

Full-length Research Article

Radiographic Evaluation of Posterior Tibial Slope Angle: Its Relationship with Socio-Demographic Factors and Effects on Knee Function

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Summary: Major activities in life depend on the proper function of the knees, which in turn is determined by the posterior tibial slope angle (PTSA) of the knee. However, beyond certain degrees of PTSA the likelihood of the risk for tears in the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL) and menisci increases, which consequently impairs knee joint functions. The objectives of this study were to determine PTSA, its relationship with sociodemographic factors and effect on subjective knee joint function using Tegner activity scale. This was a prospective cross-sectional observational study that was conducted in the Radiology Department of a Tertiary hospital over a 6-months period. PTSA of the lateral radiographs of 152 subjects were evaluated. Tegner activity scale was administered on each subject to subjectively ascertain knee joint function. Chi square and Pearson's correlation were used to analyze the data. Mean PTSA for the right and left knees were $11.03 \pm 0.25^{\circ}$ (SEM) and $11.02 \pm 0.26^{\circ}$ (SEM). Age and body mass index (BMI) significantly correlated with right PTSA ($r = 0.404$, $P = 0.000$ and $r = -0.853$, $P = 0.000$) and left PTSA ($r = 0.408$, $P =$ and $r = -0.818$, $P = 0.000$). Mean Tegner activity scale was 8.47 ± 0.38 (SEM) and the mean BMI was 24.06 ± 0.29 kg/m² (SEM). It is concluded that mean PTSA in this study is similar to that obtained in other populations and has a significant relationship with age and BMI, and maintaining normal weight significantly positively affects PTSA to ensure optimal knee functions. This study offers regional data to assist Orthopaedic surgeons on knee ligaments evaluation and reconstruction procedures.

Keywords: Posterior tibial slope, lateral knee radiograph, knee function, tibia, knee biomechanics.

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INTRODUCTION

A great proportion of our daily activities in life depends on a perfectly functional knee joint. The knee function includes weight bearing, absorbing and adjusting pressures and blows during working, running, jumping and maintaining the position (Karimi *et al.*, 2017; Al Badwi *et al.*, 2023). Posterior tibial slope angle (PTSA) plays a crucial role in the stability and biomechanics of the knee joint. Changes in this angle has a significant effect on knee function and various pathologies in the knee have also been reported to be associated with it (Karimi *et al.*, 2017; Hassa *et al.*, 2023).

The increase in PTSA is accompanied by an increased risk of anterior cruciate ligament (ACL) tear, knee instability, progressive loosening of the tibio-fibular joint gap as a result of decreased collateral ligament tension during flexion, increased likelihood of medial meniscal posterior root tears and the development of spontaneous osteonecrosis of the knee (Koga *et al.*, 2022; Aljuhani *et al.*,

2020; Karimi *et al.*, 2017; Hassa *et al.*, 2023). On a beneficial note, increased PTSA ensures the attainment of a full range of motion in the knee of an individual which enhances excellent performance of general physical activity. At the other end of the spectrum, a reduced PTSA increases the strain on the posterior cruciate ligament following total knee arthroplasty and may be a contributing factor in failed PCL surgeries (Aljuhani *et al.*, 2020; Thirunarayanan *et al.*, 2021; Shelburne *et al.*, 2011; Pangaud *et al.*, 2020). Poorly managed PCL strain or injury results in the development of medial femoral osteoarthritis and patellar osteoarthritis (Yang *et al.*, 2023).

The essence of evaluating PTSA is due to the rising number of knee reconstruction surgeries globally, especially knee joint replacements and the important role of maintaining normal lower limb angles to maintain the fundamental functions of the joints (Karimi *et al.*, 2017). Evaluation of PTSA has major applications in total knee arthroplasty (TKA), high tibial osteotomy (HTO) and

anterior cruciate ligament (ACL) reconstruction surgery (Chen *et al.*, 2022). An increase in the medial and lateral PTSA by 10 leads to a 1.24-fold and 1.17-fold increase in graft failure, respectively, and the risk of graft failure is substantial in high PTSA which is extremely undesirable. To achieve perfect outcomes in knee function following surgeries, PTSA needs to be precise for a given population (Kasman *et al.*, 2023). Socio-demographics such as ethnicity, age, gender and body mass index are important factors that play important roles in the modification of the PTSA and by implication, knee joint function (Bisicchia *et al.*, 2017).

Tegner activity scale is a standardized method for grading knee function and it requires individuals to select their level of sports participation which best describes their current level of activity. Although originally utilized for patients with ACL injury, it has been modified for normal populations. In addition, it significantly correlates with other equally reliable knee function evaluation tests (McHugh *et al.*, 2020). Patient-reported-outcome-measures (PROMs) such as Tegner activity scale, have been demonstrated to effectively differentiate favourable outcomes, in terms of knee joint functions, and unfavourable outcomes (Hung *et al.*, 2024).

There is a significant correlation between conventional radiograph evaluated PTSA and 3-D evaluated PTSA, employing either a CT scan or MRI, with an average error of about 3.400. Moreover, the costs of CT and MRI scans are expensive for clients and besides, they are not readily available in many climes (Bisicchia *et al.*, 2017).

The findings of this study will be of immense assistance to orthopaedic surgeons by way of identifying patients that may be at a great risk of ACL & PCL injury and tailor PTSA reconstruction that is within the normal range to obtain optimal knee function. Therefore, it is pertinent for Orthopaedic surgeons to have knowledge of the average PTSA of indigenes in this locality.

This study was aimed at determining Posterior tibial slope angle, its relationship with sociodemographic factors and effect on subjective knee joint function using Tegner activity scale.

MATERIALS AND METHODS

Study design: This was a prospective cross-sectional observational study that was conducted in the Radiology Department of a tertiary health facility located in the South-south region of Nigeria. The five-month study commenced from June 2023 to November 2023. The study population consisted of the patients requested to conduct knee radiographs in the Radiology Department. Approval for this

study was obtained from the institutional review board (IRB), and all subjects involved gave consent before inclusion in the study.

Exclusion criteria: Below 18 years of age, previous and recent bone fractures around the knee, congenital bone anomalies, bone tumours, osteomyelitis, obvious lower limb soft tissue swelling, knee osteoarthritis, surgical implants around the knee, diagnosed ACL injuries, previous knee joint surgery and presence of foreign bodies around the evaluated knee radiograph.

Sampling technique and sample size: Purposive sampling technique was utilised for the study. One hundred and fifty-two subjects were subsequently recruited.

Clinical assessment: Medical history including body mass index (BMI) was obtained from the consenting subjects. Tegner activity scale evaluation questionnaires were administered to the subjects to record their knee function scores (McHugh *et al.*, 2020). The knees of the subjects were clinically assessed, and anterior drawer test and pivot shift test were done to rule out ACL injury or deficiency (Singh *et al.*, 2023).

Radiographic technique and PTSA evaluation: The radiographic technique was standardized for all the subjects. Antero-posterior and lateral view radiographs with superimposed condyles were obtained from the subjects using BRIVO XR575 X-ray machine in the Radiology Department, but only the lateral views were utilized for this study.

To acquire the lateral view radiographs, the subjects were positioned with the knees flexed at approximately 25 - 30°. The central x-ray beam was directed vertically towards the medial aspects of the knee joint with a cephalad angulation of about 5 - 7° (Singh *et al.*, 2023).

Measurement of the PTSA was done manually using the anterior tibial cortex method on a digital viewer. A straight line was drawn through the anterior cortex of the tibial shaft and it was extended proximally to be intersected by a second straight line drawn tangential to the proximal tibial articular surface connecting the anterior and posterior ends of the 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 is the PTSA (Figure 1). The authors who measured the posterior tibial slope angles of the subjects' lateral knee radiographs were different from the ones who administered the Tegner activity scale questionnaire.

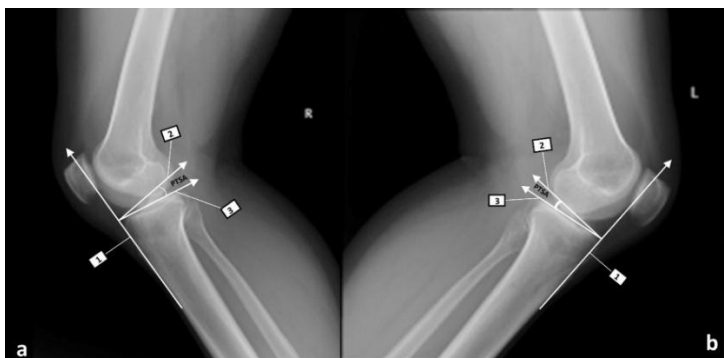


Plate 1:

Lateral radiographs of the right knee (a) and left knee (b). 1 – Anterior cortical line. 2 – Line perpendicular to line 1. 3 – Tangential line to the tibial plateau. PTSA – Posterior tibial slope angle

Statistical analysis: The statistical packages for social sciences version 23 (SPSS Inc., Chicago, IL, USA) was employed to analyze the data obtained. The values were reported as means ± standard error of mean (SEM). Appropriate tables were the means of displaying results where applicable. Chi square analysis and ANOVA were done to assess the relationship of all the variables with right and left PTSA, respectively and to measure the differences in the values of these variables. P value < 0.05 was considered statistically significant

RESULTS

The study group consisted of 41 males and 111 females. Most of the subjects were married (78.95%), had tertiary education (65.13%) and employed (61.33%). Few subjects were widowed (6.58%) and divorced (1.97%), about one-third of the subjects had secondary education (34.87%) and slightly above one-third of the subjects were unemployed (38.67%). No subject had primary education (0%). Gender (P = 0.416 and P = 0.62), was not significantly associated with Right PTSA and Left PTSA (Table 1).

Right PTSA and left PTSA ranges from 4.00⁰ to 16.00⁰, respectively. The least age of the subjects was 18 years while the oldest was 61 years. Age significantly correlated with right PTSA (r = 0.404, P = 0.000) and left PTSA (r = 0.408, P = 0.000) and in both instances the correlation strength was moderate. BMI also significantly correlated with both the right PTSA (r = -0.853, P = 0.000) and left PTSA (r = -0.818, P = 0.000) negatively but with a high strength respectively. Tegner activity scale ranged from 5.32 to 9.10 with a mean value of 8.47±0.38 (SEM) (Table 2).

The 34 – 49 years age group had the highest frequency (57.90%) while ≥50 years age group had the least frequency of subjects (11.84%). The right PTSA and left PTSA progressively increased with the age groups and the

difference in the mean values of the angles at these different age groups were significant (P = 0.002, respectively). The highest Tegner activity scale was 7.83±0.28 (SEM) and it was noted in the 34 – 49 years age group while the least, which was 7.21±0.56 (SEM), was noted in the 18 - 33 years age group (Table 3).

Table 1:

Association of categorical sociodemographic variables with right and left PTSA

	n, (%)	Right PTSA (°)		Left PTSA (°)	
		df	P value	df	P value
Gender					
Male	41 (26.97)	11	0.416	12	0.662
Female	111 (73.03)				
Marital status					
Married	120(78.95)	22	0.058	36	0.066
Single	19 (12.50)				
Divorced	3 (1.97)				
Widowed	10 (6.58)				
Educational status					
Primary	0 (0)	11	0.668	12	0.144
Secondary	53 (34.87)				
Tertiary	99 (65.13)				
Employment status					
Employed	92 (61.33)	11	0.054	12	0.038
Unemployed	60 (38.67)				

(*) – P value less than 0.05 is significant; PTSA – Posterior tibial slope angle.

Most of the subjects had normal weight (42.76%) while few of the subjects were obese (24.34%). Obese subjects were noted to have the least mean right PTSA (8.64±0.30⁰ (SEM)) and mean left PTSA (8.86±0.27⁰ (SEM)) and the difference in the mean values of the right and left PTSA in the various BMI groups were significant (P = 0.000, respectively). Tegner activity scale was highest in the normal weight group (8.39±0.81 (SEM)) (Table 4).

Table 2:

Mean and correlation of continuous socio-demographic variables and Tegner activity scale with right and left PTSA

	Min	Max	Mean±SEM	RIGHT PTSA (°)		LEFT PTSA (°)	
				Correlation coefficient (r)	P value	Correlation coefficient (r)	P value
Age (years)	18.00	61.00	36.25±1.03	0.404	0.000*	0.408	0.000*
BMI (kg/m²)	19.54	34.11	24.06±0.29	-0.853	0.000*	-0.818	0.000*
Tegner activity scale	5.32	9.10	8.47±0.38	-0.249	0.072	-0.305	0.063
Right PTSA (°)	4.00	16.00	11.03±0.25	NA	NA	0.929	0.000*
Left PTSA (°)	4.00	16.00	11.02±0.26	0.929	0.000*	NA	NA

(*) – P value less than 0.05 is significant; BMI – Body mass index; PTSA – Posterior tibial slope angle

Table 3:

Distribution and analysis of variance of the continuous socio-demographic variables and Tegner activity scale in the Age groups

AGE GROUPS	n, (%)	Age (years)	BMI (kg/m ²)	Right PTSA (°)	Left PTSA (°)	Tegner Activity Scale
		Mean±SEM	Mean±SEM	Mean±SEM	Mean±SEM	Mean±SEM
18 – 33 years	46 (30.26)	28.83±0.85	27.70±0.67	10.56±0.56	10.67±0.56	7.21±0.56
34 – 49 years	88 (57.90)	42.83±0.61	26.23±0.36	12.49±0.28	12.57±0.31	7.83±0.28
≥50 years	18 (11.84)	53.68±1.10	23.01±0.70	12.74±0.70	12.70±0.60	7.69±0.66
P value		0.000*	0.083	0.002*	0.002*	0.174

(*) – P value less than 0.05 is significant; BMI – Body mass index; PTSA – Posterior tibial slope angle

Table 4:
Distribution and analysis of variance of the continuous socio-demographic variables and Tegner activity scale in the BMI groups

BMI GROUPS	n, (%)	BMI (kg/m ²)	Age (years)	Right PTSA (°)	Left PTSA (°)	Tegner Activity Scale
		Mean±SEM	Mean±SEM	Mean±SEM	Mean±SEM	Mean±SEM
Normal weight (18.50 – 24.99) kg/m²	65 (42.76)	22.12±0.19	48.23±1.45	14.51±0.15	14.54±0.24	8.39±0.81
Overweight (25.00 – 29.99) kg/m²	50 (32.90)	28.47±0.21	49.98±1.59	10.19±0.29	10.17±0.27	8.00±0.25
Obese (≥ 30.00) Kg/m²	37 (24.34)	31.41±0.18	37.50±2.15	8.64±0.30	8.86±0.27	6.80±0.30
P value		0.000*	0.000*	0.000*	0.000*	0.066

(*) – P value less than 0.05 is significant; BMI – Body mass index; PTSA – Posterior tibial slope angle

DISCUSSION

PTSA in conjunction with preserved anterior cruciate ligaments play preponderant roles in providing normal knee joint range of motion and biomechanics (Hassa *et al.*, 2023). In this study the mean PTSA for the right and left knees were 11.03±0.25° and 11.02±0.26°. A plethora of research findings fairly aligned with our results and these included; Singh *et al.*, (2023) in India (right PTSA - 12.76°±2.35° and left PTSA - 12.55±2.46°, with overall mean PTSA of 13.60±3.50°), Aljuhani *et al.*, (2020) whose retrospective cohort study evaluated 524 knee radiographs of Saudi indigenes (right PTSA - 13.60±3.40° and left PTSA - 13.70±3.30°, with an overall mean PTSA of 13.60±3.40°), Saidapur *et al.*, (2023) in India, whose study involved 153 osteoarthritic subjects, also noted an overall mean PTSA of 11.50±1.34°, Katchy *et al.*, (2019) in South-East Nigeria, also observed that the overall mean PTSA in 265 retrospectively evaluated knee radiographs of Igbos was 11.90±3.40° and Kavak *et al.*, (2024) in Turkey, who employed three methods to measure PTSA, realized that the right PTSA (11.08±2.04°) and left PTSA (10.99±2.26°) were also similar to our findings using the anterior tibial cortex technique. However, Thirunarayanan *et al.*, (2021), who evaluated osteoarthritic knees of Indians, observed an overall mean PTSA value (14.05°) that was higher than the findings of this study and also that of Saidapur *et al.*, (2023), who similarly evaluated the knee radiographs of Indians with osteoarthritis of the knee. Osteoarthritic degeneration has been postulated as one of the possible pathogenetic factors that lead to an increase in PTSA values (Thirunarayanan *et al.*, 2021).

Some of the studies that utilized 3-D imaging for the evaluation of PTSA, such as those of Karimi *et al.*, (2017) in Iran, who evaluated 132 knee MRI images and Hassa *et al.*, (2023) whose study involved the assessment of 89 knee CT images of Turkey citizens, observed lower PTSA values compared to the findings of this study (medial PTSA - 7.78±2.48° and 8.97±2.93°; lateral PTSA - 6.85±2.24° and 8.35±2.53°, respectively). However, a study conducted by Endo *et al.*, (2020) that had to do with 62 MRI-evaluated knee images of Japanese college students who had a mean age of 21.1 years, demonstrated congruity with the results of this study as they reported that the overall mean medial PTSA for the dominant and non-dominant knees were 9.70°±2.10° and 10.10°±1.80° while the overall mean lateral PTSA for the dominant and non-dominant knees were 9.60°±2.10° and 9.60°±1.80°.

Kasman *et al.*, (2023) in Turkey, conducted a clinical outcome follow-up on patients who had arthroscopic ACL reconstruction with hamstring tendons, and demonstrated

that the mean Tegner-Lysholm knee score for those with PTSA above 10° (88.20±8.80°) was insignificantly higher than those whose PTSA was below 10° (85.60±9.10°). The subjects whose PTSA was above 10° had a mean value of 11.10±0.80° which was similar to the mean values of the right and left PTSA in this study, and this probably suggests that knee function is excellent at this PTSA with reduced risk for a knee ligament tear (Kasman *et al.*, 2023).

The subjects in this study had a high overall mean Tegner activity scale of 8.47±0.38 which was attained with a mean PTSA of 11.03±0.25° and 11.02±0.26° for the right and left knee respectively. It can be propounded that knee activity and functions are likely utmost at the mean PTSA for the population within the metropolis of this study. Hung *et al.*, (2024) observed that medial tibial slope and lateral tibial slope had a significantly negative correlation with Lysholm score ($r = -0.300$, $P = 0.000$ and $r = -0.366$, $P = 0.000$) and Tegner score ($r = -0.328$, $P = 0.000$ and $r = -0.383$, $P = 0.000$), respectively. They inferred that individuals with a high slope angle usually experience low functional outcomes evidenced by their low score in the Lysholm score scale. Elaborating on the probable pathogenesis of this observation, Singh *et al.*, (2023) succinctly noticed that when the mean PTSA rises to a certain level a plateau sets in, in terms of general physical activity and the permissible range of motion in the knee, followed by a decline.

Li *et al.*, (2023) observed in their study that mean PTSA in subjects with bilateral ACL tears was 11.17° while those with unilateral ACL tears was 9.72° and the difference of these mean values was significant ($P = 0.005$). Even though the mean PTSA in this study was similar to their value we could not determine the presence of ligament tears in the knees of our subjects.

Age and BMI were relevant socio-demographic factors in this study since they both had a significant relationship with right and left PTSA. Singh *et al.*, (2023) who similarly observed a significant correlation between age and PTSA however, found out that as age advanced the PTSA significantly reduced at the right and left knees ($P < 0.001$, respectively). In this study, a positive correlation was rather noticed between both variables. Bone cortical thickness reduces with age, especially after 50 years, and this can be accelerated by unhealthy lifestyle (Vári *et al.*, 2023). It can thus be propounded that age affects the thickness of the tibial plateau, which is a major determinant of the posterior slope orientation and consequently, PTSA.

The mean BMI of the subjects in this study was observed to exhibit a significant negative correlation with PTSA such that as the BMI increases, PTSA reduces. When an individual's BMI rises, a proportional hike in biochemical

bone markers occurs, which induces a rapid decline in bone resorption markers while bone formation markers increase with heightened osteoblastic stimulation. ^U These biochemical alterations, coupled with the mechanical effect of the increased lean mass volume of the body weight on bone, result in an elevation in the bone mineral density (which increases tibial bone cortical thickness and reduces PTSA). Even in menopause, higher BMI decelerates bone loss (Vári *et al.*, 2023; Rinonapoli *et al.*, 2021). Buttressing this postulation, it was observed that a weight loss of about 14% or more within a three to four months period results in significant bone loss and this is more profound in women than men (Shapses and Riedt, 2006). In alliance with our findings, Singh *et al.*, (2023) lucidly demonstrated that a rise in BMI was significantly associated with a reduction of PTSA ($P = 0.001$). BMI is a modifiable sociodemographic factor which can possibly be adjusted to fit into the desired PTSA of a patient for optimal knee joint function. Kizilgoz *et al.*, (2019) in Turkey, on the other hand, demonstrated that BMI increased linearly with the increase in medial and lateral PTSA. However, Karimi *et al.*, (2017), Katchy *et al.*, (2019), de Sousa Filho *et al.*, (2021), and Fares *et al.*, (2023) all reported that PTSA had no significant relationship with socio-demographics of their subjects.

It is pertinent to note that sequel to total knee arthroplasty, the reconstructed PTSA predominantly influences knee stability and the tension in ACL and PCL. Furthermore, postoperative stiffness, abnormal femoral rollback and polyethylene wear can be a consequence of an abnormal PTSA (Aljuhani *et al.*, 2020). Racial homogeneity of the recruited subjects was not maintained, since most of them were from multiple tribes in the country and also were indigenes of other countries. This means that our findings might not be specific for the population in the locality of this study. However, the mean PTSA in this study was observed to have a good Tegner activity scale. The utilization of MRI, which is the gold standard imaging modality for the evaluation of the knee (Aljuhani *et al.*, 2020), would have been suitable to determine both medial and tibial PTSA in individuals with ligament tears or to objectively rule out subjects with knee ligament tears.

It is concluded that mean PTSA in this study is similar to that obtained in other populations and has a significant relationship with age and BMI, and maintaining normal weight significantly positively affects PTSA to ensure optimal knee functions. This study offers regional data to assist Orthopaedic surgeons on knee ligaments evaluation and reconstruction procedures.

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