Geometric analysis of medio-lateral position of patella: A new measuring tool

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Abstract

Background: Evaluation of medio-lateral position of patella is necessary for diagnosis and treatment of patellofemoral diseases.

Objective: In the present study, we aimed to evaluate medio-lateral patellar position differences and to define a new practical measuring tool which enables us to analyze relationships of the points at the knee.

Materials and Methods: Total of 120 healthy volunteers (60 men and 60 women) were included in our study and both of their knees were measured. In the research, the gender groups and right-left differences were evaluated. In the measurements, a four-lever measuring tool designed for this study was used. The four anatomic points of the knee which are center of patella, *epicondylus lateralis*, *epicondylus medialis* and middle point of *tuberositas tibiae* were used.

Results: While patella is 76% lateral in the right knee, it is 90% lateral in the left knee in men. As for woman, while it is 50% lateral in the right-knee, it is 30% lateral in the left-knee. In medio-lateral patellar position, while bilateral asymmetry is 28% in men, it is 50% in women. In measurements of knees of women and men, significant differences were detected both in the right and left knees ($P < 0.05$ and $P < 0.001$).

Conclusion: The patellofemoral order differences between men and women can explain anatomic reasons of patellofemoral diseases, which are encountered more in women than men.

Key words: Anatomy, patella, patellofemoral order, tuberositas tibiae

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Introduction

Medio-lateral patellar position is deemed as a sign of patellofemoral pain syndrome and patellar instability. Evaluation of medio-lateral position is crucial for successful application of patellofemoral therapeutic taping techniques.[1]

The aim of our study is to determine medio-lateral location differences of patella in healthy individuals of Turkish population. Furthermore, this study introduces a new practical measuring tool which shall control the factors affecting patellar position during the measurement and which enables us to analyze the relationship of four anatomic points of the knee (center of patella, *epicondylus lateralis*, *epicondylus medialis* and middle point of *tuberositas tibiae*) with each other.

Patellofemoral pain syndrome is a general knee disease seen in people and teenagers under physical activity. Patellofemoral order is defined in all cases with patellofemoral pain syndrome. However, patellofemoral disorder is not sufficient alone for initiation of patellofemoral pain.[2]

The patients may show various patellar order samples.[3] Patellar disorder is associated with function impairment of *m.quadriceps femoris* of patellar painful knee. Different components of *m.quadriceps femoris* affect the patella

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differently. Especially, dynamic muscle imbalance between *m.vastus medialis* and *m. vastus lateralis* is discussed frequently.[4] These muscles mainly use transverse power on patella.[5]

Definitive diagnosis of function impairment seen in clinical practices is important. This is especially necessary to evaluate position of the patella for application of patellar taping. This is a general application for treatment of patellofemoral pain. Anatomic findings are necessary to determine direction of patellar taping.[6] While determining patellar disorder, Quadriceps angle (Q-angle) or medio-lateral location measurements of patella can be used.

Q-angle is a measurement of patellofemoral joint mechanism used in musculoskeletal medicine. When Q-angle exceeds 15-20 degrees, patellofemoral pain and extensor mechanism of the knee contribute to function impairment.[7] The abnormal low values are associated with various pathologies.[8] The diversity in Q-angle is also associated with the soft tissue as well as lower extremity bone order. With the pulling of tendon, the moving structure of the patella changes. The patella should be located at center for measurement of Q-angle. There is a relationship between patellofemoral pain syndrome and lateral position of the patella. If patella moves 1 mm laterally from the center, the Q-angle decreases for 1.1 degree. If patella is located 5 mm laterally, the Q-angle decreases for 5.5 degrees.[9]

Medio-lateral location of patella is measured in two ways. The first method was defined originally by McConnell[6] and researched by many authors for evaluation of patella position. Reliability of the evaluated method was found to be poor by some researchers.[10,11] However, Herrington[12] and Herrington and Nester[13] found application of the method of McConnell by the clinicians safe. In this method, the index fingers are put on *epicondylus lateralis* and *epicondylus medialis*. The thumbs are put on the center of patella. Medio-lateral position of patella is found by visual calculation of the distance between index fingers and thumbs.[6] The second method marks the band between *epicondylus lateralis* and *epicondylus medialis* and middle point of patella. The medial and lateral distance between the marked points is measured with a tape measure.[12]

Concerning these two different methods, which evaluate medio-lateral patellar position, it is seen that the method of Herrington[12] is better than the method of McConnell[6] in terms of inter-tester reliability and validity. However, when these two methods, which evaluate medio-lateral position are compared, both of the methods can be used to determine the most suitable method for evaluation of the patients with different patellofemoral diseases. In the studies, poor definitions of medio-lateral patellar position tests are seen. The studies may not show the factors such as lower extremity rotation, *m. Quadriceps femoris* contraction, or flexion of the knee. These variables may affect patellar position.[1]

In this study, we designed a new measuring tool to measure the position of patella. We aim to control the factors which affect patellar position with the measuring tool we used in this method. The relationship between the four anatomic points of the knee which are center of patella, *epicondylus medialis*, *epicondylus lateralis* and middle point of *tuberositas tibiae* can be determined simultaneously. With this method, the position of patella can be measured practically and faster.

Materials and Methods

Subjects

Our study included 120 volunteers (60 men and 60 women) aged between 18 and 26, and both their right and left knees were measured. Volunteers included in the study were without any knee disability. Mean body weight and height of men were 74 kg and 181 cm, respectively. And, mean body weight and height of women were 61.5 kg and 163 cm, respectively. All of the volunteers were selected from those with no knee injuries or disorders. The report of ethics committee was obtained for the research. The people who would participate in the study filled the forms voluntarily and they were included in the study.

Procedures

In the present study, four anatomic points were determined for measurement at knee: 1) center of patella (P); intersection point of the longest vertical and transverse axis by determining circumference of patella; 2) *Tuberositas tibiae* (T); intersection point of vertical and transverse middle axis of *tuberositas tibiae*; 3) *Epicondylus lateralis* (L); peak point of *epicondylus lateralis* determined by manual examination; 4) *Epicondylus medialis* (M); peak point of *epicondylus medialis* determined by manual examination. When the volunteers included in the study were at supine position and their feet were of neutral rotation, the measuring tool was placed into its tray. It was attended that *m. quadriceps femoris* was not in contraction and the knee was at 20 degree flexion. At this position, the four anatomic points were determined by an 18-year experienced physiotherapist. The measuring tool designed for this study was placed upon the knee. The four moving and adjustable levers of the tool were brought to the four anatomic points. After the relationship between anatomic points was determined, the levers were fixed [Figure 1]. The measuring tool was separated and then the knee was taken out of the tray. The determined anatomic points were transferred to the paper placed under the tool. A straight t-square was used to transfer the points to the paper. Therefore, the relationship of the four points that was determined on the knee with each other is shown on the paper [Figures 2-3]. This operation was applied separately for right and left knees of every volunteer. The distances between the points transferred to the paper were measured and recorded. The test was repeated randomly in 10 volunteers for reliability test.

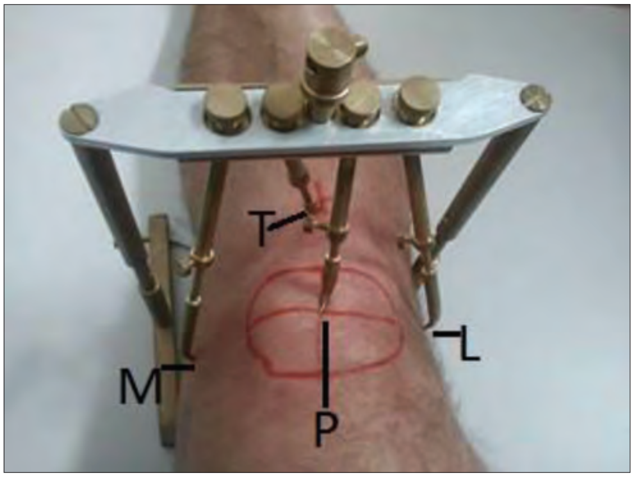

Figure 1: Measurement of the knee's anatomic points: P: Centre of patella; T: Middle point of *tuberositas tibiae*; L: Middle point of *epicondylus lateralis*; M: Peak point of *epicondylus medialis*

Figure 2: Measuring tool for anatomic points of knee. Relationship of the knee's anatomic points on paper. P: Centre of patella; T: Middle point of *tuberositas tibiae*; L: Middle point of *epicondylus lateralis*; M: Peak point of *epicondylus* medialis; A: The point where the line combining peak points of *epicondylus medialis* and *epicondylus lateralis* intercepts with centre of patella in 90 degrees; B: The point where the line combining peak points of *epicondylus medialis* and *epicondylus lateralis* intercepts with middle point of *tuberositas tibiae* in 90 degrees

Description of measuring tool

The measuring tool designed for our study is placed on a tray (floor) of 175 × 160 mm. There are two feet in height of 175 mm on the floor. Height of these feet can be increased up to 220 mm in four steps. The feet can be fixed at each step. The part with four levers is mounted on the feet. This part is separable whenever desired. It can be fixed to the piece combining the feet at the top. Each of the lever on the tool moves widely around itself. Furthermore, height of each lever can be extended. When measurement is made, the moving parts of the levers can be fixed with a screw system. The end point of each lever is twisted and sharpened for easy contact with the determined point. The last part of the lever can rotate around itself. If necessary, the upper side of the tool can be separated and the knee can be placed upon the tray. Anatomic points are determined by combining the tool. The levers are brought to these points and then fixed. After the knee is taken out of the tool, projection of anatomic points is reflected on the paper placed to the tray.

Statistical analysis

In statistical analysis of the collected data, SPSS (Version 14) program was used. Total of 60 female and 60 men were included to parametric statistical measurement. Female and male gender groups and right-left side differences were analyzed of each measurement. Among the repeated measurements, Cronbach's Alpha reliability analysis was made. Medio-lateral position of patella was calculated for women and men in percentage.

Results

The distances between anatomic points determined on the knee were analyzed statistically in male and female gender groups separately for the right and left knee Tables 1-2.

When the line between M and L is taken as reference, center of patella is located 76% laterally (46/60), 21% medially (13/60) and 1% middle (1/60) in the right knee of men. It is located 90% laterally (54/60), 8% medially (5/60) and 1% middle (1/60) in the left knee of men. In men, medio-lateral position of patella shows bilateral asymmetry at the rate of 28% (17/60). In men, while point A is more lateral than point B at the rate of 21% (13/60) in left knee, this rate is 10% (6/60) in the right knee. When the line between M and L is taken as reference, center of patella is located 50% laterally (30/60), 46% medially (28/60) and 3% middle (2/60) in the right knee of women. It is located 30% laterally (18/60), 68% medially (41/60) and 1% middle (1/60) in the left knee of women. In women, medio-lateral position of patella shows bilateral asymmetry at the rate of 50% (30/60). In women, point A is 1% lateral than point B only in left knee. The reliability coefficient was 0.86 in Cronbach's Alpha reliability test we performed for 10 randomly repeated measurements. Reliability of our study is good according to this result.

Discussion

Intra-tester reliability of the tests for medio-lateral patellar position is good. However, inter-tester reliability is variable. Validity criteria of these tests are moderate according to the worst rate. However, the results are evaluated and mentioned as limited to the knowledge today. The most important two diagnoses are poor documentation of tests and methods for medio-lateral patellar position and limited definition of subject characteristic.[1]

In our study, we used a method other than the two methods used in medio-lateral position studies of patella.[6,12] In this method, we used a measuring tool with four levers designed for this study. Therefore, we were able to evaluate the data obtained from four different points of knee at the same time. This tool enables us to evaluate the relationship of four different anatomic points with each other without changing position of the knee. Furthermore, it also makes it possible to make studies more practically and in a shorter time on many individuals.

There are studies stating that there are no significant differences between supine position and vertical position measurements in Q-angle measurements.[14] This fact can also be valid for medio-lateral patellar position tests. We performed our study in supine position in order to control *m. quadriceps femoris*. While the knee is not at flexion, patella is located slightly laterally. When the knee is at flexion of 20 degrees, patella is more central.[15] In order to keep the patella at center and to prevent contraction of *m. quadriceps femoris*, we made the measurements when the knee was at the position of 20 degree flexion. Flexion degree of the knee is an important factor. Some researchers evaluated 20 degree flexion of the knee compared to full extension.[12,13,16]

Q-angle values for medial and neutral position of patella are within the range of reported values. When the patella is at lateral position, Q-angle values decrease below the reported ones normally. Specially in women, these values are close to the reported values pathologically.[13] As lateral position of patella increases, it contributes to patellofemoral pain and function impairment in the knee's extensor mechanism.[7] Medio-lateral position of patella affects Q-angle.

Q-angle is significantly higher in women than men and it shows bilateral symmetry.[7] In our study, while it is 40% lateral in women (50% in the right and 30% in the left), this rate is 83% in men (76% in the right and 90% in the left) according to LM line of patella. While patella is 57% medial (48% in the right and 68% in the left) in women, it is 14% medial (21% in the right and 8% in the left) in men. We see that patella is located more laterally in men than women. Furthermore, the distance between A and B is longer in women (men - right: 13.35 and left: 8.73; women - right: 20.93 and left: 14.36). This data shows us that the distance between the center of patella and middle line of *tuberositas tibiae* is longer at transverse axis in women than men. In our study, it is seen that patella is more medial in women than men and the transverse distance between the patella and *tuberositas tibiae* is longer. Therefore, Q-angle is higher in women.

Patella shows 61% bilateral symmetry at medio-lateral position. While this rate is 72% in men, it is 50% in women. In our study, medio-lateral position and bilateral symmetry of patella shows more diversity in women than men. The role of *m. vastus medialis* is important for medial stabilization of patella.[17] It is considered that higher patellofemoral joint connection forces and an increase in lateral force lead to an increase in Q-angle.[18]

It has been reported that patellofemoral pain syndrome, some running injuries such as tibial stress fractures are higher twice in female runners than the male runners.[19] The increase in Q-angle plays a role in the increase of frequency of patellofemoral disorders in women.[20] Patella is located more medially in women and it plays a role in increase of Q-angle. Patella is more bilaterally asymmetric in women than men and it is located in different positions; and this situation plays a role in higher incidence of patellofemoral disorders in women.

While significant differences at the right and left knee in terms of TB, LA, MA, AB and PT values are seen in men, the significant differences are only seen in terms of MA, AB and PT values in women. The distance to PT may give us information about the height of *ligamentum patellae*. *Ligamentum patellae* are 8.1 mm longer (5.7 mm in the right and 10.5 mm in the left) in men than women. Although *ligamentum patellae* are longer in men, it makes us think that *m. quadriceps femoris* keeps patella more stably.

In measurement of LM both in right and left knees in terms of PA, TB, LA, MA, AB and PT values for knee measurements of women and men, significant differences are only seen in right knee. In LB and MB measurements, there is no significant difference between women and men. The significant difference of measurements between anatomic points evaluated in the

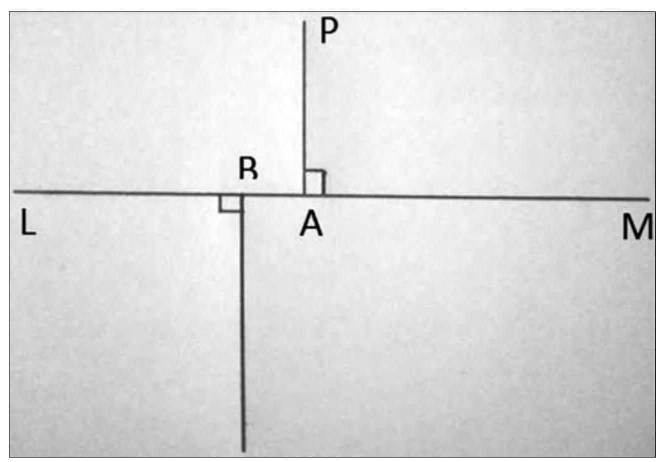

Figure 3: Relationship of the knee's anatomic points on paper. P: Centre of patella; T: Middle point of *tuberositas tibiae*; L: Middle point of *epicondylus lateralis*; M: Peak point of *epicondylus medialis*; A: The point where the line combining peak points of *epicondylus medialis* and *epicondylus lateralis* intercepts with centre of patella in 90 degrees; B: The point where the line combining peak points of *epicondylus medialis* and *epicondylus lateralis* intercepts with middle point of *tuberositas tibiae* in 90 degrees. Measuring tool for anatomic points of knee

Table 1: Statistical analysis of the knee's anatomic points

Parameter	Gender	Side	*N*	Mean	SD	SEM
PA*	M	R	60	13.58	7.13	0.92
	F	R	60	18.93	9.27	1.19
	M	L	60	13.46	7.42	0.95
	F	L	60	16.91	8.38	1.08
TB**	M	R*	60	61.56	8.98	1.15
	F	R	60	48.30	7.51	0.97
	M	L*	60	64.08	8.51	1.09
	F	L	60	48.81	9.30	1.20
LA**	M	R*	60	48.20	9.09	1.17
	F	R	60	56.63	10.70	1.38
	M	L*	60	43.33	9.43	1.21
	F	L	60	53.45	9.81	1.26
MA**	M	R*	60	60.81	8.76	1.13
	F	R	60	48.71	10.54	1.36
	M	L*	60	64.25	11.16	1.44
	F	L	60	53.06	9.93	1.28
LB	M	R	60	36.66	8.69	1.12
	F	R	60	36.60	9.80	1.26
	M	L	60	38.50	8.69	1.12
	F	L	60	39.16	9.15	1.18
MB	M	R	60	71.91	8.39	1.08
	F	R	60	68.63	11.85	1.53
	M	L	60	69.83	10.29	1.32
	F	L	60	67.26	9.68	1.24
AB**	M	R*	60	13.35	10.68	1.37
	F	R**	60	20.93	9.86	1.27
	M	L*	60	8.73	6.03	0.77
	F	L**	60	14.36	8.63	1.11
PT**	M	R*	60	76.48	7.41	0.95
	F	R*	60	70.75	8.62	1.11
	M	L*	60	78.38	7.06	0.91
	F	L*	60	67.86	8.49	1.09
LM*	M	R	60	109.01	6.71	0.86
	F	R	60	105.60	9.02	1.16
	M	L	60	108.51	7.62	0.98
	F	L	60	106.45	8.44	1.08

P=Center of patella; T=Middle point of *tuberositas tibiae*; L=Middle point of *epicondylus lateralis*; M=Peak point of *epicondylus medialis*; A=The point where the line combining point M and L intercepts with center of patella in 90 degrees; B=The point where the line combining point M and L intercepts with middle point of *tuberositas tibiae* in 90 degrees; r=Right; l=Left; SD=Standard deviation; SEM=Standard error mean, Parameter=*$P<0.05$ **$P<0.001$, the difference between women and men, Side:* $P<0.05$ **$P<0.001$, the difference between right and left side, PA=The distance between P and A, LA=The distance between L and A, TB=The distance between T and B, LB=The distance between L and B, MB=The distance between M and B, AB=The distance between A and B, PT=The distance between P and T, LM=The distance between L and M

knee between women and men gives light to anatomic reasons of frequency of knee injuries seen in women.

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Table 2: Medio-lateral positions of patella and *tuberositas tibiae* in women and men

Parameter	Gender	Side	*N*	Minimum	Maximum	Mean	SD
LB	M	R	60	6.00	60.00	36.66	8.69
		L	60	26.00	76.00	38.50	8.69
	F	R	60	21.00	63.00	36.60	9.80
		L	60	15.00	70.00	39.16	9.15
MB	M	R	60	51.00	93.00	71.91	8.39
		L	60	36.00	88.00	69.83	10.29
	F	R	60	38.00	97.00	68.63	11.85
		L	60	39.00	89.00	67.26	9.68
LA	M	R	60	25.00	70.00	48.20	9.09
		L	60	16.00	67.00	43.33	9.43
	F	R	60	31.00	81.00	56.63	10.70
		L	60	28.00	76.00	53.45	9.81
MA	M	R	60	43.00	82.00	60.81	8.76
		L	60	24.00	88.00	64.25	11.16
	F	R	60	29.00	69.00	48.71	10.54
		L	60	34.00	75.00	53.06	9.93

SD=Standard deviation, LB=The distance between L and B, MB=The distance between M and B, LA=The distance between L and A, MA=The distance between M and A

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