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The Association Between Patellofemoral Pain Syndrome and Lower Extremity Biomechanics

Patellofemoral Ağrı Sendromu ile Alt Ekstremite Biyomekaniği Arasındaki İlişki

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ABSTRACT Objective: Patellofemoral pain syndrome (PFPS) is a pathology of the knee joint that is particularly common among physically active younger individuals. It is associated with adverse consequences both on the quality of life and daily functional activity. In this study, we aimed to assess the association between PFPS and alterations in Q angle, A angle, sulcus angle, and the foot pronation, which may affect the alignment of the lower extremity. **Material and Methods:** A total of 130 patients diagnosed with unilateral PFPS and 100 healthy subjects without anterior knee pain have been enrolled. Foot pronation measured using foot posture index 6, Q angle, A angle, sulcus angle, pain severity, as well as functional status were evaluated in all participants. **Results:** There was no statistically significant difference between the groups in terms of age, gender and body mass index (BMI) (p<0.05). Patients with PFPS had statistically significantly higher Foot Posture Index 6 (FPI-6) scores, Q angle, A angle, and sulcus angle as compared controls (p<0.05). **Conclusion:** Elevated Q angle, A angle, sulcus angle, and over-pronation of the foot may lead to PFPS. PFPS is a multifactorial condition that requires a detailed evaluation with respect to malalignment of the lower extremity as well as the correction of the underlying pathology.

Keywords: Patellofemoral pain syndrome; Q angle; A angle; foot pronation

ÖZET Amaç: Patellofemoral ağrı sendromu (PFAS); özellikle genç, fiziksel olarak aktif bireylerde sık görülen bir diz problemidir. Hastaların hem yaşam kalitesini hem de günlük yaşamlarındaki fonksiyonel aktivitelerini olumsuz etkilemektedir. Bu çalışmada, alt ekstremite dizilimini etkileyebilen Q açısı, A açısı, sulkus açısı ve ayak pronasyonundaki değişikliklerin PFAS ile ilişkisini araştırmayı amaçladık. **Gereç ve Yöntemler:** Çalışmaya unilateral PFAS tanısı konan 130 hasta ile ön diz ağrısı tariflemeyen 100 sağlıklı kişi alındı. Tüm bireyler, Foot Posture Indeks 6 kullanılarak ölçülen ayak pronasyonu, Q açısı, A açısı, sulkus açısı, ağrı şiddetleri ve fonksiyonel seviyeleri açısından değerlendirildi. **Bulgular:** Çalışmaya alınan gruplar arasında yaş, cinsiyet ve beden kitle indeksi (BKİ) açısından istatistiksel anlamlı farklılık yoktu (p<0,05). PFAS'lı hastalar ile asemptomatik bireyler karşılaştırıldığında Foot Posture Index 6 (FPI-6) skorları, Q açısı, A açısı ve sulkus açısı değerleri PFAS'lı hastalarda kontrol grubundan istatistiksel olarak anlamlı derecede daha yüksekti (p<0,05). **Sonuç:** Artmış Q açısı, artmış A açısı, artmış sulkus açısı ve ayak pronasyonunda artma PFAS'ye yol açabilir. Multifaktöriyel bir hastalık olan PFAS'de alt ekstremite dizilim bozukluğu ayrıntılı olarak incelenmeli ve tedavide patolojik neden düzeltilmeye çalışılmalıdır.

Anahtar Kelimeler: Patellofemoral ağrı sendromu; Q açısı; A açısı; ayak pronasyonu

Patellofemoral pain syndrome (PFPS) is a disorder that commonly affects physically active younger individuals.[1,2] It is responsible for 10% of all musculoskeletal complaints, and 20 to 40% of all knee problems.[3-5] Although a variety of terms have been proposed to describe the patellofemoral pain including the patellofemoral syndrome, patellofemoral arthralgia, extensor mechanism dysplasia, retropatellar pain syndrome, lateral patellar compression syndrome, patellofemoral dysfunction, anterior knee pain, and patellofemoral joint syndrome, none of these terms have gained widespread acceptance.[6-8] Pain associated with PFPS is described as a pain of blunt, insidious, and gradually worsening character. Pain is aggravated with bending the knees, squatting down, or climbing up the stairs.[2,4,9] Etiopathogenesis of PFPS remains unelucidated, despite a number of different factors that have been implicated.[10] A variety of different problems associated with increased pressure on the patellofemoral joint through malalignment of the lower extremity have been linked with PFPS. Despite this etiological heterogeneity, conservative therapy is widely acknowledged as the most appropriate therapeutic strategy with exercise and physiotherapy as a major part of the management.[11,12]

In this study, our aim was to assess the association between PFPS and alterations in the Q angle, A angle, sulcus angle, and foot pronation, which have an impact on the alignment of the lower extremity.

MATERIAL AND METHODS

A total of 130 patients with complaints of knee pain and subsequently diagnosed as having unilateral PFPS and 100 healthy individuals without anterior knee pain were included in the study. A positive result in at least one of the following four tests was considered to be diagnostic for PFPS: 1) Pain elicited by compression of patella toward the femur or in the mediolateral direction (patellar compression test); 2) Pain by compression of patella toward femur during isometric knee extension (Clark's test); 3) Tenderness on the posteromedial or posterolateral surfaces of patella; 4) Pain elicited with single leg mini-squat or step down exercise. Inclusion criteria were age between 18 and 45 years, minimum symptom duration of 3 months, unilateral pain, absence of knee range of motion, presence of anterior or retropatellar pain in at least three of the six predefined activities (climbing down or up the steps, squatting, running, jumping, prolonged sitting with knees flexed 90°), gradual onset of symptoms with no associated traumatic injury, a minimum pain score of 3 on visual analogue scale (VAS) score, and pain in the patellar facet when stepping down a 25-cm step or double leg squatting. Patients with previous history of knee surgery, meniscal or ligamentous pathology, effusion, Osgood Schlatter syndrome or Sinding Larsen Johansson syndrome, projecting pain in the knee, history of trauma or fracture, and patellofemoral osteoarthritis were excluded. After adequate information on the nature and purpose of the study was provided to the participants, written consent forms were obtained. The study protocol was approved by the Ethics Committee of the Ankara Research and Training hospital (approval date and no: 04 Nov 2015, 2015-5165). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Age, height, weight, body mass index (kg/m^2), duration of pain, and dominant and involved extremity were recorded in all patients. The dominant extremity was defined as the limb that was preferentially used when stepping up.

Patients were asked to score the severity of pain on a 0 to 10 cm VAS (0: no pain, 10: intractable pain) scale.

Subjective function assessments were based on Kujala patellofemoral scoring system, which consists of a 0 to 100 point scale for a total of 13 items including limping, loading, walking, climbing up and down the stairs, squatting, running, prolonged sitting with knees flexed, pain, swelling, abnormal and painful patellar movements, groin atrophy, and flexion restriction.[13] The best score is 100 points. The validity and reliability studies of the Turkish version were carried out in 2010, where adequate internal-consistency and high reproducibility were confirmed, demonstrating the utility of this scale for functional assessment of Turkish patients with PFPS.[14]

Foot Posture Index Version 6 (FPI-6) was used for assessing increased foot pronation. FPI-6 is a simple clinical assessment tool with good validity and reliability that assess the foot posture in all three planes without a requirement for special equipment. The following six areas are assessed using FPI-6 with the patient standing comfortably on both feet: head of talus palpation, supra and infra-lateral malleolar curvature, calcaneal angle, talonavicular prominence, medial longitudinal arch and antero-posterior foot alignment. For each assessment a score between -2 (significant supination) and + 2 (significant pronation) is given, with 0 point showing the normal position. Thus a total score between -12 (significant supination) and + 12 (significant pronation) is obtained and recorded.[15,16]

Q angle was measured while the patient was in supine position, with the knees extended and leg being in neutral position, without voluntary contractions of the quadriceps.[1,17] The midpoint of the patella and the tuberositas tibia were marked with a pen. The patient was asked to hold the thread fixed at anterior superior iliac spine, and the other end of the thread was fixed in the midpoint of patella. The angle between the line formed by the thread and the line drawn from patellar midpoint to tuberositas tibia was measured using a standard goniometer.

The A angle assesses the relationship between the tibial tubercle and patella. It is used for the evaluation of patellar glide, tilt and rotation, and is measured by a standard goniometer as the angle between a line dividing patella into two and the line drawn from tuberositas tibia to the apex of the inferior patellar pole (Figure 1).[18]

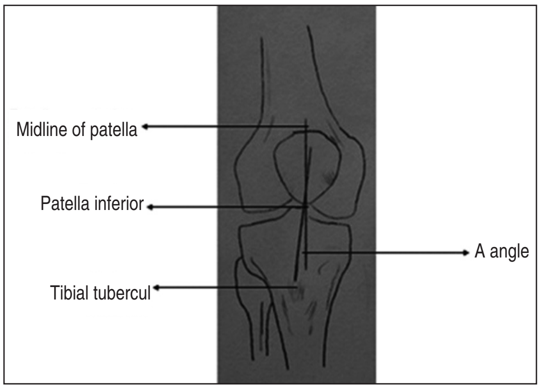

FIGURE 1: A angle.

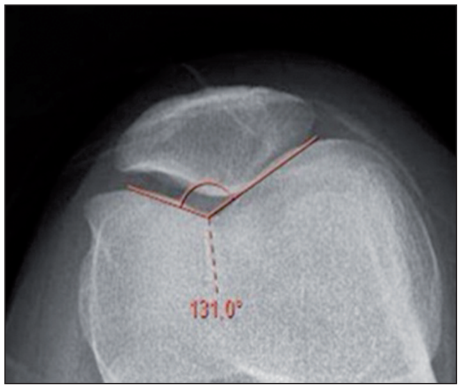

FIGURE 2: Sulcus angle.

In all patients, antero-posterior knee radiographs (knees flexed at 30 degrees), lateral knee radiographs, and tangential radiographs (Merchant view) in supine position with the knees flexed at 45 degrees and the beams directed vertically at 30 degrees from the caudal direction were obtained.[19] Merchant views were used to assess the sulcus angle (Figure 2).

STATISTICAL ANALYSIS

Study data were entered into SPSS (Statistical Package for Social Sciences) for Windows 22.0 (SPSS Inc, Chicago, IL) for data analysis. The descriptive statistics were presented with median (minimum-maximum), frequency, and percentage. Categorical variables were analyzed using Pearson's Chi-Square Test and Fisher's Exact Test. The normal distribution of the variables was tested using visual (histograms and probability graphs) and analytic (Kolmogorov Smirnov/Shapiro-Wilk Tests) methods, and not all continuous variables were found to conform to normal distribution. The statistical significance of the difference between two independent groups was analyzed with Mann Whitney U Test. The association between variables was evaluated using Spearman's Test. The level of statistical significance was set as $p<0.05$.

RESULTS

Of the 230 participants, 130 (56.5%) had PFPS, while the remaining 100 subjects (43.5%) were otherwise healthy. These two groups were referred to as "patients" and "controls", respectively. Except for the dominant extremity, two groups were comparable with respect to descriptive statistics (Table 1).

The median duration of pain among patients was 6 months (min 3, max 6 months), with the me-

TABLE 1: The distribution of descriptive characteristics in study groups.

	Patients (n=130)	Controls (n=100)	p
Age (year)	33 (18-45)	30.5 (18-44)	0.744*
Gender			
Male	41 (31.5)	26 (26.0)	0.359**
Female	89 (68.5)	74 (74.0)	
Height (cm)	165 (150-181)	165 (155-182)	0.989*
Body weight (kg)	70 (48-110)	70 (48-95)	0.862*
BMI (kg/m^2)	25,71 (19.03-35.92)	25,74 (18.29-39.54)	0.424*
Dominant side			
Right	118 (90.8)	72 (72.0)	<0.001**
Left	12 (9.2)	28 (28.0)	

Continuous variables are presented as median (min, max), and categorical variables are presented as numbers (percentage).
*Mann-Whitney U Test; **Chi-square test.

dian VAS score being 70 (min 40, max 90), and median Kujala score being 56 (min 30, max 80) (Table 2).

Subjects in the patient group had significantly higher median FPI6 score, Q angle, A angle, and sulcus angle values (Table 3).

Female patients had significantly higher median Q angle and A angle values as compared to male patients (Table 4).

Both male and female patients had significantly higher median FPI6 scores and median Q angle, A angle, and sulcus angle values as compared to their sex-matched counterparts ($p<0.05$) (Table 5).

CONCLUSION

Patellofemoral pain syndrome is a common and challenging knee pathology that may have adverse effects on both the quality of life and daily living activities.[20] Despite the lack of clear understanding on etiology of PFPS, several factors have been implicated.[10] Again, studies examining a wide range of factors that may be associated with biomechanical alterations of the lower extremity have failed to accurately identify the relative contributions of these factors to the development of PFPS. Among these, increased articular pressure and malalignment of the lower extremity seem to represent the two most plausible etiological mechanisms. In our study, we aimed to examine the association between PFPS and a number of factors that may have an impact on the alignment of the lower extremity including the Q angle, A angle, sulcus angle and foot pronation.

Although a variety of scoring systems have been developed to assess pain, physical capability, functional status, and quality of life in patients with knee disorders, those that directly address PFPS are scarce in number. Currently, Kujala patellofemoral scoring system is one of the most widely utilized tools for assessing the physical capability in patients with PFPS.[13,21] In a 2010 study by Kuru et al. examining the validity of the Turkish version of the Kujala patellofemoral scoring system, the mean Kujala score was 76.8 and 75.2 in the first and second assessments, respectively.[14] In a study by Yelvar et al. patients with PFPS were assigned to two groups, and the mean Kujala scores in the first and second groups were 48 and 49.3, respectively.[22] In our study, the median Kujala score in subjects with PFAS was 56.

TABLE 2: The median duration pain, VAS scores and Kujala scores in patients.

(n=130)	Median (min, max)
Duration of pain (month)	6 (3-40)
VAS	70 (40-90)
Kujala	56 (30-80)

TABLE 3: Median FPI-6 scores, Q angles, A angles and sulcus angles in study groups.

	Patient (n=130) Median (min, max)	Control (n=100) Median (min, max)	p*
FPI6	4 (-4;11)	1 (-3;7)	**<0.001**
Q angle	22 (12;30)	17,5 (12;23)	**<0.001**
A angle	18 (10;27)	11 (8;15)	**<0.001**
Sulcus angle	148 (134;158)	135 (126;151)	**<0.001**

*Mann-Whitney U test.

TABLE 4: Gender distribution of median FPI-6 scores, Q angles, A angles, and sulcus angles in patients.

	Male (n=41) Median (min, max)	Female (n=89) Median (min, max)	p*
FPI6	4 (-2;11)	4 (-4;11)	0.068
Q angle	19 (12;29)	23 (17;30)	**<0.001**
A angle	15 (10;27)	18 (10;26)	**0.029**
Sulcus angle	149 (134;158)	147 (137;156)	0.538

*Mann-Whitney U test.

TABLE 5: Gender distribution of median FPI-6 scores, median Q angles, median A angles, and median sulcus angles in patient and control groups.

		Patient	Control	
		Median (min, max)	Median (min, max)	p*
Male	FPI6	4 (-2;11)	2 (-3;6)	<0.001
	Q angle	19 (12;29)	15 (12;18)	<0.001
	A angle	15 (10;27)	11 (8;15)	<0.001
	Sulcus angle	149 (134;158)	136 (126;151)	<0.001
Female	FPI6	4 (-4;11)	1 (-2;7)	<0.001
	Q angle	23 (17;30)	18 (12;23)	<0.001
	A angle	18 (10;26)	11 (8;15)	<0.001
	Sulcus angle	147 (137;156)	135 (126;150)	<0.001

*Mann-Whitney U Test.

Q angle is the angle between a line connecting the ASIS (anterior superior iliac spine) and midpoint of patella and a line connecting this point and tuberositas tibia. In clinical practice, it is frequently used to assess the malalignment of the lower extremity as well as the patellar instability. A Q angle greater than 20 degrees is indicative of lateral shift of patella, leading to increased stress on the patellofemoral joint.[23] Q angle is 3 to 6 degrees higher in women than in men. According to Fulkerson, a Q angle of greater than 15 and 20 degrees in men and women, respectively, were suggestive of potential abnormality.[17,24] Literature data on the causative role of increased Q angle in the development of PFPS has been controversial. In a study by Kaya et al. examining the association between Q angle and malalignment of the lower extremity in patients with PFPS, a static measurement of the Q angle was performed, and a potential association between PFPS and elevated Q angle has been observed.[25] Similarly, Haim reported an association between a Q angle of greater than 20 degrees and PFPS.[23] Silva et al. comparing 29 female patients with 25 healthy sex-matched individuals failed to detect significant differences between the two groups with respect to static Q angle values.[26] Again, Park et al. did not observe an elevated static Q angle in subjects with PFPS.[27] In a study by Türkmen et al. involving 14 subjects with PFPS and 14 healthy individuals, Q angle was measured separately during supine, sitting, and standing positions. No significant Q angle differences between patients and controls were detected in any of these comparisons.[28] A major explanation for the marked controversy between study results is the difference in methodologies utilized for measurements. Q angle measurements are yet to be standardized. Also, no consensus exists as to whether Q angle should be measured in supine or standing positions, or regarding the position of the knee during the measurement. Generally, Q angle is measured when the patient is in supine position, with full extension of the knee and without contractions in the quadriceps muscles.[29] However, since this measurement is performed under static conditions, it does not consider the forces pulling the patella laterally when the patient is standing, potentially leading to faulty interpretation of the results.[30] Another proposed methodology involves the measurement of the Q angle when the patient is standing and the knee is at extension.[31] This method has been claimed to provide more accurate Q angle predictions, as it allows measurement during functional extensor mechanisms.[32] We also measured the Q angle statically in our patients in the supine position, and found significantly higher Q angle values in patients with PFPS than controls. With regard to gender differences, both male and female patients with PFPS had significantly higher Q angle values than in their counterparts. Although the results of our study suggests a potential role for increased Q angle in the etiology of PFPS, further studies with larger patient and control populations examining static and dynamic Q angle measurements are warranted to better elucidate the role of Q angle in the etiology of PFPS.

The A angle is a reflection of the association between patella and tibial tubercle. It is the angle between a line dividing patella into two halves and a line drawn from tuberositas tibia to the apex of the inferior pole of patella. Arno found the A angle of greater than 35 degrees in patients with PFPS.[33] On the other hand, DiVeta et al. found the average A angle of 23.2 and 12.3 degrees in patients with PFPS and control subjects, respectively, in their study examining the patellar alignment, proposing that increased A angle may lead to development of PFPS.[34] Similarly, we found a significant difference in A angles measured in our patients with PFPS, i.e. 17.21 degrees, versus healthy controls, i.e. 11.4 degrees.

Patellar lateralization and rotation may lead to an increased A angle. Although the role of A angle measurements in the detection of patellar malalignment has been subject to research, its clinical utility has been limited due to the absence of a consensus regarding the measurement technique as well as the challenges in defining the lines forming the angle.

The sulcus angle is the angle between the highest point of the medial condyle, the deepest depression of the trochlear sulcus, and the highest point of the lateral femoral condyle. In axial radiographs obtained with the knees flexed at 30 to 45 degrees, the measured sulcus angle is approximately 140 degrees.[35] Laprade and Culham found no significant differences between patients with PFPS and healthy volunteers with respect to sulcus angle measurements.[36] Similarly, Haim et al. found no significant differences in sulcus angles between 61 military personnel with PFPS and 25 healthy individuals.[23] In our study, the calculated sulcus angles in patients with PFPS and in controls were 147.49 and 136.26 degrees, respectively, with a significantly higher sulcus angle value in PFPS than in controls in both sexes. However, within each of patient and control groups, there were no significant differences in sulcus angle measurements between male and female participants. An increased sulcus angle is an indication of the lateral subluxation of the patella in the trochlear sulcus, hence patellar instability. Also, an elevated Q angle has been frequently associated with patellar instability and lateral subluxation of the patella. In the current study, a positive but weak correlation was found between Q and sulcus angles, which may account for the high Q angle in our patient group. Also, we believe that increased sulcus angle may cause patellar hypermobility, which has recently been frequently implicated in the etiology of PFPS.

It is generally recommended that patients with PFPS be assessed with regard to the posture of the feet. Increased pronation of the foot is a known cause of PFPS and may mechanically prevent external rotation of tibia by causing internal rotation of the tibia during the stepping phase.[37] A number of different methods have been described for assessing foot pronation, although their reliability is questionable. On the other hand, Foot Posture Index-6 (FPI-6) is a simple method requiring no equipment that can assess foot posture in three planes of the foot. It has been reported to be a reliable tool to assess foot posture in individuals with or without PFPS. Barton et al. reported higher occurrence of foot pronation in patients with PFPS than healthy individuals.[16] Chuter showed that FPI has high predictive value in demonstrating the dynamic foot functions.[38] In our study, the mean FPI score in subjects with PFPS and in control subjects was 3.80 and 1.68, respectively, with a significant difference between the two groups. Therefore, we showed that increased foot pronation, as documented by static measurements during standing, may lead to a predisposition for PFPS by causing increased foot pronation during dynamic foot functions. There was a weak positive correlation between FPI score and Q angle in patients with PFPS. Since increased foot pronation prevents external tibial rotation, it is expected that Q Angle does not stretch; and the relationship between them can be explained by static measurement of Q Angle. Accurate prediction of the dynamic foot posture is of clinical significance when choosing foot orthosis for the treatment of PFPS, and in this regard, FPI-6 seems to offer a practical guidance.

CONCLUSION

In conclusion, this study examined factors that may have a biomechanical impact on the lower extremity and that may lead to malalignment of the lower extremity in patients with PFPS. Based on our results, we believe that Q angle, sulcus angle, and foot pronation should be evaluated in patients with PFPS, and attempt to identify the factors responsible for patellofemoral malalignment should be made through a comprehensive physical examination for this multifactorial condition.

Declaration of conflicting interests

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