

# Varus Inclination of the Tibial Plateau in Thai Adults: A Concise Radiographic Evaluation

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**Objective:** To identify the normal inclination of the tibial plateau in Thai adults.

**Material and Method:** Anteroposterior knee-to-ankle radiographs of 13 healthy Thai male (26 knees) and 11 healthy Thai female (21 knees) subjects aged 20-40 years were obtained with the x-ray beam angled 10° caudally. A special splint was used for rotational control of the examined limbs. Medial proximal tibial angles (MPTA) were measured. The tibial plateau inclination (TPI) was calculated (90° minus MPTA) and analyzed.

**Results:** The mean age of the male subjects was  $27.9 \pm 2.5$  years and that of the female subjects was  $30.5 \pm 5.4$  years ( $p = 0.173$ ). There was no significant difference in TPI between the male ( $3.2 \pm 1.7^\circ$ , range 0-6°) and female ( $2.5 \pm 2.3^\circ$ , range 0-7°) ( $p = 0.207$ ) subjects. For each gender, there was no significant difference of TPI between the right and the left knees ( $p = 0.656$  and  $p = 0.386$  for men and women, respectively). No correlations of TPI with age, weight, height or BMI were observed in the present study.

**Conclusion:** Through a concise radiographic evaluation, the commonly reported 3° of TPI can be applied in Thai subjects. In clinical use, this finding can assist the surgeons to restore the tibial plateau geometry for fracture treatments and correct the deformity during reconstructive knee surgery.

**Keywords:** Tibial plateau, Medial proximal tibial angle, Thai

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A comprehensive assessment of lower limb alignment, especially in the coronal plane, is important for orthopedic surgeons who perform reconstructive surgery of the knee. In osteoarthritic knees, the coronal limb alignment can predict the progression of disease<sup>(1,2)</sup>. Furthermore, poor alignment after high tibial osteotomy and total knee arthroplasty has been reported to correlate with higher complication and failure rates<sup>(4-9)</sup>. Anatomical inclination of the tibial plateau, which determines the obliquity of the knee-joint surface, is one of the contributing factors that affect limb alignment and realignment procedures. Although normal values for this inclination (range 0.1-5.5° of medial inclination) have been reported in several studies that involved populations of various sex, race and geographic differences<sup>(10-12)</sup>, no similar studies have been performed in Thai adults. Furthermore, using weight-bearing films of the entire lower limbs in those

studies<sup>(10-12)</sup>, which was difficult to control the limb rotation and x-ray beam direction, might not be suitable for evaluation of the tibial plateau inclination.

The present study therefore aimed to identify the normal inclination of the tibial plateau in Thai adults with the new concise radiographic evaluation.

## Material and Method

Between July and August, 2009, healthy Thai volunteers who were aged 20-40 years were included in the present study. The exclusion criteria were knee pain, a history of knee injury, any knee or ankle disorders. Finally, 13 males (26 knees) and 11 females (21 knees) were available for the present study, which was approved by the Ethics Committee of Siriraj Hospital.

## Radiographic evaluation

All subjects were asked to lie down and wear the specially designed splint with their knees fully extended. This splint consists of a plastic brace portion that is attached to a reinforcing wooden portion. Two Velcro straps at the lower third of the thigh and the proximal half of the leg were used to control the lower

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extremity rotation, which aimed to position the patella facing forward. At the ankle level, another plastic brace was attached for maintaining the ankle in the neutral position (90° of dorsiflexion) (Fig. 1). A supine anteroposterior knee-to-ankle digital radiograph was obtained with the x-ray beam angled 10° toward the foot of the patient (Fig. 1). A cassette was placed immediately behind the leg. The distance between the x-ray tube and the cassette was 0.6 meters. Radiographic adequacy was defined when one-fifth of the patella was centered over the femoral condyles and the tibiotalar articular surfaces were parallel.

The digital films were interpreted using the measurement tools of patient archiving and communication system (PACS). The center of the knee was identified as the midpoint between the tips of the tibial spines (Fig. 2) whereas the center of the ankle was identified as the center of the talus at the level of subchondral bone<sup>(10)</sup> (Fig. 2). A line connecting those two centers represented the tibial mechanical axis (TMA). Next, the medial proximal tibial angle (MPTA)<sup>(13)</sup>, which is formed by a line tangent to the

tibial plateau and the anatomical axis of the tibia, was measured (Fig. 2). Finally, the degrees of tibial plateau inclination (TPI) was calculated as 90° minus the degrees of MPTA and recorded as the primary outcome. A positive value represented medial or varus inclination, and a negative value represented lateral or valgus inclination.

#### Statistical analysis

The data were analyzed using the commercially available SPSS statistics software, version 13.0. Data are expressed as the mean  $\pm$  SD for continuous variables whereas the categorical variables are presented as frequencies and percentages. The differences in the quantitative and qualitative data were analyzed using the unpaired Student's t-test and the Chi-square test, respectively. Pearson correlation coefficient was used to determine the correlation between the degrees of TPI and the subjects' demographics. Differences with p-values less than 0.05 were regarded as statistically significant. The intra- and inter-observer reliability in measuring the radiographic



**Fig. 1** The picture demonstrates the radiographic method to obtain a supine anteroposterior knee-to-ankle film with the x-ray beam angled 10° caudally



**Fig. 2** The radiograph shows the identification of (A) the center of the knee (CK), (B) the center of the ankle (CA) and (C) the tibial mechanical axis (TMA) and the medial proximal tibia angle (MPTA) measurement

outcome of the two investigators was expressed as intraclass correlation coefficients (ICCs).

## Results

The subjects' characteristics are shown in Table 1. The mean age of the male volunteers was  $27.9 \pm 2.5$  years and that of the female volunteers was  $30.5 \pm 5.4$  years ( $p = 0.173$ ). Male subjects had slightly higher body mass index (BMI) than the female subjects. In radiographic assessment, the TPI of the males had a mean of  $3.2 \pm 1.7^\circ$  (range  $0-6^\circ$ ) whereas those of the females had a mean of  $2.5 \pm 2.3^\circ$  (range  $0-7^\circ$ ) (Table 2). However, there was no significant difference between these groups ( $p = 0.207$ ). Considering the TPI within

each gender, although the right knees had slightly more varus TPI than the left knees (Table 2), the differences were not statistically significant ( $p = 0.656$  and  $0.386$  for males and females, respectively). In further analysis, Pearson's correlations coefficients did not demonstrate any correlations between the degrees of TPI and the subjects' characteristics ( $p > 0.05$ ). Furthermore, for the reliability of the measurements, ICCs of more than 0.9 were expressed as either intra- or inter-rater agreement.

## Discussion

Knowledge of the normal anatomy of the lower extremity is very important for orthopaedic

**Table 1.** Patient Characteristics

Characteristics	Male (n = 13)	Female (n = 11)	p-value
Age (yrs)*	$27.9 \pm 2.5$	$30.5 \pm 5.4$	0.173
Side (Right: Left)	13: 13	11: 10	0.896
Weight (kgs)*	$73.1 \pm 8.6$	$55.7 \pm 10.4$	< 0.001
Height (cms)*	$174.2 \pm 5.9$	$157.6 \pm 6.3$	< 0.001
BMI (kg/m <sup>2</sup> )*	$24.1 \pm 2.9$	$22.5 \pm 4.5$	0.322

\* The values are presented as the mean and the standard deviation  
 BMI = Body mass index

**Table 2.** Comparison of Tibial Plateau Inclination in Caucasian, Chinese and Thai Adults\*

Races	The series of	Men			Women		
		Right	Left	Both	Right	Left	Both
Caucasian	Moreland et al <sup>(11,****)</sup>	$3.0 \pm 1.6$	$2.6 \pm 1.4$	-	-	-	-
	Hsu et al <sup>(12,****)</sup>	-	-	$1.0 \pm 1.4^{**}$	-	-	$0.1 \pm 1.9^{**}$
	Harvey et al <sup>(16,*****)</sup> (FOA)	-	-	$1.5^{***}$	-	-	$1.6^{***}$
Chinese	Bellemans et al <sup>(17,*****)</sup>	-	-	$3.5 \pm 2.2$	-	-	$2.4 \pm 1.8$
	Tang et al <sup>(10,*****)</sup>	$4.7 \pm 2.5^{**}$	$5.0 \pm 2.2^{**}$	$4.9 \pm 2.3^{**}$	$5.3 \pm 2.5^{**}$	$5.5 \pm 2.5^{**}$	$5.4 \pm 2.5^{**}$
Thai	Harvey et al <sup>(16,*****)</sup> (BOA)	-	-	$1.3^{***}$	-	-	$1.6^{***}$
	Current study	$3.4 \pm 1.8$	$3.1 \pm 1.8$	$3.2 \pm 1.7$	$2.9 \pm 2.4$	$2.0 \pm 2.2$	$2.5 \pm 2.3$

\* The values are presented as the mean and the standard deviation

\*\* The values are significantly different from those in the current study ( $p < 0.05$ )

\*\*\* The values are presented as the mean

\*\*\*\* The authors study 25 male subjects

\*\*\*\*\* The authors study 30 male and 30 female subjects

\*\*\*\*\* The authors study 97 male and 134 female subjects from Framingham Osteoarthritis Study (FOA); and 166 male and 173 female subjects from Beijing Osteoarthritis Study (BOA)

\*\*\*\*\* The authors study 250 male and 250 female subjects

\*\*\*\*\* The authors study 25 male and 25 female subjects

surgeons. Many orthopaedic procedures, such as the correction of deformities and total joint arthroplasty, require the applications of this anatomical knowledge. TPI is one of the most commonly used anatomical measurements, especially for reconstructive knee surgery. Although a 3-degree varus inclination of the knee-joint surface with reference to the mechanical axis of the tibia, which was documented by Hungerford<sup>(14)</sup> and Insall et al<sup>(15)</sup>, was often reported, a variation of the TPI that ranged from 0.1 to 5.4 degrees has been reported in previous studies<sup>(10-12,16)</sup>. To the best of our knowledge, there was no similar study performed in Thai adults. The authors therefore aimed to determine the normal TPI value in Thai adults by using the new concise radiographic method.

In the present study, the tibial plateau of the Thai subjects had a medial or varus inclination of  $3.2 \pm 1.7^\circ$  (range 0-6°) in men and  $2.5 \pm 2.3^\circ$  (range 0-7°) in women. These values were similar to those of the Caucasian subjects in the studies by Moreland<sup>(11)</sup> ( $p = 0.406$  and  $0.275$  for right and left knees in men, respectively) and Bellemans et al<sup>(17)</sup> ( $p = 0.500$  and  $0.811$  for men and women, respectively); however, Hsu et al<sup>(12)</sup>, who also studied Caucasian subjects, reported significantly lower TPI values ( $p < 0.001$  for both men or women). Additionally, in Chinese subjects, Tang et al<sup>(10)</sup> reported a mean TPI of  $4.9^\circ$  in men and  $5.4^\circ$  in women that are significantly larger than those in the current study ( $p = 0.004$  and  $< 0.001$  for men and women, respectively). The comparison of TPI among different races is summarized in Table 2. Unlike the study by Hsu et al<sup>(12)</sup>, no significant difference in the TPI between the genders was observed in the present study.

All previous studies<sup>(10-12,16,17)</sup> measured the radiologic values using weight-bearing films of the entire lower limbs. Although this method was considered to be the gold standard for the measurement of limb alignment, it might not be suitable for the evaluation of TPI. The limb rotation was proven to affect the MPTA measurement<sup>(18)</sup>; however, the authors believe that the posterior tibial slope makes the MPTA measurement more difficult because of the superimposition between the anterior and posterior parts of the tibial plateau. The authors thus created a special splint to control the limb rotation and angled the x-rays beam  $10^\circ$  caudally, according to a study of the posterior tibial slope in normal Japanese knees by Matsuda et al<sup>(19)</sup>. With this technique, the authors easily identified the articular surface of the tibial plateau.

These findings can be applied in clinical practice because the normal TPI value in Thai subjects

can be used to determine whether a knee deformities originated in the proximal tibia and to restore the tibial plateau geometry in patients with tibial plateau fractures. Furthermore, the present study confirmed the  $3^\circ$  externally rotated placement of the femoral component to produce a rectangular flexion gap in a mechanical model of total knee arthroplasty<sup>(20)</sup>.

Although the sample size of our study seems to be small, a power analysis indicates that it was sufficient to detect a distance from mean to a limit of  $1^\circ$  ( $\pm = 0.05$ , two-sided significance level). The authors thought that the detection of  $\pm 1^\circ$  difference of TPI was sufficient for the application in clinical practice. Nevertheless, there were several limitations in the present study. First, the authors did not assess another radiologic alignment values (e.g. the femorotibial angle or posterior tibial slope) that have also never been studied in Thai subjects. Second, there was no comparison between the measured MPTAs of the anteroposterior and tangent views of the knees. The authors also didn't know which view gives more accurate data when compared to the true anatomy. Finally, the present study focused only on the healthy subjects. The further study in osteoarthritic Thai patients should not be ignored.

In conclusion, to the best of our knowledge, this is the first study on TPI evaluation in Thai adults. Through a concise radiographic evaluation, the commonly reported  $3^\circ$  of TPI can be applied in Thai subjects.

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#### Potential conflicts of interest

None.

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## การศึกษาหามุมลาดเอียงเข้าในของหัวกระดูกหน้าแข้งในคนไทยโดยประเมินจากการถ่ายภาพรังสี

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**วัตถุประสงค์:** เพื่อศึกษาหามุมลาดเอียงเข้าในของหัวกระดูกหน้าแข้งในคนไทย

**วัสดุและวิธีการ:** จากการถ่ายภาพทางรังสีตั้งแต่ข้อเข่าถึงข้อเท้าในแนวหน้า-หลัง ของผู้ชายไทย 13 คน (26 เข่า) และผู้หญิงไทย 11 คน (21 เข่า) ที่มีอายุตั้งแต่ 20-40 ปี โดยจัดให้ลำแสงเอกซเรย์ทำมุม 10 องศา ไปทางเท้า และควบคุมการบิดหมุนของขาด้วยอุปกรณ์ตามชนิดพิเศษ นำภาพถ่ายที่ได้มาทำการวัดมุม medial proximal tibial angle (MPTA) แล้วทำการคำนวณวิเคราะห์หาค่ามุมลาดเอียงเข้าในของหัวกระดูกหน้าแข้งในคนไทย

**ผลการศึกษา:** อายุเฉลี่ยของผู้ชายไทยที่เข้าร่วมการศึกษาเท่ากับ  $27.9 \pm 2.5$  ปี และผู้หญิงไทยเท่ากับ  $30.5 \pm 5.4$  ปี โดยไม่พบความแตกต่างอย่างมีนัยสำคัญของค่ามุมลาดเอียงเข้าในของหัวกระดูกหน้าแข้งระหว่างผู้ชาย ( $3.2 \pm 1.7^\circ$ , พบช่วงตั้งแต่  $0-6^\circ$ ) และผู้หญิง ( $2.5 \pm 2.3^\circ$ , พบช่วงตั้งแต่  $0-7^\circ$ ) เมื่อวิเคราะห์ในแต่ละเพศพบว่า เข่าข้างขวา จะมีค่ามุมลาดเอียงมากกว่าเข่าซ้ายเล็กน้อย ( $p = 0.656$  และ  $p = 0.386$  สำหรับเพศชายและหญิงตามลำดับ) และการศึกษาไม่พบความสัมพันธ์ของค่ามุมลาดเอียงกับ อายุ น้ำหนัก ส่วนสูง หรือ ดัชนีมวลกาย

**สรุป:** จากการทบทวนการศึกษาที่ผ่านมา พบว่าการศึกษานี้เป็นการศึกษาแรกที่ทำการศึกษาหาค่ามุมลาดเอียงของหัวกระดูกหน้าแข้งในคนไทย โดยประเมินจากภาพถ่ายรังสีที่ถ่ายด้วยวิธีใหม่ และผลการศึกษาที่ได้พบว่า ค่ามุมลาดเอียงที่  $3^\circ$  ซึ่งใช้กันโดยทั่วไป สามารถนำมาประยุกต์ใช้ในผิวกระดูกหน้าแข้งในคนไทยได้

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