Original Article

Anatomical variation of posterior slope of tibial plateau in adult Eastern Indian population

Shyamalendu Medda, Rajib Kundu[1], Sohini Sengupta[2], Ananda Kisor Pal[3]

Abstract

Background: Upper surface of the proximal tibial end, tibial plateau, has a slope directed posteroinferiorly relative to the long axis of the middle of the shaft. It has important consideration in surgeries such as knee arthroplasty, high tibial osteotomy, and medical imaging of the knee joint. The aim of the present study was to estimate the tibial plateau angle (TPA) by plain radiograph in the adult Eastern Indian population as during literature review, we were unable to find any study, except one (without specific reference axis), on this variable among the Indian population.

Materials and Methods: A sample was taken from adult patients attending the outpatient department of orthopedics of the institute with minor knee problems. Measurement of the TPA was done in the true lateral radiographs of the knee joints of the selected subjects by a standardized method.

Results: TPA varied widely from 6° to 24°, with the mean ± standard deviation value 13.6° ±3.5°. Student's unpaired *t*-test revealed no significant difference of TPA between left and right knees, both in male (P = 0.748) and female (P = 0.917) separately and in the entire study population irrespective of gender (P = 0.768). Comparison of TPA between male (13.3° ± 3.3°) and female (13.9° ± 3.4°) by Student's unpaired *t*-test showed no sexual dimorphism (P = 0.248). There were poor correlations of TPA with age and body mass index.

Conclusion: The present study described the variations of the TPA in the adult Eastern Indian population (range 6°–24°, mean ± SD 13.6° ± 3.5°, no laterality, no sexual dimorphism, poor correlation with age and BMI). Knowledge of this study could be used in different orthopedic surgeries and imaging technique in or around the knee joint.

Key words: Anterior cruciate ligament, knee arthroplasty, osteoarthritis, osteotomy, tibia, tibial plateau
MeSH terms: Anterior cruciate ligament, arthroplasty, replacement, knee, osteoarthritis knee, tibia, osteotomy

Introduction

Proximal surface of the upper end of tibia, tibial plateau, bears a slope directed posteriorly and inferiorly relative to the long axis of the middle of the shaft. The slope varies widely.[1-3] It may vary with age,[4] squatting habit,[5] between sexes,[2,6] or there may be no sexual dimorphism.[7,8] Slope of medial and lateral plateau may differ significantly.[6]

The slope is an important consideration in knee biomechanics,[9] modification of radiological techniques,[3,10] and surgeries such as high tibial osteotomy for genu recurvatum deformity,[11,12] tibiofemoral osteoarthritis,[13] and knee arthroplasty.[14-17]

Only one study[5] (which was lacking description of reference axis, important for comparison with other studies) in Indian population was found during literature review. The aim of the present study was to estimate the tibial plateau slope in the adult Eastern Indian population. Objectives of the study were as follows:

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To provide range, mean, standard deviation of tibial plateau angle (TPA) in a section of adult Eastern Indian population. Identify any laterality identify any sexual dimorphism and assess correlation of the angle with age and body mass index (BMI).

Materials and Methods

A convenient sample was taken from adult patients (at least 18 years of age and skiagrams showing complete epiphyseal fusion around the knee) attending the outpatient department of orthopedics of our institute with minor knee problems such as mild soft tissue injury, superficial bruise around the knee, and pain and/or stiffness of knee joint. Patients with any congenital anomaly or deformity, fracture, and/or dislocation (recent or old) of the lower limb were excluded from the study. Advanced osteoarthritis (Kellgren–Lawrence grade >2)[13,18,19] and anterior cruciate ligament (ACL) injury[7,20-25] were the exclusion criteria for their possible association with the slope. ACL injury was excluded clinically (proper history and physical examinations - combination of anterior draw test, Lachman test, prone Lachman test, and pivot shift test) and, of course, diagnosed cases (by magnetic resonance imaging [MRI] and/or arthroscopy) of ACL injury were not included in the study.

No patient was exposed to X-ray without proper clinical indications for the purpose of his or her diagnosis or treatment. Clearance of the Institutional Ethics Committee was obtained. Before examination, proper consent was taken from each subject and procedural matters were explained properly. Heights and weights of the patients were measured with the same measuring tape and weighing machine, respectively, to calculate the BMIs of the patients in the unit of kilograms per meter square. Squatting habits of the subjects were assessed by enquiring about their daily activities. Routine clinical examinations were performed including combination of anterior draw test, Lachman test, prone Lachman test, and pivot shift test).

Anteroposterior and true lateral view radiographs (showing superimposition of the femoral condyles) of the knee joints of the selected subjects were taken by experienced technicians using same X-ray machine (Electromedical) of the department of radiodiagnosis of the institute with an exposure of 45 kV of 100 mA (exposure time varied according to the soft tissue thickness around the knee). Radiographic technique was similar to all the subjects. For the lateral view radiograph, the patients were lying on the same side of the affected knee, which were flexed about 25°–30°. The central X-ray beam was directed vertically toward the medial aspect of the knee joint, with about 5°–7°cephaled angulation.[26]

Measurements were taken in the true lateral view radiographs of properly selected patients by the single observer under guidance of an experienced radiologist using the SigmaView software version 3.6.1.0 (Manufactured by AGFA HealthCare, AGFA-Gevaert N.V, Septestraat 27, B-2640 Mortsel, Belgium). A straight line (anterior cortical line) was drawn along the anterior cortex of the middle of the shaft of the tibia, and it was extended proximally to be intersected by the second straight line drawn tangential to proximal tibial articular surface connecting most anterior and posterior ends of tibial plateau. A further straight line was drawn from the point of intersection perpendicular to the anterior cortical line. The angle between this perpendicular line and the tangential line along the tibial plateau was the TPA [Figure 1]. For practical purpose, the angle formed by the first and the second line subtracted from 90° was the TPA. In true lateral view roentgenogram of the knee, medial and lateral plateau was almost superimposed and the measured angle was a two-dimensional approximation of complex, asymmetric three-dimensional surface ignoring the difference between medial and lateral plateau.[6] The method adopted here was first described by Moore and Harvey.[3] Radiographs showing osteophytes in the anterior and/or posterior ends of the tibial plateau were excluded because of difficulty in measurement.

Collected data were analyzed statistically using following software available in the institute:

Statistica version 6 (StatSoft Inc., Tulsa, Oklahoma, USA 2001): MedCalc version 11.6 (MedCalc Software, Mariakerke, Belgium, 2011).

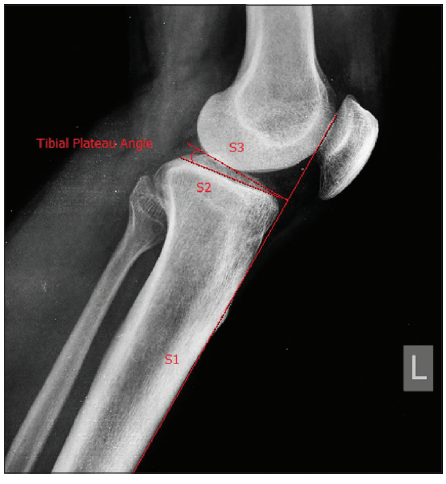

Figure 1: X-ray (L) knee joint lateral view showing measurement of tibial plateau angle (S1-anterior cortical line, S2-line tangential to the tibial plateau, S3-line perpendicular to S1 at the point of intersection of S1 and S2)

Intraobserver variation was assessed.

Results

Mean age was 46 (range 22–76 years) years for male and 44 (range 18–70 years) years for female ($P = 0.36$). Mean height was 167 (range 146–184 cm) cm for male and 154 (range 142–171 cm) cm for female ($P < 0.001$). Mean weight was 67 (range 42–87 Kg) Kg for male and 57 (range 40–102 Kg) Kg for female ($P < 0.001$). There was no significant gender difference in calculated BMI ($P = 0.544$) [Table 1]. All the subjects were habitual squatter.

Out of 184 cases (knees), 79 were diagnosed normal, 37 with superficial soft tissue injury, 32 had mild osteoarthritis, 26 moderate osteoarthritis and 10 patellofemoral osteoarthritis [Figure 2]. "Normal" cases were incidentally found either to exclude suspected silent pathologies or to investigate referred pain to knee.

Kolmogorov–Smirnov test accepted normal distribution of data of TPA of the right and left sides both in male and female.

TPA varied widely from 6° to 24°, with the mean value of 13.6° and standard deviation of 3.5°.

Student's unpaired *t*-test revealed no significant difference of TPA between the left and right knees, both in male ($P = 0.748$) and female ($P = 0.917$) separately and in the entire study population irrespective of gender ($P = 0.768$) [Table 2].

Comparison of TPA between male (13.3° ± 3.3°) and female (13.9° ± 3.4°) gender (each subject contributing two observations when both right and left knee values were present) by Student's unpaired *t*-test showed no sexual dimorphism ($P = 0.248$) [Table 3].

There were poor correlations of TPA with age [Figure 3, Pearson's correlation coefficient *r* - 0.02; $P > 0.05$] and BMI [Figure 4, Pearson's correlation coefficient *r* - 0.05; $P > 0.05$].

Repeated measurement of 75 cases (36 for right knee and 39 for left knee) in 3 sets at 1-week intervals by the same observer revealed strong agreement (intraclass correlation coefficient >7). Hence, intraobserver variation was insignificant.

Discussion

An important feature of our study was that we measured the TPA in subjects with very well-defined demographic and

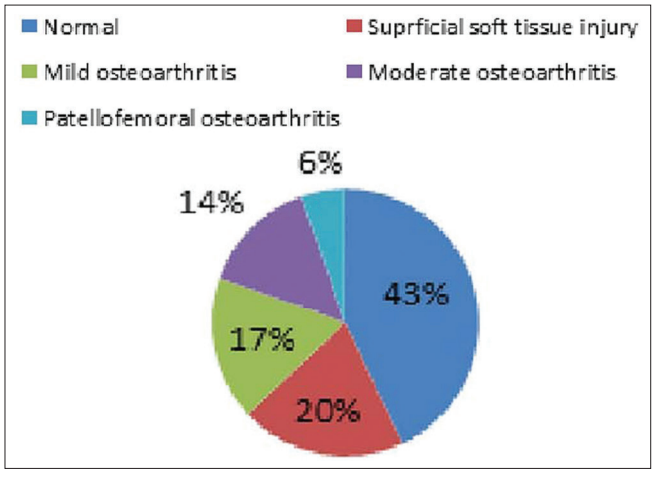

Figure 2: Diagnoses of the cases (knees) included in the study

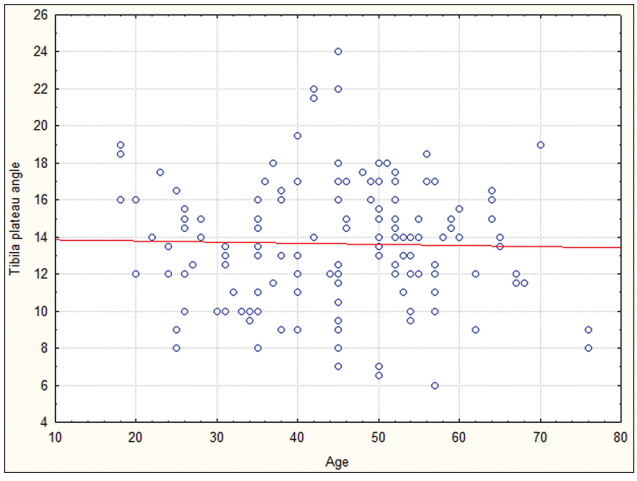

Figure 3: Scatterplot correlating tibial plateau angle (TPA) with age

Table 1: Morphometric parameters of the study population

Parameter	Male (*n*=43)		Female (*n*=65)		*P*	Both male and female (*n*=108)	
	Range	Mean±SD	Range	Mean±SD		Range	Mean±SD
Age (years)	22-76	46±14	18-70	44±12	0.36	18-76	45±13
Height (cm)	146-184	167±7	142-171	154±5	<0.001	142-184	159±9
Weight (kg)	42-87	67±9	40-102	57±10	<0.001	40-102	61±11
BMI (kg/m^2)	16-34	24±2.6	17-43	24±4.2	0.544	16-43	24±3.7

SD=Standard deviation, BMI=Body mass index

clinical characteristics using anterior cortical line which was used in majority of studies.[1-3,18,27-29] TPA can be measured in true lateral view roentgenogram of the knee joint either in living subjects[1-3] or in cadavers.[18] The variation of medial and lateral plateau of the tibia can be separately studied either by MRI scan[6] or by computerized tomographic (CT) scan.[30] The slope can also be measured in dry bones by goniometer[3] or parallelogram.[5] The values of the TPA differ significantly with the changes of reference axes,[28] but there is a strong correlation among values obtained from different reference axes.[27] Table 4 shows different studies on measurement of TPA using similar reference axis.

Moore and Harvey[3] studied the slope in the American population from radiographs of fifty subjects (gender and age were not mentioned). According to their study, the slope varied from 7° to 22°, with the mean ± standard deviation (SD) 14° and ± 3.7°. The results of the present study (range 6°–24°, mean ± SD 13.6° ± 3.5°) were similar to that of Moore and Harvey.[3] In the French population, Brazier *et al.*[27] found smaller value (range 3.47°–20.29°; mean ± SD 11.4° ±3.6°). Another study by Genin *et al.*[29] on the French population showed much lesser value, ranging from −1° to 18° and mean ± SD of 7.9° ± 3.2°.

Table 2: Tibial plateau angle (°) of right and left knee in male and female

Gender	*n*	Right knee		*n*	Left knee		*P*
		Range	Mean±SD		Range	Mean±SD	
Male	32	6.0-19.5	13.4±3.4	37	6.0-18.5	13.1±3.2	0.748
Female	55	6.5-22.0	13.9±3.3	60	7.0-24.0	13.8±3.4	0.917
Both male and female	87	6.0-22.0	13.7±3.4	97	6.0-24.0	13.6±3.3	0.768

SD=Standard deviation

Table 3: Tibial plateau angle (°) of both knees in male and female

Parameter	Male	Female	*P*
n	69	115	
Range	6-19.5	6.5-24	
Mean±SD	13.3±3.3	13.9±3.4	0.248

SD=Standard deviation

Table 4: Tibial plateau angle (using similar reference axis) in different population

Authors	Population	Gender	Tibial plateau slope (°)	
			Range	Mean±SD
Moore and Harvey[3]	American	Not specified	7-22	14.0±3.7
Brazier *et al.*[27]	French	Male and female	3.47-20.29	11.4±3.6
Genin *et al.*[29]	French	Male and female	−1-18	7.9±3.2
Didia and Jaja[1]	Nigerians	Male and female	0-24	12.3±4.9
Chiu *et al.*[18]	Chinese	Male and female	5-22	14.7±3.6
Yoo *et al.*[28]	Korean	Female	5-23.2	13.8±3.5
Present study	Indian	Male and female	6-24	13.6±3.5

SD=Standard deviation

Chiu *et al.*[18] studied the slope in donated cadavers from the Chinese population in a radiological method that was comparable to the method of Moore and Harvey,[3] who described the measurement of slope, in knee skiagram of live patients. The results of the study of Chiu *et al.*[18] (range 5°–22°, mean ± SD 14.7° ± 3.6°) were similar to the present study. In the Nigerians,[1] range of variation of the slope was wider (0°–24°) and mean ± SD (12.3° ± 4.9°) was slightly lesser than the present study. In all of the aforesaid studies, measurements were taken from skiagrams.

During literature review, we failed to find a study on the variation of tibial plateau slope in the Indian population, except the work of Kate and Robert,[5] which did not mention the reference axis of measurement of the slope, hence unsuitable for comparison to other studies. Kate and Robert[5] studied the slope in dry bones, so demographic profile of the subject could not be provided. Kate and Robert[5] studied the tibial plateau slope in the dry bones from the Indian population with the help of parallelograph. According to them, the TPA varied from −8° to 25° (mean ± SD 11.75° ± 7°).

Khattak *et al.*[2] studied the variation of TPA (medial and lateral plateau were measured separately) in healthy volunteers from the Pakistani population of both sexes in the true lateral radiographs of the knee joint in a method similar to the present study. However, in their study, they found that medial tibial plateau slope was significantly greater than lateral in female but not in male. The mean medial tibial plateau slope in female was significantly greater than that of male. There was no gender variation in the lateral plateau slope. In the present study, mean value of the slope was not significantly different between genders (male 13.3 ± 3.3, female 13.9 ± 3.4, $P = 0.248$). Sexual dimorphism was not found in the study of Didia and Jaja[1]

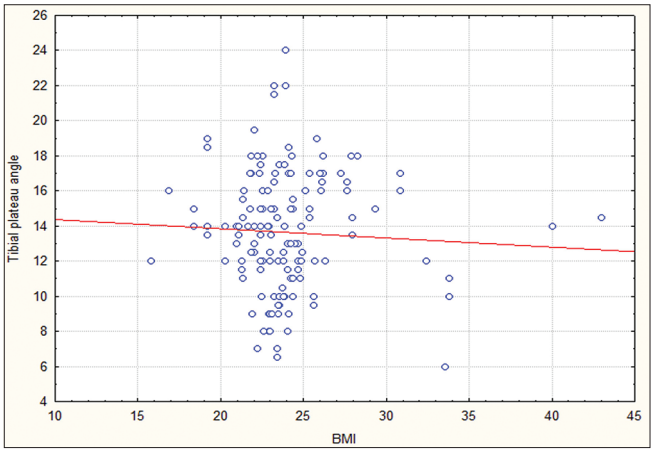

Figure 4: Scatterplot correlating angle of tibial plateau slope with body mass index (BMI) (apparent inverse relation of the angle with the body mass index is not statistically significant)

in the Nigerians [Table 5]. Yoga *et al*.[8] also found no sexual dimorphism in the Malaysians. Separate measurement of medial and lateral plateau was not attempted in the present study as explained later.

Hashemi *et al*.[6] in an MRI study of knee found that both medial and lateral plateau slope were significantly greater in female than in male and lateral tibial plateau slope was significantly more than that of medial one in both sexes. The reference axis used by Hashemi *et al*.[6] was the anatomical axis of the tibial shaft drawn in the sagittal plane. It was different than that used in the present study and others.[1-3,18,27-29]

Variable opinions were found regarding correlation between TPA and age of the subjects. Titze[4] showed that the tibial plateau slope decreased from 27° at birth to 4° at 19 years. According to his opinion, the greater angle at birth was due to acute flexion of the knees of the fetus in the limited space within the uterine cavity. Studies on tibial plateau slope in teenage population were few, which,[7] in contrast to the observations of Titze,[4] showed no association of age with TPA in teenage population with nonunited epiphyses. All the subjects in the present study were skeletally matured. Teenage patients showing nonunion of epiphyseal cartilage were excluded to avoid the effect of possible higher value of their TPA on the entire sample. However, in the present study, age was found not to be correlated with the TPA. Hashemi *et al*.[6] also found similar results in skeletally matured subjects in their MRI-based study.

There was poor correlation between BMI and TPA in the present study. In the literature, no study was found to assess the correlation between BMI and the slope.

Modifications of radiological technique (tibial plateau view) on the basis of tibial plateau slope were described for diagnosis and measurement of displacement of tibial plateau fracture[3] and also for assessment of tibiofemoral osteoarthritic changes.[10] Value of TPA in Indian population as provided in the present study might be helpful to design such studies in radiological modifications in this population.

There were several limitations of the present study. Slope of the medial and lateral plateau, which may differ significantly,[2,6] could not be measured separately because it was considered difficult to measure in the lateral view radiograph.[6] Particularly, separate measurement of the lateral plateau in radiographs was poorly correlated with actual measurement in bones.[18] Therefore, separate measurements of medial and lateral plateau in the lateral view knee radiographs were not attempted in the present study though Khattak *et al*.[2] did so. Further study using MRI or CT scan should be performed in future. Another limitation was that it was a hospital-based study. An important feature in our study was that the patient profiles were very clearly delineated. The subjects of this study were selected from the patient with minor knee problems. Association of TPA with noncontact ACL injury[7,20-25] and advanced tibiofemoral osteoarthritis[13,18,19] are subjected to debate. We excluded the patients whose diseases were known or suspected to be associated with TPA. Jiang *et al*.,[19] in a retrospective study, found no significant difference of the TPA between patient with and without osteoarthritis though Hernigou *et al*.[13] and Chiu *et al*.[18] suggested association between TPA and osteoarthritic tibial bone loss. Advanced osteoarthritis (Kellgren–Lawrence grade >2) was excluded from our study. The patients with slightest clinical suspicion of ACL injury (and of course diagnosed cases of ACL injury) were also excluded from the present study because of the possible association with TPA.[7,20-25] Proper history and combination of four physical examinations (anterior draw test, Lachman test, prone Lachman test, and pivot shift test) were used to exclude ACL rupture because individual history item or physical test was not enough to exclude the probability of ACL injury while in contrast combinations of clinical tests had higher diagnostic accuracy.[31] Ideally, properly selected volunteers who are absolutely free from pathology of knees should be included in the study to reduce or eliminate the sampling error and these subjects must be investigated by a safer imaging technique such as MRI scan (which is definitely costlier). We appreciate that such a small sample may not exactly represent the population, but it is an attempt to through light in this important anatomical aspect in the Indian population.

Table 5: Comparison of tibial plateau angle (°) between male and female in different studies using similar reference axes

Parameter	Mean±SD		
	Didia and Jaja[1]	Khattak *et al*.[2]	Present study
Male	11.9±5.3	12.5±3.7	13.3±3.3
Female	12.4±5.1	14.1±4.5	13.9±3.4
P	>0.05	0.02	0.248

SD=Standard deviation

Conclusion

The present study described the variations of the TPA in a section of the adult Eastern Indian population (range 6°–24°, mean ± SD 13.6° ± 3.5°, no laterality, no sexual dimorphism, poor correlation with age and BMI). Knowledge of this study could be used in different orthopedic surgeries in or around the knee joint (such as high tibial osteotomy, knee arthroplasty, tibial plateau fracture) and also in imaging technique for better visualization of the tibial plateau. Further studies should be performed for better

understanding of the normal anatomy of the slope, its importance in the biomechanics of knee joint, and its association with different diseases.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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