MEASUREMENTS OF PATELLOFEMORAL MORPHOLOGY CHARACTERISTICS IN INDONESIAN POPULATION: AN MRI BASED STUDY

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ABSTRACT

Patellar malalignment is the imbalance relationship between patella and trochlea, in which clinical findings most of the time are obscured; hence diagnosis is often challenging. Magnetic resonance imaging (MRI) is the most sensitive tool to detect subtle patellar malalignment features, so diagnosis can be made early. However, there has been no clear consensus on the normal value of patella morphology until today. This study aims to determine patellofemoral morphology values in Indonesian using MRI. This was a retrospective study of 202 patients aged 18-40 years old with knee problems without patellar instability. Patellar morphology parameters including Insal Savati ratio (IS ratio), patellar tilt angle (PTA), sulcus angle (SA) and tibial tubercle-trochlear groove distance (TT-TG) were evaluated and recorded for statistical analysis. There was no significant correlation between anthropometric values and patellar morphology values. There were significantly higher PTA, SA and TT-TG values in females compared to males. The mean value of the IS ratio in the Asian population using MRI was 0.99 ± 0.14, PTA was 9.09 ± 6.88, SA was 139.20 ± 6.38, and TT-TG distance was 8.00 ± 5.25. Further studies with larger samples and multi-center results are required.

Keywords: Patellofemoral Morphology; MRI; Indonesian; Insall-Savati Ratio; Patellar Tilt Angle; Sulcus Angle; TT-TG Distance.

INTRODUCTION

The patellofemoral disorder is classified by Lyonnaise school[1] into three groups: objective patellar instability, potential patellar instability and painful patella syndrome. There are three principal factors of instability: trochlear dysplasia, abnormal patellar height and patellar position.[2]

The objective patellar instability group includes patients who have experienced at least one episode of patellar dislocation or subluxation and currently presents at least one of the principal factors of instability.[2] Potential patellar instability group includes patients who have never experienced dislocation or subluxation, whose main symptom is pain and presenting one or more of the principal factors of instability. Patellofemoral pain syndrome (PFPS) group includes patients whose main symptom is pain without any principal factors of instability can be identified, although some newer studies are against that.[3,4]

Studies have shown differences in knee measurements between races and ethnicities.[5,6] However, until today, there has been no consensus of the normal patellofemoral morphology parameter measurements. It is often difficult to diagnose patellofemoral malalignment during clinical examination without obvious clinical symptoms. An MRI imaging with clear cut normal values will aid in the decision making of daily clinical practice.

This study evaluates the patellar instability parameters measurements in young adult patients presenting knee pain without

objective patellar dislocation or subluxation (i.e. patients presenting with ligamentous injury, meniscus injury, or knee sprain) in the Asian population using Magnetic Resonance Imaging (MRI). This study aims to obtain the distribution of average normal patellofemoral morphology measurements in the Asian population. Prior knowledge of these values will give the surgeon a more detailed pre-operative planning and additional knowledge to prevent patellofemoral problems in the future.

MATERIALS AND METHODS

Patient Selection

A total of 202 knees MRIs were evaluated retrospectively from 153 patients with various knee pathology (Table 1) from January 2019 to December 2020. Inclusion criteria were patients aged 18-40 years old. Exclusion criteria were prior knee surgery, increased Q angle ($>20^0$) and presence of J-sign on physical examination. Height and weight were recorded on the MRI day. Informed consent was obtained from participants. This study has been reviewed and approved by the Institutional Review Board of our hospital and conducted in accordance with the Declaration of Helsinki. Informed consent from all participants has been obtained prior to the study.

Table 1. Clinical Indications for MRI in 202 patients

Clinical Indication	No of Patients
Suspected anterior cruciate ligament injury	63
Suspected posterior cruciate ligament injury	7
Suspected medial meniscus injury	74
Suspected lateral meniscus injury	23
Suspected medial and lateral meniscus injuries	13
Suspected osteoarthritic changes	4
Other (loose body, knee mass, swelling)	18

MRI Protocol

We used 3.0 Tesla MRI (thickness, 3.0 mm; 2,500-3,000/18-50; matrix size, 384 x 256; FOV, 16 x 16 cm) using high definition Siemens Magnetom Skyra machine. Images then were measured using Carstream Vue Motion (Carestream Health Inc, Rochester, NY). Axial proton density-weighted images were performed on an extended knee to measure patellar alignment parameters, while sagittal proton density-weighted images were used to assess patellar height position.

Insall-Savati Ratio

Insall and Savati described a method to determine patellar position depending on the ratio of the length of the patellar tendon to the diagonal length of the patella. The length of the patellar tendon and patella is different in each section of MRI, then an evaluation of Insall-Savati Ratio on MRI is performed on a single mid-sagittal image. In MRI, the length of the patella is the distance between anterior-inferior and posterior-superior corners, and the length of the patellar tendon is determined by measuring the shortest line drawn parallel to the deepest edge of the patellar tendon (Figure 1).[7,8] If the ratio of the tendon length to the patella length is greater than 1.52 in men and 1.32 in women, a patella alta diagnosis is made; if the ratio is smaller than 0.79 in men and 0.74 in women, a patella baja diagnosis is made.[9]

Figure 1. Measurement of the Insall-Savati Ratio on a Proton-Density Sagittal MRI slice

Patellar Alignment

There were three different measurements of patellar alignment made on the axial proton

density sequence: patellar tilt angle, sulcus angle and TT-TG.

Patellar Tilt Angle (PTA)

Pattellar tilt is measured between a line joining the medial and lateral facets of the patella and a line tangent to the posterior femoral condyle (Figure 2). The patellar tilt of more than $\geq 15^0$ suggests instability.

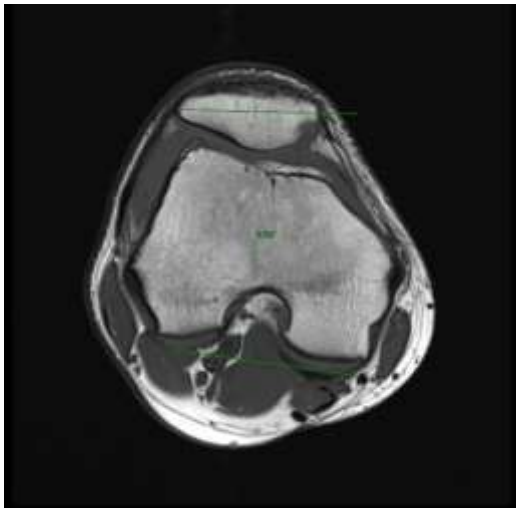

Figure 2. Measurement of Patellar Tilt Angle on proton-density axial MRI.

Sulcus Angle (SA.)

Sulcus angle is the angle formed between medial and lateral trochlear facets. SA was measured on axial MRI according to van Huyssteen et al.[10] Normal SA range 138 ± 6^0, SA more than 145^0 was considered abnormal.

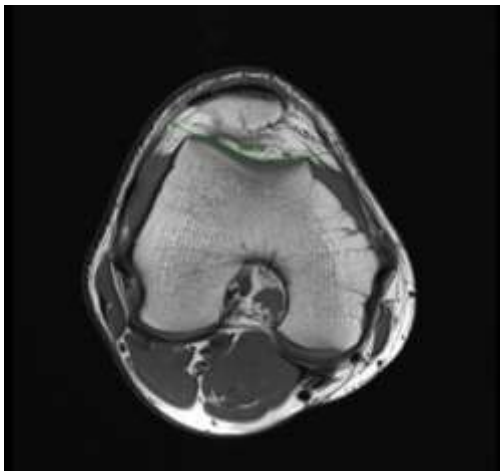

Figure 3. Measurement of the Sulcus Angle to determine trochlear dysplasia on proton-density axial MRI

TT-TG Distance (TTTG)

A reference point at the physeal scar of the lateral femoral condyle was used to measure TT-TG distance. According to Schoettle et al.,[11] TT-TG distance is measured on transverse MRI slice as the length of both the position of the tibial tuberosity (TT) and trochlear groove (TG) are cross-sectioned (Figure 4). Distance more than 20 mm is considered abnormal.[7,8]

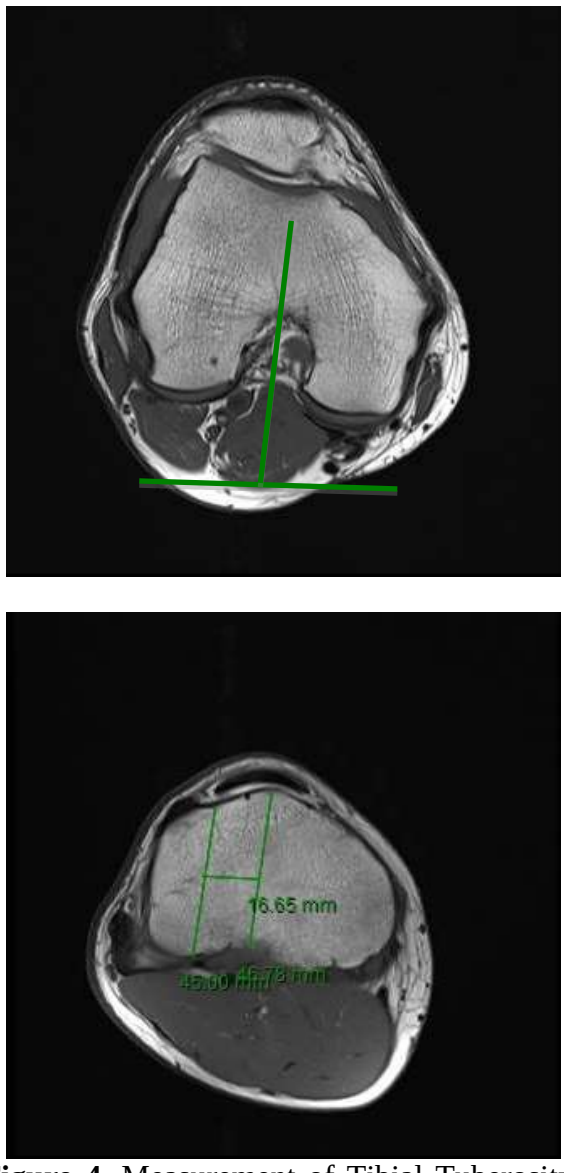

Figure 4. Measurement of Tibial Tuberosity-Trochlear Groove Distance on Axial Proton Density MRI

Statistical Analysis

All data were collected and analyzed using SPSS software version 23. Descriptive statistics were calculated for all variables.

Independent T-Test was used to compare the differences between gender and IS ratio, SA, PTA, and TT-TG distance. All significance level was set at $P < 0.05$. Pearson rank correlation coefficient was calculated to evaluate the association between the IS ratio, SA, PTA and TT-TG distance with patient's weight, height and BMI. The strength of the correlation was indicated by the coefficient -1 to +1. When the relationship of one variable decreases while the other increases, the coefficient is negative but greater than -1; when both variable increases, the coefficient is positive but less than +1; and when a relationship is random or non-existent, the coefficients are nearly zero. Intra- and inter-observer reliability of the IS ratio, SA, PTA and TT-TG on MRI were analyzed with an intra-class correlation coefficient (ICC). The strength of agreement can range from 0 to 1 (0.90 excellent; 0.80, good; 0.60-0.79, moderate; 0.59, poor).

RESULTS

A total of 202 patients were involved in this study with the following anthropometry (Table 2).

Table 2. Physical characteristics of the participants

	Height (cm)	Weight (kg)	BMI (kg/m^2)
Total	169.21 ± 7.90	76.36 ± 14.96	26.50 ± 4.61
Male (n = 146)	171.98 ± 5.45	81.12 ± 12.70	27.44 ± 3.98
Female (n = 56)	162.00 ± 8.74	63.74 ± 12.96	24.41 ± 5.39
P-value [a]	<0.0001	<0.0001	<0.0001

Data were given in mean ± standard deviation
BMI Body mass index (kg/m^2)
[a] P-value: comparison of values between males and females

We found a significant difference in all mean patellar parameters value between males and females (Table 3). Insall savati ratio in male is significantly higher (1.02 ± 0.13) compared to female (0.94 ± 0.16), p = 0.001. Meanwhile, PTA, SA, and TT-TG distances were higher in females than males (Table 3).

Table 3. Measurements of Patellar Parameters in Men and Women

	Mean IS[b] Ratio (Ratio ± SD)	Mean PTA[c] (^{0} ± SD)	Mean SA[d] (^{0} ± SD)	Mean TTTG[e] (^{0} ± SD)
Male	1.02 ± 0.13	7.65 ± 5.58	138.63± 6.45	7.34± 3.98
Female	0.94 ± 0.16	12.85 ± 8.44	140.70± 6.01	9.74± 7.41
P-value	0.001	<0.0001	0.039	0.025
Total	0.99 ± 0.14	9.09 ± 6.88	139.20± 6.38	8.00± 5.25

Data were given in mean ± standard deviation (SD.)
[a] P-value: comparison of values between males and females; [b] IS: Insall Savati; [c] PTA: Patellar Tilt Angle; [d] SA: Sulcus Angle; [e] TTTG: Tibial Tubercle-Trochlear Groove distance

There were weak correlations between anthropometric values and all patellofemoral morphology measurements, but the highest correlations were found between height and IS ratio, PTA, SA and TT-TG distance (Table 4).

Table 4. Correlation between Anthropometric Values and Patellofemoral Parameters

	Pearson-Rank Correlation[a]		
	Height	Weight	Age
IS Ratio[b]	0.300	0.203	-0.035
PTA[c]	-0.302	-0.224	0.014
SA[d]	-0.176	0.088	0.058
TT-TG distance [e]	-0.344	-0.033	0.054

[a] The strength of agreement can range from 0 to 1 (>0.80, good; 0.60-0.79, moderate; <0.59, poor); [b] IS: Insall Savati; [c] PTA: Patellar Tilt Angle; [d] SA: Sulcus Angle; [e] TTTG: Tibial Tubercle-Trochlear Groove distance

Intrarater ICC reliability values range from good to excellent for all parameters (0.813 – 0.942), while interrater ICC within all parameters ranged within good values (0811 – 0.838) (Table 5).

Table 5. ICC[a] Values for Patellofemoral Morphology Measurements

Variable	Intrarater ICC		Interrater ICC
	Rater 1	Rater 2	
IS Ratio[b]	0.986	1.012	0.832
PTA[c]	8.732	9.315	9.781
SA[d]	142.71	135.66	142.33
TT-TG distance [e]	12.214	10.115	6.721

[a] ICC, intraclass correlation coefficient; [b] IS: Insall Savati; [c] PTA: Patellar Tilt Angle; [d] SA: Sulcus Angle; [e] TTTG: Tibial Tubercle-Trochlear Groove distance

DISCUSSION

Our study is the first study evaluating the range of normal patellofemoral morphology values in the Asian population using MRI. Knowledge of normal values in a certain population is pivotal in determining treatments for patellofemoral problems. Recent studies showed different ethnicities could influence knee sizes.[11] Present patellofemoral morphology values mostly show a normal range from Caucasian knees.[2,4,12,14] However, there has been no specific literature evaluating patellofemoral sizes that could aid in the decision making of patellofemoral problems.

Patellar height position affects the join-reaction force on the patellofemoral joint. A higher riding patella or patella alta will reduce patellofemoral contact area leading to patellofemoral pain and instability.[15] One of the most common methods in determining the patellar height is the IS ratio. Several studies showed no significant differences in IS ratio between gender.[16] On the other hand, our study showed a significantly higher IS ratio in males compared to females, which is probably due to a higher percentage of male participants compared to females (146 vs 56). Although the mean IS ratio was statistically significant, the clinical value was not clinically significant (1.02 ± 0.13 vs 0.94 ± 0.16). Further studies are recommended with an equal number of participants' gender to obtain a clear difference of IS ratio between gender.

It has been proven that IS ratio can be measured more precisely on MRI.[8] Previous studies showed a range of 0.8-1.2 is considered normal for IS ratio.[7] Hong et al., 2020 defined the normal range of IS ratio between 0.92 ± 0.14 for females and 0.87 ± 0.14 for males, respectively for the Korean population.[17] Our study showed a bit higher value of IS ratio (0.99 ± 0.14) which might be caused by the increased length of the patellar tendon, which is often increased by squatting or kneeling habit, common in our country. The difference of the normal value indicates that it is necessary to analyze the distribution of the normal IS ratio value for each population prior to determining the analysis of patellar alta or patellar baja.

Increased patellar tilt angle (PTA) indicates patellar malalignment in terms of patellar position. PTA can be used to quantify mediolateral displacement of the patella relative to the femur, known as patellar tracking. There has been no consensus of the value of patella tracking needing surgical treatment. However, several studies suggested that a value of more than 20 degrees of lateral patellar tilt is the threshold of a lateral retinacular release on CT imaging.[18,19]

Osman et al., 2016[13] evaluated that the mean PTA within the normal control group was 9.45 ± 3.0, approximately the same as our finding (9.09 ± 6.88). Our study also found significantly higher PTA in females than males (12.85 ± 8.44 vs 7.65 ± 5.58, $p < 0.0001$), which is probably due to the more valgus position of the female knee creating a higher pressure on the lateral side of patella hence tilting the patella laterally.

There have been controversies regarding the effect of gender on trochlear morphology. Several studies did not show any significant difference in the sulcus angle between males and females.[20,21] However, our study found a significantly higher SA in the female population compared to the male population, similar to Koh et al., 2019.[22] However, our average SA was 139.20 ± 6.38, which was similar to Osman et al.'s result (134.4 ± 4.1).

Thakkar et al., 2015[23] proved that an abnormal TT-TG distance is the most useful

measurement among various static MRI parameters to correlate with patellar chondrosis and joint effusion. As we have understood that patellar position and alignment might vary during a static MRI, however, TT-TG distance is relatively stable measurements hence might be used as the determining parameter of treatment. Diederichs et al.[24] suggest a value of TT-TG distance more than 20 mm was considered abnormal. Our TT-TG result was slightly lower than previous results, which was 8.00 ± 5.25 mm. There was a significant difference with female TT-TG higher than male TT-TG distance in our study.

Although we excluded patients with obvious patellar dislocation or subluxation clinically, there is a possibility that the same patient has a potential instability factor. Further studies evaluating patients' association with potential instability factors and an unrelated knee injury (i.e. ACL/PCL injury or meniscus injury) are needed.

CONCLUSION

The mean value of IS ratio in the Asian population using MRI was 0.99 ± 0.14, PTA was 9.09 ± 6.88, SA was 139.20 ± 6.38, and TT-TG distance was 8.00 ± 5.25. There were significant differences in patellofemoral values between males and females. However, there were weak correlations between anthropometric values and patellofemoral measurements. Further studies with larger samples and multi-center results are required.

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