

## Anatomic Variation of Posterior Slope of Tibial Plateau in Adults

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### ABSTRACT

#### Introduction

Posterior tibial slope (PTS) is the tilt bore by the tibial plateau posteriorly and inferiorly relative to the long axis of the shaft of tibia. Mean PTS in each population is imperative to keep within the normal range as possible for good outcome of different surgeries around the knee. Measurement of the PTS using plain radiograph is a cost effective, facile approach and can be done without the use of advanced imaging modalities.

#### Methods

A prospective observational study was done from January to December 2020. Patients presenting to Outpatient Department at National Trauma Center, NAMS with minor knee problems like soft tissue injury, pain, and stiffness were included in the study. PTS was measured via software on a true lateral radiograph of affected knee and its mean value was correlated with parameters, namely, age, sex, BMI, laterality, and race.

#### Results

Mean PTS was  $10.35^{\circ} \pm 2.03^{\circ}$  (range 3-14<sup>o</sup>) in the study size of 185. The mean age of study population was  $41.25 \pm 15$  years (range: 19-73 years). There were 96 males and 89 females in the study. Mean PTS in males was  $10.65^{\circ} \pm 2.04^{\circ}$  while that in females was  $10.03^{\circ} \pm 1.97^{\circ}$ . The mean BMI of individuals in this study was  $25.3 \pm 2.61$  kg/m<sup>2</sup>. There was no statistically significant correlation of PTS with age, sex, BMI, laterality, and ethnicity.

#### Conclusion

Posterior tibial slope in adults is not influenced by sex, BMI, side, ethnicity or advancing age.

#### Keywords

Anterior cruciate ligament, lateral knee radiograph, knee, posterior tibial slope

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## INTRODUCTION

The tibial plateau bears a slope directed posteriorly and inferiorly relative to the long axis of the shaft of tibia.<sup>1</sup> Studies note that the normal posterior tibial slope (PTS) is between -5 and 24 degrees.<sup>2,3</sup>

It is obtained by measuring the angle between the tangent to the tibial plateau and the perpendicular to the middle part of the diaphysis of the tibia.<sup>4</sup> PTS has been assessed using various methods ranging from direct cadaveric measurements and plain radiographs to computed tomography (CT) scans and magnetic resonance imaging (MRI).

The geometry of tibial plateau directly affects tibiofemoral biomechanics in terms of translation, screw home mechanism, and location of instantaneous center of rotation.<sup>5</sup> It has been shown that increasing PTS increases the tibial shear force and anterior tibial translation at the knee.<sup>6</sup> Hence it is imperative to keep PTS as close to normal range for best possible outcomes after ACL reconstruction, high tibial osteotomy, and knee replacement.

On the other hand, a decrease in PTS, increases strain in the posterior cruciate ligament (PCL), and may lead to failure of PCL reconstruction surgeries<sup>7</sup> and total knee arthroplasty.<sup>8</sup>

## METHODS

A prospective observational study was done from January to December 2020 at the Department of Orthopedics and Trauma Surgery, National Trauma Center, Kathmandu. An ethical approval from National Academy of Medical Sciences (NAMS) was taken prior to the study. Informed consent was obtained from all patients. Patients with minor knee problems like soft tissue injury, pain and stiffness were included in the study. Patients with congenital anomaly, deformity, dislocation, fracture, ligamentous injury, rheumatoid arthritis and advanced osteoarthritis (OA grade more than 2 on Kellgren Lawrence Scale) were excluded from this study. Patients below 18 years were not included because of the potential of open physis. Primary objective of the study was to calculate the PTS in adults. The secondary objectives were to compare laterality and assess association of other variables (age, sexual dimorphism, BMI, and ethnicity).

True lateral radiograph (showing superimposition of the femoral condyles) of the knee joint of the selected subjects was taken by radiographers, using same X-ray machine. The patients lied on the same side of the affected knee, which was flexed to about 25°-30°. The central X-ray beam was directed vertically towards the medial aspect of the knee joint, with about 5°-7° cephalad angulation.

In true lateral radiograph of the knee, medial and



Figure 1. Diagram showing measurement of PTS on lateral radiograph of knee

lateral plateau almost overlap. Hence the slope that is measured is a two-dimensional estimate of complex and skewed three-dimensional surface. Thus, the difference between medial and lateral plateau slope can be ignored in this view.

After obtaining the radiograph, a line parallel to the middle part of the diaphysis of the tibia was drawn and another line that is perpendicular to the middle part of the diaphysis and passing through the tibial plateau was drawn. Then, a third line representing the posterior slope of the tibia was drawn. Angle between the third and second line was considered the PTS.

All PTS measurements were carried out by single observer using Carestream Image Suite version 4.0.0.0.052 (Manufactured by Carestream Health Inc., 150 Verona Street, Rochester, NY 14608, USA)

Age, sex, ethnicity of the patient was recorded. 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.

Since, Nepal is an ethnically diverse country, with many castes and sub-caste, each having their own cults, we have included only Aryans and Non-Aryans as two major ethnicities after taking individual patient statement.

The collected data was stored and analyzed with statistical software (SPSS version 25.0 for windows) to get final interpretation. The results were expressed in mean  $\pm$  SD for the quantitative (continuous) data and t-test was used to correlate PTS with study variables. Significance was assumed for  $p < 0.05$ .

**RESULTS**

A total of 185 X-rays of same number of patients were studied. Mean PTS was  $10.35^0 \pm 2.03^0$  (range 3-14<sup>0</sup>) in this study. There were 96 (51.9%) males and 89 (48.1%) females. Mean age was  $41.25 \pm 15$  years and range was 19-73 years (Table 1). Mean PTS in males was  $10.65^0 \pm 2.04^0$  while that in females was  $10.03^0 \pm 1.97^0$ .

Table 1. Age distribution of the study population

Age	Number	Percentage	Mean PTS	p-value
18-30	50	27.03	$9.91 \pm 2.23$	0.99
31-40	56	30.27	$9.95 \pm 1.92$	
41-50	29	15.68	$10.48 \pm 1.71$	
51-60	23	12.43	$11.39 \pm 1.64$	
61-70	16	8.65	$11.43 \pm 1.5$	
>70	11	5.95	$10.31 \pm 2.32$	

X-Rays of 94 left and 91 right knees were taken. Mean PTS in right knee was  $10.22^0 \pm 2.19^0$  while that in left knee was  $10.48^0 \pm 1.86^0$ .

The mean BMI of individuals in this study was  $25.3 \pm 2.61$  kg/m<sup>2</sup>. There were 10 (5.4%) underweight, 72 (38.91%) pre-obese, and 5 (2.72%) obese patients.

X-Rays of 88 Aryans and 97 non-Aryans were studied. Mean PTS in Aryans was  $10.3^0 \pm 1.97^0$  while that in non-Aryans was  $10.39^0 \pm 2.08^0$ .

There was no statistically significant correlation of PTS with age (p-value= 0.99), sex (p-value =0.87), laterality (p-value: 0.37), BMI (p-value = 0.07) and ethnicity (p-value= 0.76) (Figure 1).

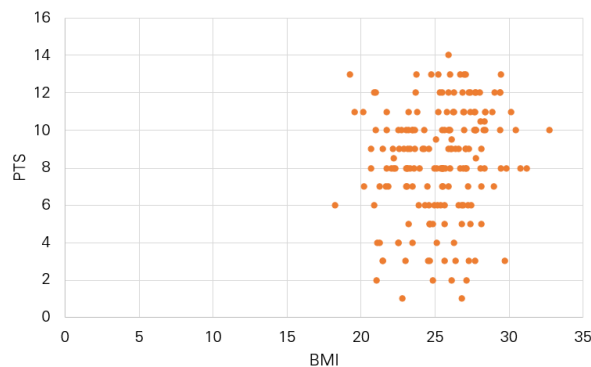


Figure 2. Scatterplot representing PTS with BMI

**DISCUSSION**

PTS is a significant entity, both scientifically and economically, because of the increase in number of increasing knee replacement surgeries and its role in maintaining lower limb mechanical alignment.<sup>9</sup>

Our finding of PTS of  $10.35^0 \pm 2.03^0$  is similar to the findings of Nekkanti S.et.al.<sup>2</sup>, Yoga et.al.<sup>3</sup> and

Yoo et.al.<sup>10</sup> However, it is lesser than the findings of Medda S, et.al.<sup>11</sup> ( $13.6^0 \pm 3.5^0$ ; range 6-24<sup>0</sup>) in east Indian population and Aljuhani W et.al.<sup>24</sup> in Saudi Arabians.

Moore et al. reported the PTS of  $14 \pm 3.7^0$  (range: 7-22<sup>0</sup>) in 50 Americans.<sup>12</sup> Similarly, Matsuda et al. obtained this value to be about  $10.7^0$  (range: 5-15.5<sup>0</sup>) in 30 Japanese patients.<sup>13</sup>

Similar studies have been done many countries like China<sup>14</sup> ( $14.7^0 \pm 3.7^0$ ; range, 5<sup>0</sup>-22<sup>0</sup>), Pakistan<sup>15</sup>, UK<sup>16</sup>, Switzerland<sup>17</sup>, and Iran.<sup>18,19</sup>

We used anterior cortical line for the measurement of PTS, also used by several authors.<sup>14,20,21</sup> However, Weinberg et al.<sup>22</sup> took for reference the center of the first third of the tibial shaft, and Han et al.<sup>23</sup> published results with four different axes: mechanical axis, anatomic axis, anterior cortices, and fibular shaft axis.

In this study, no significant correlation was found between PTS and age. It was similar to the finding of Titze<sup>25</sup> showed that PTS decreased from birth (~270) to adults (~40 at 19 years). In his opinion, greater angle at birth was due to acute knee flexion in limited space in the uterus. However, his finding was contrasted by Vyas et.al.<sup>26</sup>

Gender based differences in PTS have also been well studied. In this study, there was no significant difference in PTS between two genders. Similar findings have been reported in Indians.<sup>2,11</sup> However, there was significant difference in PTS in Pakistanis<sup>15</sup> and Americans<sup>22</sup> where females had more PTS than males. Gender differences could be related to the higher incidence of ACL rupture in females.<sup>27</sup>

Alike to the findings of Medda et.al.<sup>11</sup>, there was no significant variation between PTS and the side of the knee examined in this study.

There was no significant association between PTS and BMI in the present study. Medda S. et.al.<sup>11</sup> also revealed poor correlation between the two variables in their study.

In this study, there was no significant statistical difference in the PTS of the races studied. This finding was similar to that of Yoga R et.al.<sup>3</sup> As per deBoer<sup>28</sup>, ethnicity effects may in part be held responsible for the large range of posterior slope angles. Several studies have compared the PTS between Asians and Caucasians with varying results.<sup>16,23</sup>

There were some limitations in this study. Firstly, medial, and lateral posterior tibial slope was not measured separately. Numerous authors claimed the need for separate assessment of both plateaus because of large differences observed in cadaveric and radiologic studies.<sup>10,29</sup> Because of superimposition, the lateral PTS is difficult to identify, and separate assessment of the plateaus

Table 2. Posterior tibial slope (using similar reference axis) in various populations

Authors	Population	PTS (°)	
		Range	Mean ± SD
Medda S. et.al. <sup>11</sup>	East Indian	6-24	13.6±3.5
Nekkanti S. et.al. <sup>2</sup>	South Indian	-5 - 21	10.37°±4.59°
Moore and Harvey <sup>12</sup>	American	7-22	14.0±3.7
Yoo et.al. <sup>10</sup>	South Korean	5-23.2	13.8±3.5
Aljuhani W et.al. <sup>24</sup>	Saudi Arabian	3.8-23.9°	13.6 ± 3.4

is not reliably possible on true lateral radiographs.<sup>4,30</sup> Further, lateral slope had poor correlation with actual measurement in the study by Chiu et.al.<sup>14</sup>

In this study, anterior cortical line was used as the reference axis. However, PTS using other axes must be used and compared with the former to ascertain any significant differences.

Another limitation of this study was that PTS was calculated using plain radiograph only. We did not use CT scan or MRI for studying the PTS. Further study using MRI or CT scan should be performed in future and correlated.

Another limitation was that it was a hospital-based study. However, an important feature in our study was that the patient profiles were very clearly delineated.

Similarly, the relationship of increased PTS to ACL and PCL injury as well as osteoarthritis was not studied, which is a recent area of interest.

## CONCLUSION

The present study provided a reference range for the physiological values of PTS in adults with healthy knee. There was no association between the PTS angle and age, BMI, side, and ethnicity. The PTS value did not significantly differ between males and females.

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## CONFLICT OF INTEREST

The author(s) declare that they do not have any conflicts of interest with respect to the research, authorship, and/or publication of this article.

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