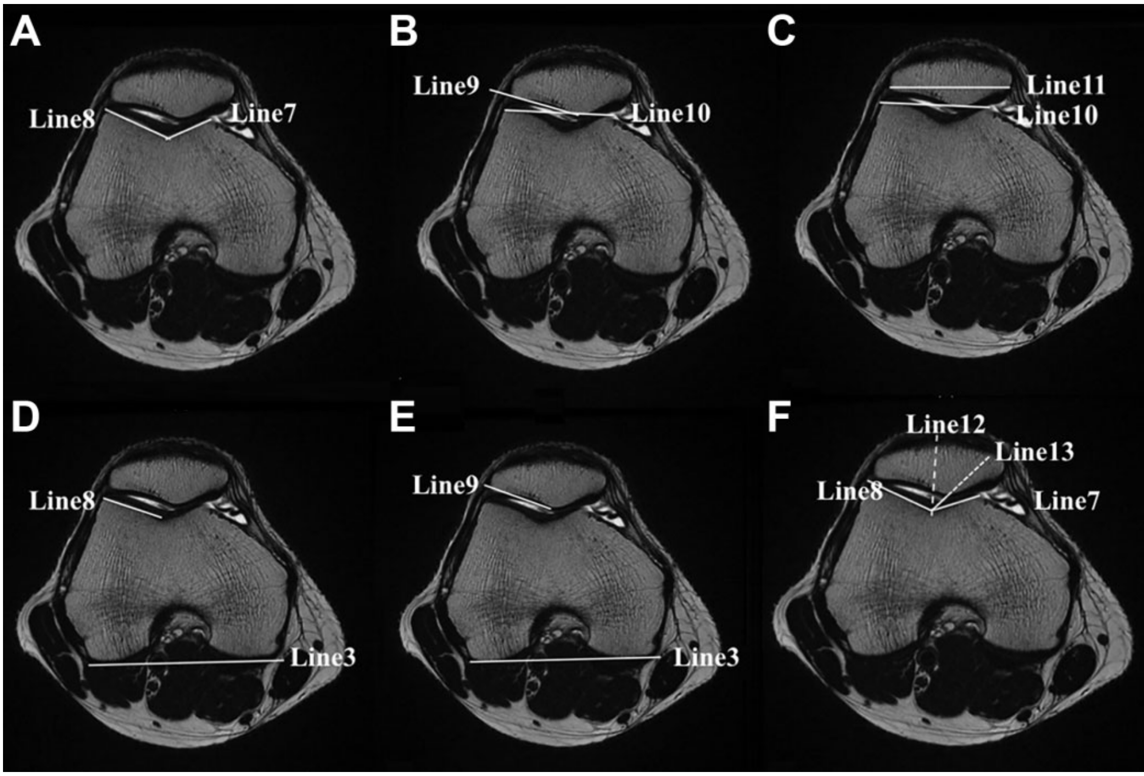


**Figure 2.** Patellofemoral (PF) angles measured on magnetic resonance imaging scans. (A) The PF sulcus angle is the angle between a line drawn between the most anterior part of the medial condyle and the deepest part of the trochlea (line 7) and a line drawn between the most anterior part of the lateral condyle and the deepest part of the trochlea (line 8).[14,27] (B) The lateral PF angle is the angle between a line drawn parallel to the lateral patellar facet (line 9) and a line drawn connecting the most anterior points of the medial and lateral condyles (line 10).[21] (C) The patellar tilt angle is the angle between a line connecting the medial and lateral corners of the patella (line 11) and a line that joins the highest points of the femoral condyles (line 10).[36] (D) The lateral trochlear inclination angle is the angle between the lateral trochlear facet (line 8) and a tangential line (line 3) through the posterior femoral condyle.[3] (E) The lateral patellar tilt angle is the angle formed by lines 9 and 3. (F) The PF congruence angle is the angle between a line bisecting the trochlear sulcus (line 12 is the bisector of lines 7 and 8) and a line (line 13) connecting the deepest part of the trochlea and the edge of the inferior tip of the patella.[1]

ICC of both measurements of the second investigator was between 0.832 (95% CI, 0.811-0.916) and 0.912 (95% CI, 0.8882-0.984). The ICC of the 2 observers was between 0.832 (95% CI, 0.811-0.916) and 0.889 (95% CI, 0.843-0.975). All measurements were between 0.75 and 0.90: good value, which indicated good agreement.

## Axial Rotational Angles

Overall, the mean internal rotation of the tibia relative to the femur (PTFA) was 5.30° ± 3.78° (range, 0.5°-13.7°). The mean external rotation of the patellar tendon with respect to the tibia (tibial Insall angle) was 10.42° ± 3.58° (range, 3.6°-17.1°), and the mean external rotation of the patellar tendon with respect to the femur (femoral Insall angle) was 6.76° ± 4.87° (range, 0.0°-16.0°).

## Quadriceps Tendinopathy

No statistically significant difference was observed between the patients with QT and those without QT in terms of age, sex, patella alta, or the Wiberg classification (Table 2). The PF sulcus angle of the patients with QT was found to be significantly higher than that of the patients without QT ($P = .009$) (Table 3).

## Patellar Tendinopathy

No statistically significant difference was observed between the patients with PT and those without PT in terms of age, sex, patella alta, and the Wiberg classification (Table 2). The femoral Insall angle of the patients with PT was found to be significantly lower than that of the patients without PT ($P = .029$) (Table 3).

All of the tendinopathies were treated nonoperatively (ice, 6 weeks of activity restriction, knee braces, and non-steroidal anti-inflammatory drugs). All of the dancers were able to continue their careers after their treatment and during the follow-up visits.

# DISCUSSION

Growing interest in injury preventive measures and the perfection of sport individualization require the

TABLE 2
Descriptive Data[a]

| | Patellar Tendinopathy | | | Quadriceps Tendinopathy | | |
|---|---|---|---|---|---|---|
| | Without (n = 25) | With (n = 7) | *P* Value | Without (n = 11) | With (n = 21) | *P* Value |
| Age, mean ± SD, y | 30.92 ± 8.22 | 27.57 ± 6.53 | .330[b] | 33.18 ± 7.91 | 28.62 ± 7.63 | .123[b] |
| Sex | | | .453[c] | | | .772[c] |
| Male | 14 (56.00) | 5 (71.43) | | 7 (63.64) | 12 (57.14) | |
| Female | 11 (44.00) | 2 (28.57) | | 4 (36.36) | 9 (42.86) | |
| Patellar characteristic | | | .583[c] | | | .205[c] |
| Normal | 19 (76.00) | 6 (85.71) | | 10 (90.91) | 15 (71.43) | |
| Alta | 6 (24.00) | 1 (14.29) | | 1 (9.09) | 6 (28.57) | |
| Patellar shape | | | .715[c] | | | .163[c] |
| Wiberg type 1 | 16 (64.00) | 5 (71.43) | | 9 (81.82) | 12 (57.14) | |
| Wiberg type 2 | 9 (36.00) | 2 (28.57) | | 2 (18.18) | 9 (42.86) | |

[a]Data are reported as n (%) unless otherwise indicated.
[b]Independent *t* test.
[c]Chi-square test.

TABLE 3
Tibiofemoral Rotational Angles and PF Angles[a]

| | Patellar Tendinopathy | | | Quadriceps Tendinopathy | | |
|---|---|---|---|---|---|---|
| | Without (n = 25) | With (n = 7) | *P* Value | Without (n = 11) | With (n = 21) | *P* Value |
| Condylar twist angle | 7.53 ± 1.99 | 8.09 ± 1.78 | .512[b] | 7.66 ± 2.26 | 7.65 ± 1.79 | .983[b] |
| Posterior condylar angle | 3.65 ± 1.66 | 4.14 ± 1.77 | .496[b] | 3.65 ± 1.92 | 3.81 ± 1.57 | .790[b] |
| Whiteside line–PFCL angle | 84.72 ± 2.16 | 84.53 ± 1.97 | .831[b] | 83.99 ± 2.69 | 85.04 ± 1.66 | .180[b] |
| Femoral Insall angle | 7.74 ± 4.78 | 3.26 ± 3.61 | **.029**[b] | 6.74 ± 4.48 | 6.77 ± 5.18 | .987[b] |
| Tibial Insall angle | 10.12 ± 3.50 | 10.59 ± 4.14 | .767[b] | 8.60 ± 3.05 | 11.07 ± 3.62 | .064[b] |
| PTFA | 5.02 ± 3.32 | 6.63 ± 5.25 | .452[c] | 4.85 ± 4.11 | 5.64 ± 3.68 | .405[c] |
| PF sulcus angle | 129.28 ± 6.03 | 127.56 ± 5.50 | .502[b] | 125.25 ± 5.18 | 130.81 ± 5.39 | **.009**[b] |
| PF congruence angle | 10.94 ± 10.15 | 14.99 ± 6.72 | .386[c] | 13.78 ± 5.44 | 10.80 ± 11.12 | .351[c] |
| Lateral PF angle | 7.98 ± 3.99 | 9.44 ± 5.30 | .431[b] | 8.82 ± 5.04 | 8.03 ± 3.90 | .626[b] |
| Patellar tilt angle | 13.24 ± 5.17 | 10.70 ± 4.09 | .242[b] | 12.40 ± 3.84 | 12.83 ± 5.61 | .821[b] |
| Lateral trochlear inclination angle | 23.15 ± 4.63 | 24.14 ± 3.72 | .606[b] | 24.26 ± 5.23 | 22.90 ± 3.98 | .414[b] |
| Lateral patellar tilt angle | 14.05 ± 4.66 | 15.13 ± 6.87 | .629[b] | 13.29 ± 5.71 | 14.80 ± 4.84 | .436[b] |

[a]Data are reported as mean ± SD in degrees. Bolded *P* values indicate statistically significant differences between groups. PF, patellofemoral; PFCL, posterior femoral condylar line; PTFA, posterior tibiofemoral angle.
[b]Independent *t* test.
[c]Mann-Whitney *U* test.

understanding of risk factors. Angles and lines and the combination of these may give an affordable insight to inherent risk factors. In this study, we identified the femoral Insall angle and PF sulcus angle to be important variations on the development of PT and QT, respectively, whereas many other parameters, such as patellar shape, tibial Insall angle, lateral PF angle, PF congruence angle, lateral trochlear inclination angle, and lateral patellar tilt angle, proved to be irrelevant to the extensor mechanism tendinopathies in our study. The above-mentioned measurements and angles are being used to delineate PF biomechanics that explain the exposure to strain and painful conditions in certain patients. This study is the first to analyze the axial-plane anatomy of the extensor mechanism to identify morphological intrinsic risk factors of jumper's knee in dancers. In addition to sagittal-plane loading, the extensor mechanism is also exposed to rotational loads in the axial plane in this population of patients. In our patients, the femoral Insall angle and PF sulcus angle were found to be the decisive factors in the development of jumpers' knee. There has only been one study analyzing the sagittal plane of the extensor mechanism to identify the morphologic intrinsic risk factors of PT.[9] Another study reported that popliteus tendinitis was not found to be related to tibiofemoral angles measured on axial MRI scans.[5]

Jumping and landing create strain about 6 to 8 times the body weight (∼8000 N) on the patellar tendon in athletes. This is much more than the 500-N force during normal walking.[12,33] Classical ballet and modern dance have been shown to be as physically demanding as many team sports (basketball, soccer, football, and volleyball) and very jump intensive.[19] Throughout the course of their daily training and practice, dancers perform more than 200 jumping and landing activities.[25] Because of the aesthetic requirements of the performance, most of these landings are performed on a single outstretched leg, resulting in large forces being transmitted through the knee.[25] Unlike basketball, soccer, and volleyball players who do not routinely receive training on landing techniques, dancers are taught, at an early age, highly specific jumping/landing techniques focused on the achievement of a particular aesthetic appearance.[24] Girls tend to start dance training at about 6 to 8 years of age, while boys begin at about 10 to 12 years of age. Perhaps the most unique aspect of dance training for jumping is the assumption of a fully extended lower extremity (knee and hip extension), including maximal plantarflexion in midair and the appearance of a smooth and effortless landing.[30] Folk dances include far faster moves with hard landing impacts than those in ballet. Dancers of this type can reach a pace of 218 steps per minute during a performance, as recorded by a step counter.[2] Rapid and frequent repetitive knee extension during jumps may cause jumper's knee in folk dancers.

It is known that there is a significant correlation between medial patellar stability and the sulcus angle, as medial stability decreases as the sulcus angle increases.[11,18] The normal sulcus angle has previously been defined as $138^\circ \pm 6^\circ$.[26,27] In our study, the PF sulcus angle was within normal limits on all MRI scans. In addition, although the PF sulcus angle was in the normal range, the patients with QT showed a significant increase of $5.56^\circ$ compared to the patients without QT ($P = .009$).

A positive correlation has been found between passive mediolateral patellar range of motion and patella alta as well as between an increased sulcus angle and patella alta.[11] In our study, no significant relationship was found between patella alta and QT and PT.

PF joint reaction force is a force acting perpendicular to the surface of the PF joint, equal and opposite to the resultant force generated by quadriceps tendon tension and patellar tendon tension.[10] The most important factor affecting the biomechanics of the PF joint is the direction and magnitude of the force produced by the quadriceps muscle. When the quadriceps muscle contracts, it presses the patella on the femur and at the same time tries to keep the patella in the trochlear groove.[10,22,26] An increased sulcus angle may require more quadriceps power for patellar control, which may increase stress in the quadriceps tendon. The quadriceps tendon has many anatomic and kinematic factors to influence this effort, and more anatomic studies are needed on the relationship between the sulcus angle and quadriceps strain.

The Insall tibial axis is a commonly used landmark in total knee arthroplasty.[17] This axis is a reliable landmark for adjusting the rotational axis of the tibial component thus ensuring femorotibial compatibility during total knee replacement surgery. Incorrect rotational placement of the tibial component is avoided by this landmark and that helps preventing patellofemoral maltracking and early loosening of the arthroplasty components.[41]

While there was no significant difference between the patients with and without PT in terms of the rotation of the tibia with respect to the femur and the rotation of the patellar tendon with respect to the tibia, the patients with PT had $4.48^\circ$ less rotation of the patellar tendon in relation to the femur (femoral Insall angle) than did the patients without PT ($P = .029$).

The patellar tendon extends along the knee joint and is not only subject to strain in the sagittal plane but also subject to knee rotation strain in the axial plane. Anatomic rotational axis changes in the axial plane may also be causing PT. Axial rotation of the PF joint and factors resisting overvalgus are necessary for optimal PF joint motion. Excessive external rotation of the knee joint places the tibial tuberosity and patellar tendon more laterally than the distal femur. This multiplies the spring effect on the patella.[35] These rotational forces can increase stress on the patellar tendon.

Knee injuries are often rotational injuries in dancers.[40] Turnout, which is one of the basic positions of ballet, is also used frequently by folk dancers.[2] The ideal turnout is $180^\circ$ in total for the 2 lower extremities. For each limb, 60% of the turnout is provided by the hips, and 40% is provided by the tibia, knee, foot, and ankle.[8] Dancers who cannot create enough rotation at the hip level try to compensate for this by forcing their knees, feet, and ankles.[8,28] Meniscal, ligament, and PF joint injuries can occur easily in the knee joints forced to rotate in dancers.[8] Unlike athletes' knees, dancers' knees are exposed to external rotation so much that this can be the cause of jumper's knee.

A small sample size is the main limitation of this study. However, even with a limited sample size, the statistical results were acceptable and informative in this specialized group of patients. To avoid type I errors, the appropriate test was selected by looking at the distribution of the variables, and the reliability and homogeneity of the tests were also checked. Power analysis could not be conducted, as this is the first study on this subject, and this study was conducted on a special group followed and treated by a single orthopaedic specialist at a single center for a decade. The accuracy and reliability of measurements were checked using the ICC, and all measurements were greater than the desired 0.700 value.

## CONCLUSION

The results of this study indicate that the PF sulcus angle and rotation of the patellar tendon in relation to the femur (femoral Insall angle) on axial MRI scans were important anatomic variations in the development of jumper's knee in professional dancers. The role of tibiofemoral rotational alignment needs to be investigated further with a larger sample size.

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