Print ISSN: 2321-6379
Online ISSN: 2321-595X
DOI: 10.17354/ijss/2017/555

Original Article

Magnetic Resonance Imaging Study of Age and Sex Variation in the Anatomy of Patellofemoral Articulation

Reshma Muhamed[1], Vasudha V Saralaya[2]

[1]Assistant Professor, Department of Anatomy, Kannur Medical College, Anjarakandy, Kannur, Kerala, India, [2]Professor, Department of Anatomy, Kasturba Medical College, Mangalore, Karnataka, India

Abstract

Background: The knee joint is one of the strongest and most complex joints in the human body. The knee is a tricompartmental joint. It is formed by union of the patellofemoral joint (PFJ) and the medial and lateral tibiofemoral joints. PFJ is a complex structure comprising the extensor mechanism of the knee and the femoral trochlea. Females are more prone to recurring dislocations of the PFJ. They are afflicted by isolated PF twice as frequently as males. The anatomical background for this prevalence needs to be studied.

Aim of Study: The aim of the study was to study the age and gender variations in various morphometric parameters of the PFJ to the highest possible accuracy using magnetic resonance imaging (MRI) in South Indian Population aged 20–70 years; to provide a baseline data of PFJ morphometric parameters in South India.

Materials and Methods: The parameters studied in the study were knee joint MRI obtained from the records of Department of Radiology with the following settings: (1) All studies were performed with a Signa 1.5 T MRI System (GE, Milwaukee, WI, USA). (2) At the time of imaging, every patient was made to lay supine with the knee joint straightened and neutrally rotated. (3) T2-weighted sagittal and axial images of knee joint were studied. (4) The slice thickness for all the sequences was 4 mm. The PF anatomy and congruence were assessed using a total of 22 parameters.

Observations and Results: Out of the 140 knee MRI records, 70 (50%) were males, and 70 (50%) were females. Among the 70 males MRI records, 31 (44.3%) were of the right knee and 39 (55.7%) of the left knee. Of the 70 female Knee MRI, 39 (55.7%) were of the right and 31 (44.3%) of the left knee. The mean value reveals statistically significant difference ($P \leq 0.05$, Student's unpaired *t*-test) across gender for 18 out of the 22 parameters denoting sex variation in the PFJ among the South Indian population.

Conclusions: From our present MRI study in 70 males and 70 females representing the South Indian population, it was concluded that 18 out of the 22 morphometric parameters of the PFJ depicted significant gender variation ($P \leq 0.05$, Student's unpaired *t*-test). 16 parameters were found to be statistically highly significant with a *P* value below 0.001.

Key words: Arthrosis, Knee joint, Magnetic resonance imaging scan, Morphometry, Patellofemoral joint

INTRODUCTION

The anatomic morphology and the congruence of the patella and femoral trochlea are the biomechanical basis for knee flexion and extension.[1] Although patellofemoral joint (PFJ) disorders are difficult to characterize and define, clinical data reveal three main categories of PFJ disorders - PF pain, PF instability, and isolated PF arthritis.[2] Patients with PF pain, more commonly known as anterior knee pain, feel discomfort when involved in activities such as kneeling, squatting, sitting for extended periods with a bent knee, or going up and down the stairs.[2,3] The reason behind such a PF pain, which is common among athletes as well as in sedentary individuals, is less understood.[2] The term, "Chondromalacia patellae," or

Access this article online

www.ijss-sn.com

Month of Submission : 10-2017
Month of Peer Review : 11-2017
Month of Acceptance : 11-2017
Month of Publishing : 12-2017

Corresponding Author: Reshma Muhamed, Department of Anatomy, Kannur Medical College Anjarakandy, Kannur, Kerala, India.
E-mail: nazeem86@gmail.com

softening of the cartilage, was used to indicate this pain. Recent studies have, however, attributed PF morphology and static or dynamic malalignment as an important cause of this anterior knee pain.[4] PFJ reveals numerous naturally occurring variations in the morphometry of the patella, femoral trochlea and the congruence between them. In addition to its cartilaginous layer, these alterations are thought to involve the osseous constraints of the patella and the femoral trochlea.[1] Developmental or acquired variations in the anatomy and congruence of the PFJ may cause disproportionate distribution of PFJ stress which predispose patients to develop PF pain.[5,6] The most important factors predisposing to patellar instability include trochlear dysplasia and patella Alta (high position of the patella). Characterization and quantification of these anatomic anomalies will reveal the individual mechanism of patellar instability and help the orthopedic surgeon choose the optimal treatment. PF dislocations are traumatic derangement to patellar tracking. The literature suggests that certain dysplastic features that are risk factors for patellar instability occur more commonly in females.[2] Although a gender disparity among 1st time PF dislocations is debatable, females are more prone to recurring dislocations of the PFJ.[7] This suggests a need to investigate the factors which favor recurrent dislocations in females. Understanding the PFJ morphology is the key. Osteoarthritis (OA) contributes to a major public health problem. By the year 2020, OA is expected to represent the fourth leading cause of disability.[8] OA is well known to afflict the knee joint.[9] Recent reports have emphasized the importance of PF-OA as a new entity.[10-12] Disproportionate mechanical forces produced by anterior malalignment of the knee joint, also known as PF malalignment may induce excessive stress on the articular surfaces of the PFJ predisposing to osteoarthritic changes.[13] Chronic joint injuries, weight, increasing age or overuse of the joint can also lead to PF arthritis. Studies have observed females to be afflicted by isolated PF twice as frequently as males.[10] Therefore, there is a need to look for any age and gender-related changes in the anatomy and alignment of PFJ. This can help in suggesting exercises or changes in posture of the knee that can alter the alignment of PFJ and thus decrease anterior knee pain. Very few studies have concentrated on these anatomic variations among the Indian population. This study is an attempt on our behalf to highlight the variations in anatomy and congruence of PFJ. Plain radiographic and computed tomographic studies allow descriptions or measurements of the bony PFJ. Many of such previous radiographic studies have not contemplated the articular cartilage surfaces. Unlike conventional radiographs, transverse magnetic resonance images (MRI) allow complete and clear visualization of the entire PFJ by clearly delineating the proximal portion of the femoral trochlea. MRI is recognized as a standard procedure and has replaced diagnostic arthroscopy as the primary diagnostic modality. Moreover, MRI can be used to assess anatomic variants that may contribute to chronic patellar instability and other forms of PFJ disorders.[14-18] We, therefore, tried to analyze the anatomy and congruence of the PFJ using MRI. PF pain secondary to arthrosis can be managed with a variety of operative and non-operative modalities. Patellofemoral arthroplasty (PFA) is one of the latest treatment options targeting the pain caused by severe, isolated OA of the PFJ. At present, PFA remains a contentious treatment for advanced PF-OA due to its variable outcomes. Total knee replacement rather than PFA is preferred by many surgeons for isolated advanced PF-OA, to gain more consistent outcomes.[19] One of the correctable issues is to formulate appropriate design and dimension of the prosthesis best suited for the South Indian population in particular. Gender and age variability in the dimensions of distal femur and patella may have implications for implant design and functional outcome after PFA. Hence, this study also hopes to address the unmet clinical need for PF implants that more accurately addresses the morphometric differences between male and female femur, patella and the congruence between them.

Aim and Objectives

Our study is undertaken with the following aim and objectives.

Aim of the study

The aim of the study was to study the age and gender variations in various morphometric parameters of the PFJ to the highest possible accuracy using MRI in South Indian population aged 20–70 years during the period from October 2013 to October 2015 and to provide a baseline data of PFJ morphometric parameters in South India.

Objectives

1. To study the various structures forming the knee joint using MRI scans of knee joint taken from adult live subjects.
2. To assess the PF anatomy and congruence using the patellar parameters, femoral trochlear parameters and PF congruence parameters.
3. To describe the age and gender variations between PF anatomy and congruence in adults.
4. To compare the results of this study with that of other similar published works available in literature.

Study Period

The study period was from October 2013 to October 2015.

Institute of Study

This study was conducted at Kasturba Medical College, Mangalore, Karnataka, India.

MATERIALS AND METHODS

The materials required for the present study consists of: 140 MRI scan records of the knee joint of subjects, confirming to the inclusion and exclusion criteria, collected from the Department of Radiology, Kannur Medical College, Anjarakandy, Kannur, after obtaining the Institute Ethics Committee clearance.

Study Design

The study design was a retrospective study.

Study Sample Size

A total of 140 knee joint MRI records of patients (70 males and 70 females).

Study Sample Size Calculation

By the purposive sampling method, with 95% confidence level and 90% power, the sample size of 140 subjects was calculated by the formula given below:

$$\text{Sample size}\,(n) = \frac{2\times\left(Z_{\alpha} + Z_{\beta}\right)^{2}\times\sigma^{2}}{\delta^{2}} = 70$$

(approximate value)

Z_{α} = Level of significance (95%) = 1.96

Z_{β} = Required power (90%) = 1.282

σ = Anticipated standard deviation of the parameter=1.95

δ = Test value of the difference between means =1.06

Total trial size = 2× n = 2×70 (approximate) = 140

Inclusion Criteria

Randomly selected knee joint MRI records of patients of known sex and age from 20 to 70 years, who had taken it for various reasons in the Radiology Department were included in the study.

Exclusion Criteria

Patients with a history of congenital abnormality, severe trauma, surgery, acute patellar dislocation, knee joint tumor, and rheumatic arthritis were excluded from the study.

Materials Used

The parameters studied in the study were knee joint MRI obtained from the records of Department of Radiology with the following settings: (1) All studies were performed with a Signa 1.5 T MRI System (GE, Milwaukee, WI, USA). (2) At the time of imaging, every patient was made to lay supine with the knee joint straightened and neutrally rotated. (3) T2-weighted sagittal and axial images of knee joint were studied. (4) The slice thickness for all the sequences was 4 mm. The PF anatomy and congruence were assessed using a total of 22 parameters. When the chondral surface was involved during the measurement of any parameter, the contour of the chondral surface was measured as a reference instead of the subchondral bone.[20]

To assess patellar anatomic morphology, the following parameters were studied on the patellar mid transverse layer of the axial MRIs, where the patellar maximal transverse diameter was visible.[20]

1. Patella angle (PA): Angle between the medial and lateral facets of patella with the point of the patellar central ridge as the zenith [Figures 1 and 2].
2. Patella width (PW): Distance between most medial and most lateral points of the patella [Figures 1 and 2].
3. Patella thickness (PT): Distance between the points of the patellar central ridge to the patellar anterior point [Figures 1 and 2].
4. Patella lateral facet width (PLFW): Distance between the most lateral point of the patella and the patella central point [Figures 1 and 2].
5. Patella facet thickness (PFT): Distance between patellar central point and the point of patellar central ridge [Figures 1 and 3].
6. Patella lateral facet ratio (PLFR=PLFW/PW): Patella lateral facet width:patella width.
7. Patella relative thickness (PRT=PT/PW): Patella thickness:patella width.
8. Patella facet thickness ratio (PFTR=PFT/PT): Patella facet thickness:patella thickness.

To assess femoral trochlear anatomic morphology, the following parameters were studied, measured on the initial layer of the axial MRIs.

1. Sulcus angle (SA): Angle between the medial and lateral facets of the femoral trochlea with the deepest trochlear point as the zenith [Figures 4 and 5].
2. Sulcus width (SW): Distance between the most medial and most lateral points of the femoral trochlea [Figures 4 and 5].
3. Sulcus depth (SD): Distance between the deepest trochlear point to line SW (the sulcus central point is defined as the point of intersection of the perpendicular line and line SW) [Figures 4 and 6].
4. Sulcus lateral facet width (SLFW): Distance between the most lateral point of the trochlea and the sulcus central point [Figures 4 and 6].
5. Trochlea epicondylar axis angle (TEAA): Angle between the line SW and the line of the femoral epicondylar axis [Figures 4 and 7].
6. Sulcus lateral facet ratio (SLFR=SLFW/SW): Sulcus lateral facet width:sulcus width.

7. Sulcus relative depth (SRD=SD/SW): Sulcus depth:sulcus width.

To assess PF congruence, the following parameters were measured on the initial layer of the axial MRIs, where the femoral epicondylar axis was clearly visible from the proximal to the distal portions of the PFJ.

1. Lateral patella displacement (LPD): Distance between the 2 perpendicular lines drawn to line SW from the most medial point of patella (line a) and from the most medial point of femoral trochlea (line b) [Figures 8 and 9].
2. Lateral trochlear inclination (LTI): Angle between lateral trochlear facet and the line connecting the posterior-most surface of femoral condyle [Figures 9 and 10].
3. Patella epicondylar axis angle (PEAA): Angle between the line connecting the most lateral and medial points of the patella and the line of femoral epicondylar axis [Figures 9-11].
4. Width congruence (WC): PW:SW
5. Depth congruence (DC): SD: PFT
6. Congruence angle (CA): Angle between the line connecting the point of patellar central ridge and the sulcus central point (line a) and the line bisecting the SA (line b), [Figures 11-13].
   One parameter of PF congruence was measured on the sagittal images where the patellar maximal length is visible.
7. Insall-Salvati index (ISI): Ratio of patella tendon length to the patella length (PTL/PL) [Figure 14].

Statistical Analysis

The general descriptive statistics were done for all the measurements providing means and standard deviations (SD) separately for both male and female. Student's unpaired *t*-test was used to check whether significant

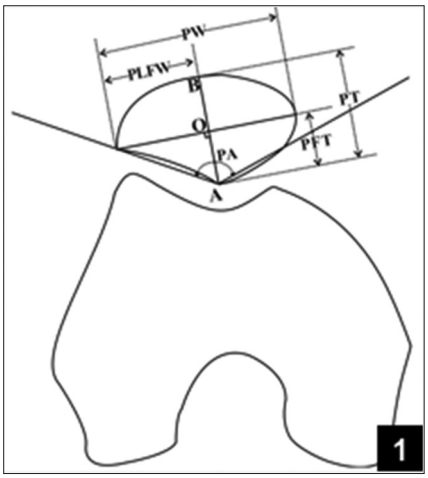

Figure 1: Parameters used to assess patellar anatomy on axial magnetic resonance images

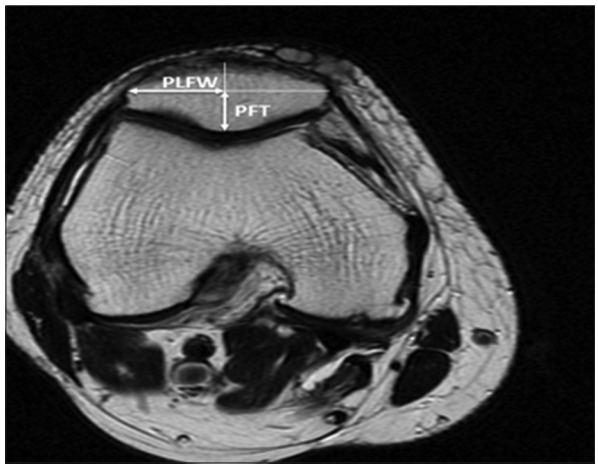

Figure 3: Magnetic resonance imaging right knee - T2 Axial section illustrating landmarks for measuring patella lateral facet width (PLFW) and patella facet thickness (PFT)

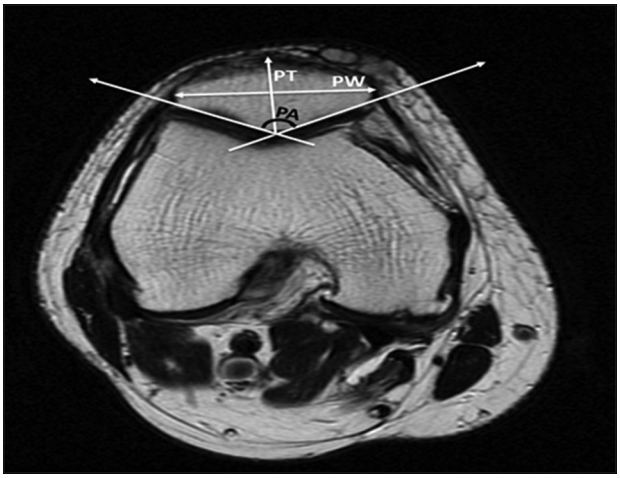

Figure 2: Magnetic resonance imaging right knee - T2 axial section illustrating landmarks for measuring patella angle (PA), patella width (PW) and patella thickness (PT)

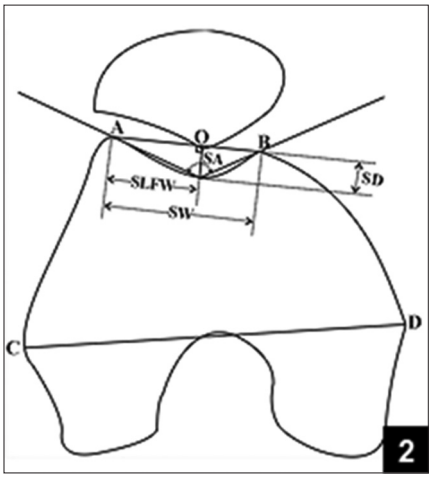

Figure 4: Diagram of parameters used to assess the femoral trochlear anatomy on the axial magnetic resonance images

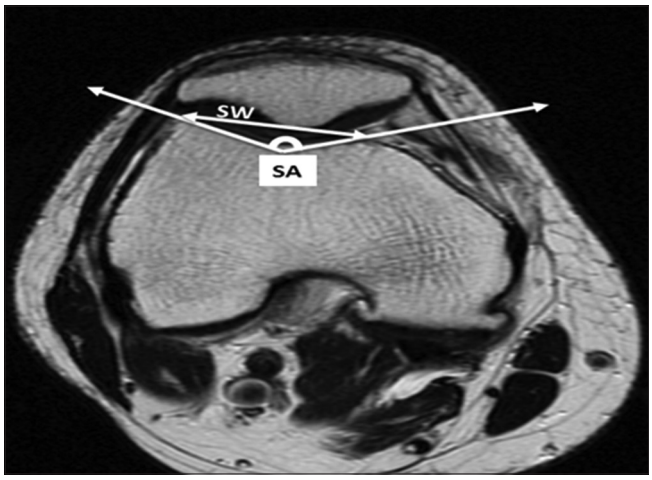

Figure 5: Magnetic resonance imaging right knee - T2 axial section illustrating landmarks for measuring sulcus angle (SA) and sulcus width (SW)

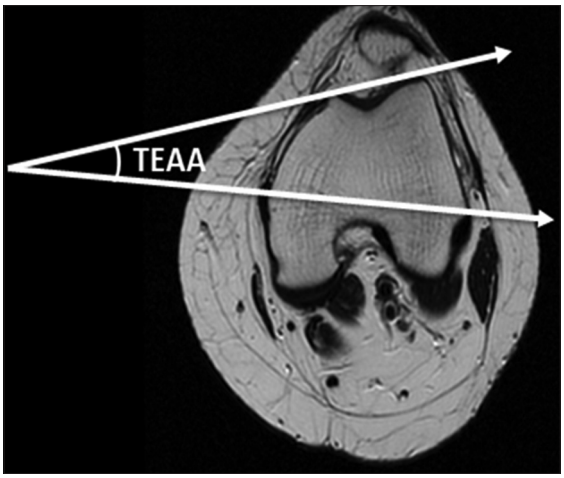

Figure 7: Magnetic resonance imaging left knee - T2 axial section illustrating landmarks for measuring TEAA

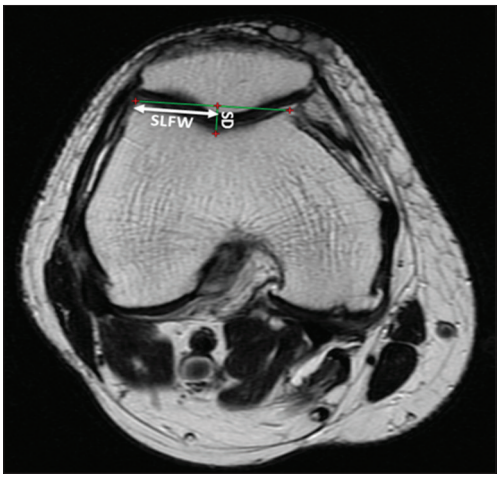

Figure 6: Magnetic resonance imaging right knee - T2 axial section illustrating landmarks for measuring sulcus depth (SD) and sulcus lateral facet width (SLFW)

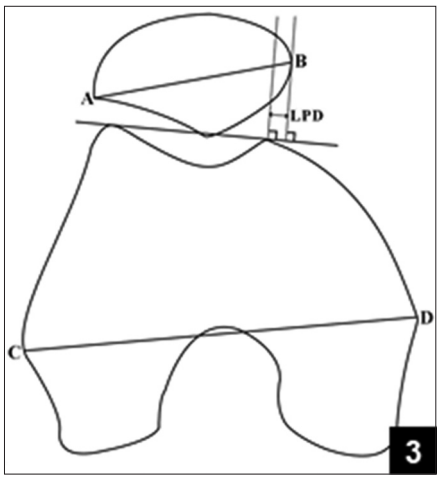

Figure 8: Diagram of parameter to assess patellofemoral congruence

differences exist ($P \leq 0.05$) between each male and female, mean measurements. ANOVA test was used to check significant differences ($P \leq 0.05$) between the mean measurements of the 4 age groups.

OBSERVATIONS

140 knee MRI records of patients collected from the Department of Radiology Kasturba Medical College, Mangalore, Karnataka, conforming to the inclusion and exclusion criteria from October 2013 to October 2015 were included in this retrospective study.

Gender Variation

Out of the 140 knee MRI records, 70 (50%) were males and 70 (50%) were females. Among the 70 males MRI records, 31 (44.3%) were of the right knee and 39 (55.7%) of the left knee. Of the 70 female Knee MRI, 39 (55.7%) were of right and 31 (44.3%) of the left knee. The mean value reveals statistically significant difference ($P \leq 0.05$, Student's unpaired t-test) across gender for 18 out of the 22 parameters denoting sex variation in the PFJ among the South Indian population as shown in Tables 1-3. Among the patellar parameters, the PA, PW, PT, PLFW, PFT, PRT, and PFT ratio exhibited statistically highly significant sexual dimorphism ($P \leq 0.001$). The only patellar parameter which was not significant statically was the PLFR. The mean value was higher in males than females except for PLFR (PLFW/PW) and PFT ratio (PFT/PT) as shown in Table 1. The comparison of SD suggests that males exhibit more variability than females in all measurements of patella except PT, PFT, PRT (PT/PW), and PFT ratio (PFT/PT) as shown in Table 1.

Analysis of trochlear parameters reveals a higher mean value in males than females except for trochlear epicondylar

Table 1: Means, standard deviations and "*P*" values of patellar parameters by sex in south indian population

Parameters	Mean		SD		*P* value (Student's *t*-test)
	Male	Female	Male	Female	
Patella angle	127.23	125.01	4.76	2.87	0.001*
Patella width	42.21	36.07	2.03	1.49	0.000*
Patella thickness	20.30	16.24	0.89	0.92	0.000*
Patella lateral facet width	22.59	19.47	1.99	1.11	0.000*
Patella facet thickness	12.21	10.26	0.77	0.99	0.000*
Patella lateral facet ratio	0.5358	0.5406	0.0495	0.0370	0.520
Patella relative thickness	0.4817	0.4513	0.0265	0.0367	0.000*
Patella facet thickness ratio	0.6024	0.6319	0.0454	0.0528	0.001*

*Highly significant. **Significant. SD: Standard deviation

Table 2: Means, SD and "*P*" values of trochlear parameters by sex in south indian population

Parameters	Mean		SD		*P* value (Student's *t*-test)
	Male	Female	Male	Female	
Sulcus angle	134.32	130.11	6.57	4.47	0.000*
Sulcus width	38.16	32.12	3.06	1.22	0.000*
Sulcus depth	8.41	7.57	1.27	0.94	0.000*
Sulcus lateral facet width	23.63	18.55	1.90	1.78	0.000*
Trochlea epicondylar axis angle	12.26	12.46	3.24	1.02	0.610
Sulcus lateral facet ratio	0.6204	0.5774	0.0390	0.0510	0.000*
Sulcus relative depth	0.2199	0.2356	0.0255	0.0273	0.001*

*Highly significant. **Significant. SD: Standard deviation

Table 3: Means, SD and "*P*" values of patellofemoral congruence parameters by sex in South indian population

Parameters	Mean		SD		*P* value (Student's t-test)
	Male	Female	Male	Female	
LTI	16.68	15.88	4.59	5.27	0.341
LPD	3.37	1.49	4.64	4.51	0.016**
PEAA	8.35	10.79	2.30	3.34	0.000*
Congruence angle	11.66	14.66	9.30	3.20	0.012**
Insall-Salvati index	1.12	1.25	0.098	0.116	0.000*
Width congruence	1.11	1.12	0.086	0.070	0.313
Depth congruence	0.6894	0.7390	0.0981	0.0707	0.001*

*Highly significant. **Significant. SD: Standard deviation, LPD: Lateral patella displacement, LTI: Lateral trochlear inclination, PEAA: Patella epicondylar axis angle

Table 4: Number of persons in each age group

Age (in years)	Total number of persons (%)
21–30	37 (26.4)
31–40	35 (25)
41–50	30 (21.4)
>50	38 (27.1)
Total	140 (100)

axis angle and SRD as shown in Table 2. Here the comparison of SD suggests that males exhibit a more variability than females in all the trochlear parameters except SLFR (SLFW/SW) and SRD (SD/SW) as shown in Table 2. Among the trochlear parameters analyzed in the South Indian population, the SA, SW, SD, SLFW, SRD, and SLFR were found to be statistically highly significant ($P \leq 0.001$) depicting gender variation.

For the PF congruence, the mean value was higher in females than males except for LTI and LPD as seen in Table 3. The comparison of SD among the PF congruence parameters reveals a more variability in males than females in all the parameters except LTI, PEAA, and ISI (PTL/PL) as seen in Table 3. Among the PF congruence parameters analyzed in the South Indian population LPD, PEAA, DC, ISI, and CA were found to be statistically significant ($P \leq 0.05$) depicting gender variation.

Age Variation

The total of 140 knee MRI records were categorized into four different age groups, 21–30, 31–40, 41–50, and >50 years with 37 (26.4%), 35 (25%), 30 (21.4%), and 38 (27.1%) persons, respectively, in each age group, as shown in Table 4.

On the evaluation of the mean value of various morphometric parameters of the PFJ, statistically significant difference ($P \leq 0.05$, ANOVA test) across the four age groups was observed for most of the parameters in the knee MRI records as shown in Tables 5-7. Among the patellar parameters, age difference in ANOVA was found in PA, PW, PFT ratio ($P < 0.001$), and PLFR ($P \leq 0.05$), but not for PT, PLFW, PFT, and PRT as shown in Table 5.

On analysis of the trochlear parameters, highly significant age difference in ANOVA was observed in SA, SD, SRD, and SLFR ($P < 0.001$), but not in SW, SLFW, and TEAA as shown in Table 6.

The PF congruence parameters showed significant age difference in ANOVA for LTI, Lateral Patellar Displacement, ISI, DC, WC ($P \leq 0.001$), and PEAA ($P \leq 0.05$), but not for CA as shown in Table 7.

On analysis of the patellar parameters, Karl Pearson correlation revealed a positive correlation of PW with age. The PA, PLFR, and PFT ratio were found to be decreasing with age. Rest of the patellar parameters did not show any significant variation trend with age as depicted in Table 8.

The SA and SLFR were found to be decreasing with increase in age. Rest of the trochlear parameters did not show any significant variation trend with age as depicted in Table 9.

The lateral patellar displacement was found to be decreasing with age. Rest of the congruence parameters did not show any significant variation trend with age as depicted in Table 10.

DISCUSSION

Disorders of the PFJ are one of the most important factors contributing to anterior knee pain which presents as a very common problem in orthopedics and sports medicine. The PFJ and its morphometry to PF pain and PF OA have been related by radiological studies previously.[5,13,21,20] Data on gender or age comparative anatomical analysis of the measurements of the PFJ are limited. Our investigation has identified several significant PF anatomic variations with respect to age and gender among the South Indian population which may account for age and gender-wise prevalence of certain PF disorders. Recently, PFA has attracted increased interest as a salvage treatment for isolated PF arthritis.[22] There is a significant difference in the morphology of the PFJ between the Asian and Western patients.[23] There is a lack of morphometric data about the Asian and particularly the Indian PFJ which could be responsible for poor clinical results following arthroplasty.[24] The radiographic studies provide an added advantage of having digital data for future reference and research. In this study, we adopted the indirect method by MRI, and all the measurements in this study were collected non-invasively.

Table 5: Means, SD and "*P*" values of patellar parameters by age in South Indian population

Parameters	Age group (Mean±SD)				*P* value
	21–30	31–40	41–50	>50	
PA	125.31±3.47	128.74±5.16	126.79±2.74	123.96±2.80	0.000*
PW	38.76±2.69	39.84±2.82	37.25±3.68	40.36±4.18	0.002*
PT	18.09±2.43	18.35±2.18	17.79±1.78	18.74±2.37	0.342
PLFW	20.99±2.32	21.63±2.78	20.51±1.52	20.92±2.03	0.235
PFT	11.05±1.35	11.36±1.34	11.54±1.52	11.04±1.06	0.335
PLFR	0.54±0.05	0.542±0.05	0.55±0.04	0.52±0.04	0.014**
PRT	0.47±0.05	0.46±0.03	0.48±0.02	0.46±0.03	0.185
PFTR	0.61±0.05	0.62±0.03	0.65±0.07	0.59±0.04	0.000*

*Highly significant. **Significant. SD: Standard deviation, PA: Patella angle, PW: Patella width, PT: Patella thickness, PLFW: Patella lateral facet width, PFT: Patella facet thickness, PLFR: Patella lateral facet ratio, PRT: Patella relative thickness, PFTR: Patella facet thickness ratio

Table 6: Means, SD and "*P*" values of trochlear parameters by age in South Indian population

Parameter	Age group (Mean±SD)				*P* value
	21–30	31–40	41–50	>50	
SA	136.79±5.46	134.25±4.62	129.54±2.60	128.01±5.64	0.000*
SW	34.19±3.03	36.31±5.04	35.26±2.89	34.91±3.69	0.124
SD	7.15±0.90	8.11±1.50	8.26±0.65	8.47±1.04	0.000*
SLFW	21.50±2.60	21.81±3.69	20.72±2.26	20.31±3.55	0.157
TEAA	12.63±2.97	12.57±3.20	12.64±0.69	11.67±1.57	0.232
SLFR	0.63±0.04	0.60±0.031	0.59±0.04	0.58±0.07	0.000*
SRD	0.21±0.02	0.22±0.024	0.24±0.02	0.24±0.03	0.000*

*Highly significant. **Significant. SD: Standard deviation, SA: Sulcus angle, SW: Sulcus width, SD: Sulcus depth, SLFW: Sulcus lateral facet width, TEAA: Trochlea epicondylar axis angle, SLFR: Sulcus lateral facet ratio

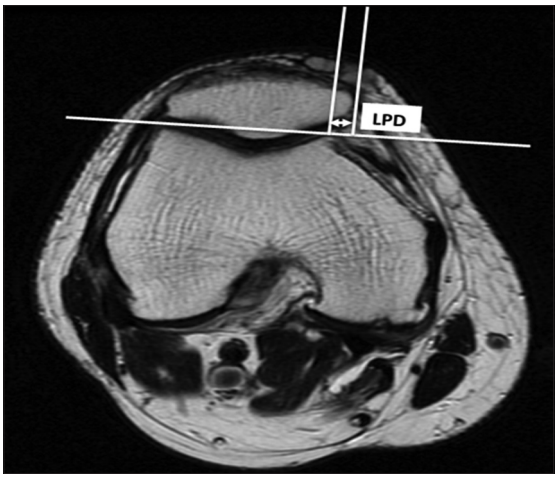

Figure 9: Magnetic resonance imaging right knee - T2 axial section illustrating landmarks for measuring lateral patella displacement (LPD)

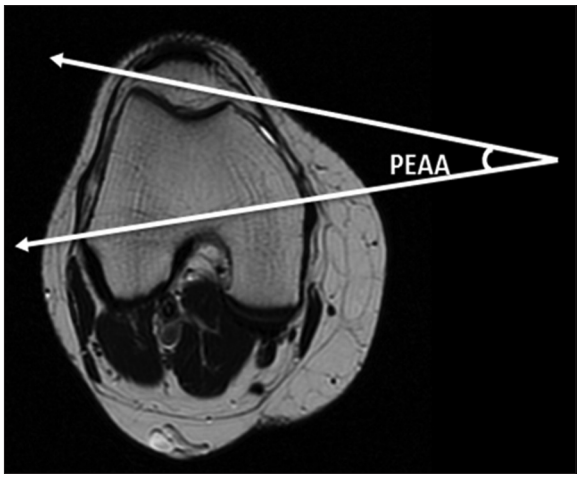

Figure 11: Magnetic resonance imaging right knee: T2 axial section illustrating landmarks for measuring patella epicondylar axis angle (PEAA)

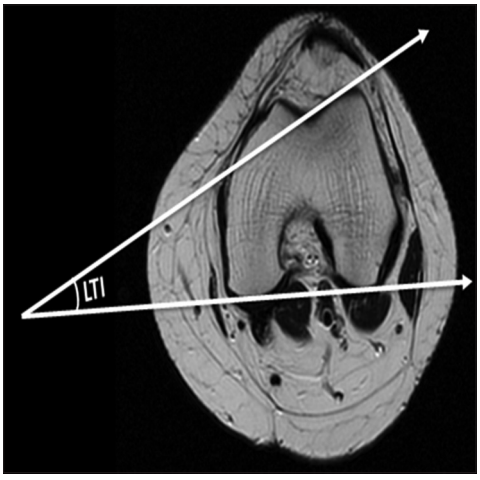

Figure 10: Magnetic resonance imaging left knee - T2 axial section illustrating landmarks for measurement of lateral trochlear inclination (LTI)

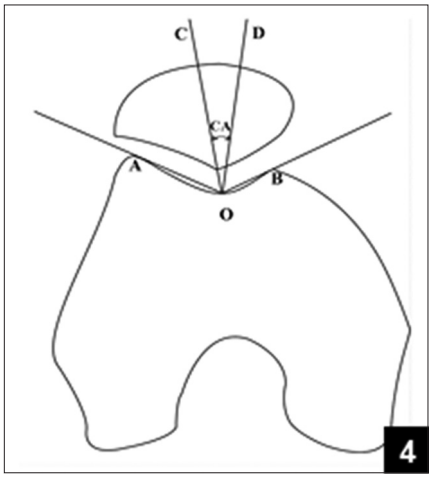

Figure 12: Diagram of congruence angle, indicated as COD

Sex Variation

From our present study of the PFJ in the South Indian Population, 18 out of the 22 parameters were found to be statistically significant, denoting sex variation in the PFJ ($P \leq 0.05$).

Patellar Parameters

The patella serves as a marker for the alignment of the extensor mechanism of the knee joint. Skeletal components play a pivotal role in the determination of sex in forensic and anthropological fields, and the bony patella has been used in many studies as a sex assessor with the highest rate of classification of 95% thereby making the patella useful for sex determination.[25,26] In our analysis of the patellar parameters from MR images, the PA, PW, PT, PLFW, PFT, PRT, and PFT ratio exhibited statistically highly significant sexual dimorphism ($P \leq 0.001$). The only patellar parameter which was not significant statically was the PLFR. It was observed that the male patellae had larger geometrical dimension than female patellae. Similar findings were observed by Yoo *et al.* in the Korean population and Baldwin *et al.* in the western population.[26,27] In our study, mean value was higher in males than females for all the patellar parameters, except for PLFR (PLFW/PW) and PFT ratio (PFT/PT). The mean PA was found to be 127.23° ± SD 4.76° in males and 125.01° ± SD 2.87° in females. It was reported that the patella of Asian population is thinner and smaller than Western subjects.[28,29] This fact is confirmed in this study on the South Indian population. Our study showed the mean PW to be 42.21 mm in males and 36.07 mm in females which was smaller than reported by Baldwin *et al.*,[27] Shang *et al.*,[29] and Yoo *et al.*[26] for Westerns, southern Chinese, and Korean population. On analysis of the mean PT, it was found to be smaller than that of the Western, Korean, and southern Chinese population.[31,32] In our study, the PT was 20.30 ± 0.89 mm for males and 16.24 ± 0.92 mm for females. Thus, the

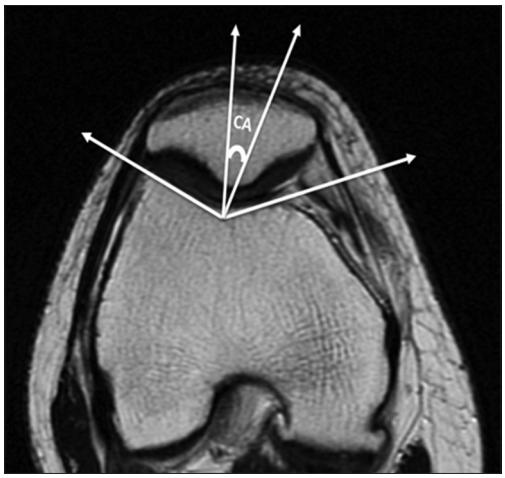

Figure 13: Magnetic resonance imaging right knee - T2 axial section illustrating landmarks for measuring congruence angle (CA)

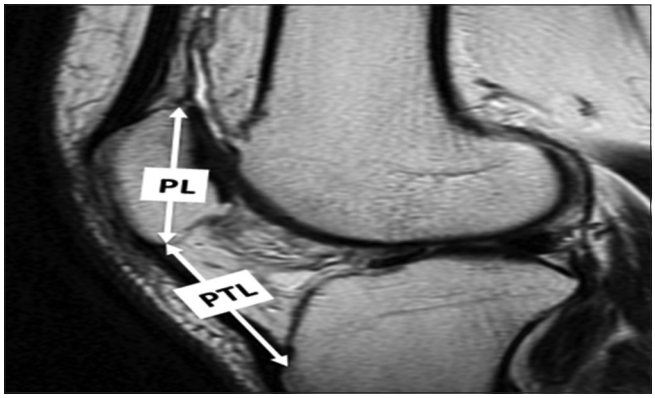

Figure 14: Magnetic resonance imaging knee - T2 sagittal image illustrating landmarks for measuring Insall-Salvati index = Patella tendon length (PTL)/Patella length (PT)

Table 7: Means, SD and "*P*" values of patellofemoral congruence parameters by age in South Indian population

Parameter	Age group (Mean±SD)				*P* value
	21–30	31–40	41–50	>50	
LTI	16.94±5.96	16.63±2.19	12.85±4.61	17.86±4.87	0.000*
LPD	5.25±2.14	4.60±2.00	1.65±4.49	−1.70±5.21	0.000*
PEAA	9.74±3.62	10.20±3.75	8.16±2.65	9.94±1.71	0.039**
CA	13.14±2.87	12.17±2.28	15.74±2.78	12.07±12.75	0.135
ISI	1.17±0.112	1.22±0.093	1.24±0.166	1.13±0.11	0.001*
WC	1.14±0.04	1.11±0.09	1.06±0.06	1.16±0.09	0.000*
DC	0.65±0.09	0.71±0.07	0.72±0.06	0.77±0.09	0.000*

*Highly significant. **Significant. SD: Standard deviation, LTI: Lateral trochlear inclination, LPD: Lateral patella displacement, PEAA: Patella epicondylar axis angle, CA: Congruence angle, WC: Width congruence, DC: Depth congruence, ISI: Insall-Salvati index

Table 8: Correlation between the patellar parameters and age

	Parameter	Karl Pearson correlation	*P* value
Age	Patella angle	−0.209*	0.013
	Patella width	0.195*	0.021
	Patella thickness	0.149	0.079
	Patella lateral facet width	0.016	0.852
	Patella facet thickness	0.014	0.865
	Patella lateral facet ratio	−0.168*	0.047
	Patella relative thickness	0.019	0.822
	Patella facet thickness ratio	−0.183*	0.031

*Significant P value ≤ 0.05. **Highly significant parameters P ≤ 0.001

South Indian female is found to have the thinnest patella of mean value 16.24 mm among the western, Korean, and South Chinese population. A comparison of PW and PT in different population groups is shown in Table 11.

We measured the PRT which is the ratio of PT to PW. This can also be used as a useful guide for estimating premorbid patellar thickness. The PRT was found to be 0.4817 and 0.4513 mm, respectively, in males and females of the South Indian Population with a statistically high significance ($P = 0.000$). PFT was 12.21 mm in males and 10.26 mm in females with a statistically high significance ($P = 0.000$). PLFW which revealed a mean value of 22.59 mm in males and 19.47 mm in females was smaller compared to the south Chinese population, 26.91 mm in males and 23.30 mm in females, while the same dimension measured in western was 29.7 mm in males and 25.3 mm in females. Yang *et al.* observed that PF cartilage lesions are more likely in those cases where a patella is dominated by a lateral articular facet.[20] This can be calculated with the PLFR which was found to be 0.5358 in males and 0.5406 in females. PFT ratio which is the ratio of PFT to PT was 0.6024 in males and 0.6319 in females with highly significant *P* value of 0.001.

Trochlear Parameters

The mechanics and pathomechanics of the PF articulation are largely dependent on the configuration and location of the intercondylar groove on the distal end of femur.[33,34] The relation between the location and orientation of the femoral sulcus, the deepest depression of the intercondylar groove to the condyles or the anatomic and mechanical axes of the femur were defined by Walmsley.[34] Patellar tracking during knee flexion is provided by the femoral trochlea, which consists of the lateral and medial facets of the femoral. Among the trochlear parameters analyzed in the South Indian population, the SA, SW, SD, SLFW, SRD, and SLFR were found to be statistically highly significant ($P \leq 0.001$) depicting gender variation. The mean SA in our study was found to be 134.32° in males and 130.11° in females. Our values were found to be lower than those according to Brattstroem[21] (142°) and Merchant[34] (138°).Murshed *et al.*[35] reported the mean SA in males and in females to be 134° ± SD 5.1° and 133.2° ± SD 6.7°, respectively, in the Turkish population. The mean

Table 9: Correlation between the trochlear parameters and age

	Parameter	Karl Pearson correlation	*P* value
Age	Sulcus angle	−0.546**	0.000
	Sulcus width	0.056	0.514
	Sulcus depth	0.360**	0.000
	Sulcus lateral facet width	−0.100	0.241
	Trochlea epicondylar axis angle	−0.162	0.055
	Sulcus lateral facet ratio	−0.260**	0.002
	Sulcus relative depth	0.402**	0.000

*Significant P value ≤ 0.05. **Highly significant parameters P ≤ 0.001

Table 10: Correlation between the patellofemoral congruence parameters and age

	Parameter	Karl Pearson correlation	*P* value
Age	LTI	−0.010	0.909
	LPD	−0.564**	0.000
	PEAA	−0.016	0.853
	Congruence angle	−0.025	0.770
	Insall-Salvati index=PTL/PL	−0.116	0.170
	Width congruence	0.152	0.072
	Depth congruence	0.412**	0.000

*Significant P value ≤ 0.05. **Highly significant parameters P ≤ 0.001. LTI: Lateral trochlear inclination, LPD: Lateral patella displacement, PEAA: Patella epicondylar axis angle, PTL: Patella tendon length, PL: Patella length

Table 11: Comparison of patella width and patella thickness

Population	Patella width		Patella thickness	
	Male	Female	Male	Female
Present study (South Indians)	42.21	36.07	20.30	16.24
Baldwin *et al*. (Western)	50.3	43.5	23.9	21.8
Yoo *et al*. (Koreans)	47.01	41.25	23.1	21.2
Shang *et al*. (South Chinese)	47.01	41.25	23.91	21.52

SD was found to be higher in males (8.41 ± 1.27 mm) than females (7.57 ± 0.94 mm) and is statistically significant ($P < 0.001$). SA and SD together can be used as a reliable tool to assess trochlear dysplasia. In our study, males had a shallower femoral groove compared to the females, which makes them more prone to patellar instability and can be an important factor causing anterior knee pain in those men involved in sports. The mean SW was found to be 38.16 ± 3.06 mm in males and 32.12 ± 1.22 mm in females. The SLFW being 23.63 ± 1.90 mm in males and 18.55 ± 1.78 mm in females. According to Poilvache *et al*. and Stoeckl *et al*.,[36,37] the TEAA is a reproducible reference for knee flexion and extension, making it an anatomical marker that indicates femoral condyles. In our study, TEAA was 12.26° for males and 12.46° for females showing no statistically significant difference between the TEAA values for males and females. All these values of femoral trochlea should be taken into consideration to tailor appropriate prosthesis for femoral component of TKA or PFA.

Congruence Parameters

Gross malalignment syndromes of the PFJ and dislocations of the patella are easily diagnosed, but more subtle malalignment and patellar tracking disorders often escape detection. The CA was described by Merchant *et al*. and used by many others as a tool to identify subtle malalignment of the PFJ.[33] In our study, the mean CA was found to be 11.66° ± SD9.30° in males and 14.66° ± SD3.20° in females. Our study revealed a more positive value of the CA compared to those of Merchant *et al*.,[34] which may be attributed to the difference in the degree of flexion of the knee while recording the measurement. In our study, we found a lower SA and higher CA in female compared to the males. This factor makes the South Indian females more prone to anterior knee pain due to increased load on the PFJ. In our study, the LPD was found to be 3.37 ± 4.64 mm in males and 1.49 ± 4.51 mm in females. The positive value indicates a lateralized position of patella. A laterally positioned patella (defined as LPD >5 mm) is associated with a high specificity for maltracking. Yang *et al*. found that LPD increases the risk for PF cartilage lesions.[20] It is thought that the distribution of stress in the PFJ changes as a result of patella displacement. In addition to the CA and LPD, we used the PEAA to assess PF congruence in the transactional images. The femoral epicondylar axis, in contrast, has been identified as the rotational axis of flexion and extension of the knee by Poilvache *et al*. and Stoeckl *et al*.[37,38] In our study, the PEAA was found to be 8.35° ± SD2.30° in males and 10.79° ± SD 3.34° in females. This is in accordance with the values observed by Yang *et al*.[36] In our study, it showed LTI to be 16.68° ± SD 4.59° in males and 15.88° ± SD 5.27° in females. This is in accordance with the values observed by Carrillon *et al*. in normal subjects of France (16.93° ± SD 4.97°).[14] LTI of men and women in our series did not show a statistically significant difference. Numerous methods exist for determining patellar height on lateral radiographs.[38-41] The most widely used method is the patellar tendon: Patella ratio of Insall and Salvati.[42] Our analysis of the ISI showed a value of 1.12 ± 0.098 in males and 1.25 ± 0.116 in females, showing a statistically high significance ($P = 0.000$).

Age Variation

This study also demonstrates differences found in the anatomical profile of the PFJ between age groups. In our study, among the patellar parameters, the significant age difference was found in PA, PW, PFT ratio ($P < 0.001$), and PLFR ($P \leq 0.05$), but not for PT, PLFW, PFT, and PRT. Furthermore, a positive correlation of PW with age was revealed by the Karl Pearson correlation

coefficient in our study. On analysis of the trochlear parameters, the significant age difference was observed in SA, SD, SRD, and SLFR ($P < 0.001$), but not in SW, SLFW, and TEAA. Furthermore, an increase in SD and SRD with age was observed. The SA and SLFR were found to be decreasing with increase in age. Rest of the trochlear parameters did not show any significant variation trend with age. Nietosvaara found the osseous SA to be inversely related to age, being flattest in young children and deepening steadily through growth.[43] The PF congruence parameters showed significant age difference for LTI, lateral patellar displacement, ISI, DC, WC ($P \leq 0.001$), and PEAA ($P \leq 0.05$), but not for CA. Furthermore, a strong positive correlation of DC with age was observed. The lateral patellar displacement was found to be decreasing with age. Rest of the congruence parameters did not show any significant variation trend with age.

SUMMARY AND CONCLUSIONS

From our present MRI study in 70 males and 70 females representing the South Indian population, it was concluded that 18 out of the 22 morphometric parameters of the PFJ depicted significant gender variation ($P \leq 0.05$, Student's unpaired t-test). 16 parameters were found to be statistically highly significant with a P value below 0.001. Significant age variation in ANOVA test was found in 14 out of the 22 parameters of the PFJ ($P \leq 0.05$). This pilot study representative of the South Indian population can provide guidelines to manufacture prosthetic inventories suitable for the Indian population having smaller anthropometric measurements than Western population, especially to design gender and age-specific prosthesis.

REFERENCES

1. Arendt E. Anatomy and malalignment of the patellofemoral joint: Its relation to patellofemoral arthrosis. Clin Orthop Relat Res 2005;436:71-5.
2. Arendt EA. Putting a little sex in your orthopaedic practice. Am Acad Orthop Surg 2007;15:268-73.
3. Iwano T, Kurosawa H, Tokuyama H, Hoshikawa Y. Roentgenographic and clinical findings of patellofemoral osteoarthrosis. With special reference to its relationship to femorotibial osteoarthrosis and etiologic factors. Clin Orthop Relat Res 1990;252:190-7.
4. Nimon G, Murray D, Sandow M, Goodfellow J. Natural history of anterior knee pain: A 14- to 20-year follow-up of nonoperative management. J Pediatr Orthop 1998;18:118-22.
5. Grelsamer RP, Dejour D, Gould J. The pathophysiology of patellofemoral arthritis. Orthop Clin North Am 2008;39:269-74.
6. Maenpaa H, Lehto MU. Patellofemoral osteoarthritis after patellar dislocation. Clin Orthop Relat Res 1997;339:156-62.
7. Fithian DC, Paxton EW, Stone ML, Silva P, Davis DK, Elias DA, *et al.* Epidemiology and natural history of acute patellar dislocation. Am J Sports Med 2004;32:1114-21.
8. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. Bull World Health Organ 2003;81:646-56.
9. Felson DT, McAlindon TE, Anderson JJ, Naimark A, Weissman BW, Aliabadi P, *et al.* Defining radiographic osteoarthritis for the whole knee. Osteoarthritis Cartilage 1997;5:241-50.
10. McAlindon TE, Snow S, Cooper C, Dieppe PA. Radiographic patterns of osteoarthritis of the knee joint in the community: The importance of the patellofemoral joint. Ann Rheum Dis 1992;51:844-9.
11. Ledingham J, Regan M, Jones A, Doherty M. Radiographic patterns and associations of osteoarthritis of the knee in patients referred to hospital. Ann Rheum Dis 1993;52:520-6.
12. Hinman RS, Crossley KM. Patellofemoral joint osteoarthritis: An important subgroup of knee osteoarthritis. Rheumatology (Oxford) 2007;46:1057-62.
13. Kalichman L, Zhang Y, Niu J, Goggins J, Gale D, Felson DT, *et al.* The association between patellar alignment and patellofemoral joint osteoarthritis features - an MRI study. Rheumatology (Oxford) 2007;46:1303-8.
14. Carrillon Y, Abidi H, Dejour D, Fantino O, Moyen B, Tran-Minh VA, *et al.* Patellar instability: Assessment on MR images by measuring the lateral trochlear inclination-initial experience. Radiology 2000;216:582-5.
15. Escala JS, Mellado JM, Olona M, Giné J, Saurí A, Neyret P, *et al.* Objective patellar instability: MR-based quantitative assessment of potentially associated anatomical features. Knee Surg Sports Traumatol Arthrosc 2006;14:264-72.
16. Miller TT, Staron RB, Feldman F. Patellar height on sagittal MR imaging of the knee. AJR Am J Roentgenol 1996;167:339-41.
17. Pfirrmann CW, Zanetti M, Romero J, Hodler J. Femoral trochlear dysplasia: MR findings. Radiology 2000;216:858-64.
18. Toms AP, Cahir J, Swift L, Donell ST. Imaging the femoral sulcus with ultrasound, CT, and MRI: Reliability and generalizability in patients with patellar instability. Skeletal Radiol 2009;38:329-38.
19. Cannon A, Stolley M, Wolf B, Amendola A. Patellofemoral resurfacing arthroplasty: Literature review and description of a novel technique. Iowa Orthop J 2008;28:42-8.
20. Yang B, Tan H, Yang L, Dai G, Guo B. Correlating anatomy and congruence of the patellofemoral joint with cartilage lesions. Orthopedics 2009;32:20.
21. Brattstroem H. Shape of the intercondylar groove normally and in recurrent dislocation of patella. A clinical and X-ray-anatomical investigation. Acta Orthop Scand Suppl 1964;68:1-148.
22. Kwak DS, Han S, Han CW, Han SH. Resected femoral anthropometry for design of the femoral component of the total knee prosthesis in a Korean population. Anat Cell Biol 2010;43:252-9.
23. Lim HC, Bae JH, Yoon JY, Kim SJ, Kim JG, Lee JM, *et al.* Gender differences of the morphology of the distal femur and proximal tibia in a Korean population. Knee 2013;20:26-30.
24. Akhlaghi M, Sheikhazadi A, Naghsh A, Dorvashi G. Identification of sex in Iranian population using patella dimensions. J Forensic Leg Med 2010;17:150-5.
25. Kemkes-Grottenthaler A. Sex determination by discriminant analysis: An evaluation of the reliability of patella measurements. Forensic Sci Int 2005;147:129-33.
26. Yoo JH, Yi SR, Kim JH. The geometry of patella and patellar tendon measured on knee MRI. Surg Radiol Anat 2007;29:623-8.
27. Baldwin JL, House CK. Anatomic dimensions of the patella measured during total knee arthroplasty. J Arthroplasty 2005;20:250-7.
28. Vaidya SV, Ranawat CS, Aroojis A, Laud NS. Anthropometric measurements to design total knee prostheses for the Indian population. J Arthroplasty 2000;15:79-85.
29. Shang P, Zhang L, Hou Z, Bai X, Ye X, Xu Z, *et al.* Morphometric measurement of the patella on 3D model reconstructed from CT scan images for the southern Chinese population. Chin Med J (Engl) 2014;127:96-101.
30. Hsu HC, Luo ZP, Rand JA, An KN. Influence of patellar thickness on patellar tracking and patellofemoral contact characteristics after total knee arthroplasty. J Arthroplasty 1996;11:69-80.
31. Bogen H. Uber familiiire luxation und rleinheit der Pat. Z Orthop Chir 1906;16:359-419.
32. Kujala UM, Osterman K, Kormano M, Nelimarkka O, Hurme M, Taimela S, *et al.* Patellofemoral relationships in recurrent patellar dislocation. J Bone Joint Surg Br 1989;71:788-92.
33. Merchant AC. Patellofemoral disorders: Biomechanics, diagnosis, and nonoperative treatment. In: Operative Arthroscopy. New York, NY: Raven Press; 1991. p. 261-75.

34. Walmsley T. The vertical axes of the femur and their relations. A Contribution to the study of the erect position. J Anat 1933;67:284-300.
35. Murshed KA, Cicekcibasi AE, Ziylan T, Karabacakoglu A. Femoral sulcus angle measurements: An anatomical study of magnetic resonance images and dry bones. Turk J Med Sci 2004;34:165-9.
36. Poilvache PL, Insall JN, Scuderi GR, Font-Rodriguez DE. Rotational landmarks and sizing of the distal femur in total knee arthroplasty. Clin Orthop Relat Res 1996;331:35-46.
37. Stoeckl B, Nogler M, Krismer M, Beimel C, de la Barrera JL, Kessler O. Reliability of the transepicondylar axis as an anatomical landmark in total knee arthroplasty. J Arth 2006;21:878-82.
38. Yang B, Tan H, Yang L, Dai G, Guo B. Correlating anatomy and congruence of the patellofemoral joint with cartilage lesions. Orthopedics 2009;32:20.
39. Grelsamer RP, Meadows S. The modified Insall-Salvati ratio for assessment of patellar height. Clin Orthop Relat Res 1992;282:170-6.
40. Blackburne JS, Peel TE. A new method of measuring patellar height. J Bone Joint Surg Br 1977;59:241-2.
41. Jacobsen K, Bertheussen K. The vertical location of the patella: Fundamental views on the concept patella Alta, using a normal sample. Acta Orthop Scand 1974;45:436-45.
42. Insall J, Salvati E. Patella position in the normal knee joint. Radiology 1971;101:101-4.
43. Nietosvaara Y. The femoral sulcus in children. An ultrasonographic study. J Bone Joint Surg Br 1994;76:807-9.

How to cite this article: Muhamed R, Saralaya VV. Magn etic Resonance Imaging Study of Age and Sex Variation in the Anatomy of Patellofemoral Articulation. Int J Sci Stud 2017;5(9):54-65.

Source of Support: Nil, **Conflict of Interest:** None declared.