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Radiographic Assessment of Tibiofibular Angles in Patients Attending Rivers State University Teaching Hospital: A Retrospective Study

Tamunokuro Ezekiel Diamond[1], Clinton David Orupabo[2]*, Baribor Maakai[3], Victory Udodirim Emenike[2], Leeleebari Martha Nwambo[2]

[1]Department of Orthopaedic Surgery, Faculty of Clinical Sciences, University of Port Harcourt Teaching Hospital, Port Harcourt, Nigeria
[2]Department of Human Anatomy, Faculty of Basic Medical Sciences, College of Medical Sciences, Rivers State University, Port Harcourt, Nigeria
[3]Department of Anatomy, Faculty of Basic Medical Sciences, College of Health Sciences, University of Port Harcourt, Nigeria

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***Corresponding Author:** Clinton David Orupabo
Department of Human Anatomy, Faculty of Basic Medical Sciences, College of Medical Sciences, Rivers State University, Port Harcourt, Nigeria

Abstract

Background: Proximal and distal tibiofibular angles describe aspects of the anatomical relationship between the tibia and fibula. Establishing their radiographic characteristics and relationships with age and sex may contribute to the understanding of lower-limb anatomy among Nigerian adults. ***Objective:*** This study assessed the mean proximal and distal tibiofibular angles among adults in Port Harcourt, Rivers State, and examined their relationships with age, sex, and right–left variation. ***Methods:*** A retrospective cross-sectional radiographic study was conducted using data from 120 Nigerian adults. Proximal and distal tibiofibular angles were assessed using available radiographic measurements. Descriptive statistics summarized the angles, Spearman's rank-order correlation examined their relationships with age, and the Mann–Whitney U test compared measurements between sexes. The Wilcoxon signed-rank test assessed paired right–left differences in proximal angles. Statistical significance was set at $p < 0.05$. ***Results:*** The descriptive findings are presented in Table 1. Age was significantly and negatively associated with the right proximal tibiofibular angle, while associations with the other three measurements were not statistically significant. No statistically significant sex-related differences were observed in the proximal or distal angles. However, a significant right–left difference was identified in paired proximal measurements, with the right angle tending to be higher than the left ($p = 0.010$). The availability of distal measurements was limited compared with proximal measurements. ***Conclusion:*** Proximal and distal tibiofibular angles varied among adults in Port Harcourt, with a significant association between age and the right proximal angle and significant bilateral variation in proximal angles. Further studies with larger samples and more complete radiographic measurements are needed to establish reliable population-specific reference values.

Keywords: Tibiofibular angle; proximal tibiofibular joint; distal tibiofibular joint; radiographic assessment; age; sex; Port Harcourt; Nigeria.

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INTRODUCTION

The tibiofibular articulations are important anatomical components of the lower limb because they contribute to the structural relationship between the tibia and fibula and the stability of the knee and ankle. The proximal tibiofibular joint is a synovial articulation between the fibular head and the lateral tibial condyle, whereas the distal tibiofibular syndesmosis is a fibrous articulation that maintains the relationship between the distal tibia and fibula. Variations in the morphology and orientation of these articulations are relevant to understanding lower-limb biomechanics and interpreting radiographic findings. Gomes *et al.,* (2026) noted that existing classifications of proximal tibiofibular joint morphology largely relied on cadaveric studies or advanced imaging techniques, limiting their routine clinical applicability. They therefore developed a standardized classification using conventional anteroposterior and lateral knee radiographs and evaluated its interobserver reliability. At the ankle, accurate assessment of the distal tibiofibular relationship is important because subtle changes in syndesmotic

alignment may be difficult to identify using conventional two-dimensional imaging alone (Shamrock *et al.,*2024).

Radiographic morphometry provides a practical approach to investigating tibiofibular anatomy in living individuals. Conventional radiographs allow the assessment of joint alignment and angular relationships, while computed tomography (CT) provides more detailed information about three-dimensional anatomical configuration. Gomes *et al.,* (2026) evaluated angular measurements obtained from standard anteroposterior and lateral knee radiographs and proposed a classification of proximal tibiofibular joint inclination. Their study demonstrated the potential of conventional radiography for describing proximal joint morphology and reported high reproducibility for the proposed classification. At the distal articulation, Kim *et al.,* (2022) examined radiographic measurements of the normal tibiofibular syndesmosis under different ankle positions and found that weight-bearing and dorsiflexion influenced selected measurements. Similarly, Bhagat *et al.,* (2024) used CT to investigate normal distal tibiofibular syndesmotic morphology in an Indian population, demonstrating the importance of population-specific anatomical measurements. Collectively, these studies highlight the value of clearly defined anatomical landmarks and standardized imaging procedures in radiographic morphometric research.

Age, sex and anatomical laterality are important considerations when describing normal anatomical variation. Morphometric studies can help establish whether measurements differ between demographic groups or between the two sides of the body. Qi *et al.,* (2020) investigated the relationship between proximal tibiofibular joint morphology and knee osteoarthritis, demonstrating the relevance of proximal joint morphology to research on knee anatomy and pathology. At the distal articulation, Shamrock *et al.,* (2022) assessed syndesmotic area measurements in healthy volunteers using weight-bearing CT and compared measurements between right and left ankles, providing reference data for evaluating normal anatomical variation. These studies support the importance of investigating anatomical measurements systematically rather than assuming that the same dimensions apply across individuals and anatomical locations.

Nevertheless, proximal and distal tibiofibular measurements represent distinct anatomical characteristics and should not be treated as interchangeable. Proximal joint inclination describes the orientation of the articulation near the knee, whereas distal syndesmotic measurements describe the spatial relationship between the tibia and fibula near the ankle. Differences in imaging modality, patient positioning and measurement landmarks can also affect the values obtained. Consequently, findings from studies using CT or weight-bearing imaging may not be directly comparable with measurements obtained from conventional radiographs. Furthermore, anatomical findings from populations outside Nigeria cannot automatically be assumed to represent Nigerian adults. These considerations support the need for locally generated radiographic data and careful interpretation of differences associated with age, sex and laterality.

Accordingly, this study assesses proximal and distal tibiofibular angles among adults in Port Harcourt, Rivers State, Nigeria, using radiographic measurements. Specifically, it determines the descriptive characteristics of the measured angles, examines their relationships with age, compares measurements between male and female participants, and evaluates right–left differences in proximal tibiofibular angles among participants with bilateral measurements. The study is significant because it contributes local descriptive evidence on tibiofibular angular morphology and explores variation according to selected demographic characteristics and anatomical side. The findings may inform subsequent anatomical and radiographic investigations and provide a basis for larger studies of Nigerian populations. However, the limited availability of distal-angle measurements means that findings for these angles must be interpreted cautiously and should not be regarded as definitive population reference values.

METHODOLOGY

Study Area and Population

This study was conducted in Port Harcourt, Rivers State, Nigeria, using archived radiographic records from the Rivers State University Teaching Hospital (RSUTH) and the University of Port Harcourt Teaching Hospital (UPTH), as specified in the study documents. The study population comprised Nigerian adults aged 18 years and above whose anteroposterior radiographs of the knee and/or ankle were available for assessment of proximal and distal tibiofibular angles. Demographic information, including age and sex, was obtained from the available records.

Research Design

A hospital-based retrospective cross-sectional design was employed to assess proximal and distal tibiofibular angles and examine their relationships with age and sex among Nigerian adults in Port Harcourt. This design enabled the assessment of existing radiographic images and the comparison of tibiofibular angles across demographic groups. Right–left differences in proximal tibiofibular angles were also examined where paired measurements were available.

Sample Size and Sampling Technique

The initial sample size was estimated using the sample size formula for estimating a population mean (also known as the single-population mean formula), based on a 95% confidence level, an assumed standard deviation of 5°, and a precision of 1°. This produced an estimated sample of approximately 96 participants. After allowing for 10% to account for incomplete records, the

required sample was approximately 106, which was rounded up to 110. Stratified random sampling based on age and sex was specified in the study documents. The final dataset used for analysis comprised 120 participants. However, the number included in individual analyses varied because some radiographic angle measurements were unavailable.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Nigerian adults aged 18 years and above.
- Individuals with available anteroposterior radiographs suitable for assessing the proximal and/or distal tibiofibular angles.
- Exclusion criteria:
- Individuals with documented or evident fractures, congenital deformities, or other abnormalities affecting the anatomical landmarks required for measurement.
- Radiographs showing orthopaedic implants or previous surgical alterations that could interfere with angle assessment.

Data Collection Procedure

Data were obtained retrospectively from archived radiographic records. A structured data extraction sheet was used to record participants' age, sex, and available right- and left-sided proximal and distal tibiofibular angle measurements. The proximal angles were assessed using the longitudinal axes of the proximal tibia and fibula on anteroposterior knee radiographs, while the distal angles were assessed using the longitudinal axes of the distal tibia and fibula on anteroposterior ankle radiographs. Measurements were recorded in degrees using the measurement procedure specified in the study documents.

Where two readings were available for an angle, they were processed according to the study's measurement protocol. The recorded data were subsequently entered into a spreadsheet for cleaning and statistical analysis. Missing measurements were retained as missing rather than estimated, and each analysis used the available observations relevant to the variables being examined.

Ethical Considerations

Ethical approval for the study was documented as having been obtained from the Research Ethics Committee of Rivers State University Teaching Hospital. As the study involved existing radiographic records, participants' identifying information was kept confidential, and data were anonymized before analysis. The extracted information was used exclusively for research purposes. No additional radiographic exposure was required for the study.

Data Analysis

Data were coded, cleaned, and analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including means, standard deviations, minimum values, and maximum values, summarized the tibiofibular angle measurements. Spearman's rank-order correlation assessed the relationships between age and the measured angles. The Mann–Whitney U test examined differences in angle measurements between males and females, while the Wilcoxon signed-rank test assessed right–left differences in proximal tibiofibular angles among participants with paired measurements. Analyses were based on available observations because of missing measurements, particularly for distal angles. Statistical significance was set at $p < 0.05$.

RESULTS

Table 1: Descriptive statistics of proximal and distal tibiofibular angles

Tibiofibular angle	n	Mean (°)	Standard deviation (°)	Minimum (°)	Maximum (°)
Right proximal	120	83.66	4.25	70.00	94.00
Left proximal	59	82.00	5.21	72.00	98.00
Right distal	15	90.93	5.60	82.00	105.00
Left distal	13	90.00	5.71	73.00	98.00

Source: SPSS output.

Table 1 presents the descriptive statistics for the proximal and distal tibiofibular angles. The mean right proximal angle was 83.66 ± 4.25°, while the left proximal angle was 82.00 ± 5.21°. For the distal measurements, the mean right angle was 90.93 ± 5.60°, compared with 90.00 ± 5.71° on the left. The right proximal angle ranged from 70° to 94°, whereas the left ranged from 72° to 98°. The right distal angle ranged from 82° to 105°, while the left ranged from 73° to 98°. The number of available measurements varied across the four angles, with fewer observations for the distal angles.

Table 2: Spearman's rank-order correlation between age and tibiofibular angles

Tibiofibular angle	n	Spearman's rho (ρ)	p-value
Right proximal	120	−0.251	0.006
Left proximal	59	0.163	0.216
Right distal	15	0.036	0.899

Tibiofibular angle	n	Spearman's rho (ρ)	p-value
Left distal	13	−0.427	0.146

Source: SPSS output.

Table 2 shows the relationships between age and the four tibiofibular angle measurements. Age had a weak negative correlation with the right proximal angle (ρ = -0.251, ρ = 0.006), and this relationship was statistically significant. The left proximal angle showed a weak positive correlation with age (ρ = 0.163, ρ = 0.216), which was not statistically significant. The right distal angle had a negligible positive correlation (ρ = 0.036, ρ = 0.899), while the left distal angle showed a moderate negative correlation (ρ = -0.427, ρ = 0.146). Neither distal-angle correlation was statistically significant. The distal findings should be interpreted cautiously because of the small sample sizes.

Table 3: Comparison of tibiofibular angles between male and female participants using the Mann–Whitney U test

Angle measurement	Sex	n	Mean (°)	SD (°)	Mean rank	U	p-value
Right proximal	Female	74	83.91	3.98	62.75	1,535.50	0.367
	Male	46	83.26	4.67	56.88		
Left proximal	Female	39	82.42	4.19	32.83	279.50	0.076
	Male	20	81.18	6.82	24.48		
Right distal	Female	9	90.89	6.35	7.50	22.50	0.594
	Male	6	91.00	4.82	8.75		
Left distal	Female	7	90.79	1.35	6.43	17.00	0.562
	Male	6	89.08	8.62	7.67		

Source: SPSS output.

SD = standard deviation; U = Mann–Whitney U statistic. P-values are the asymptotic two-tailed significance values reported by SPSS. The exact two-tailed p-values for the right and left distal angles were 0.607 and 0.628, respectively.

Table 3 presents the comparison of proximal and distal tibiofibular angles between male and female participants. The mean right proximal angle was slightly higher among females (83.91 ± 3.98°) than males (83.26 ± 4.67°). Similarly, the mean left proximal angle was higher among females (82.42 ± 4.19°) than males (81.18 ± 6.82°). For the distal measurements, the mean right angle was comparable between females (90.89 ± 6.35°) and males (91.00 ± 4.82°), while the mean left distal angle was higher among females (90.79 ± 1.35°) than males (89.08 ± 8.62°). However, none of the four comparisons was statistically significant at the 5% level (all p-values greater than 0.05). Thus, the analysis did not demonstrate statistically significant differences in tibiofibular angles between male and female participants.

Table 4: Descriptive statistics of paired right and left proximal tibiofibular angles

Measurement	n	Mean (°)	SD (°)	Median (°)	Minimum (°)	Maximum (°)
Right proximal angle	59	83.58	4.25	83.00	71.50	93.00
Left proximal angle	59	82.00	5.21	81.00	72.00	98.00

Source: SPSS output.

Table 4 presents the descriptive statistics for the right and left proximal tibiofibular angles among the 59 participants with measurements available on both sides. The right proximal angle had a mean of 83.58 ± 4.25°, compared with 82.00 ± 5.21° for the left proximal angle. The median was also higher on the right (83.00°) than on the left (81.00°). These descriptive findings indicate that the right proximal angle tended to be higher than the left, although a paired statistical test is required to establish whether the observed difference is statistically significant.

Table 5: Wilcoxon signed-rank test comparing paired right and left proximal tibiofibular angles

Test result	Value
Negative ranks (left angle lower than right)	37
Positive ranks (left angle higher than right)	18
Ties (equal angles)	4
Total paired observations	59
Z	−2.593
p-value (two-tailed)	0.010

Source: SPSS output.

Ranks are based on the difference between the left and right proximal angles (PA_Left − PA_Right).

Table 5 presents the Wilcoxon signed-rank test comparing the right and left proximal tibiofibular angles. Of the 59 paired observations, 37 participants had a lower left angle than right angle, 18 had a higher left angle, and four had equal measurements. The test indicated a statistically significant difference between the paired measurements ($Z = -2.593$, $p = 0.010$). Since the left angle was lower than the right in more participants, the findings indicate that the right proximal tibiofibular angle tended to be higher than the left.

DISCUSSION

Characterization of Proximal and Distal Tibiofibular Angles

The first objective was to determine the mean proximal and distal tibiofibular angles among adults in Port Harcourt, Rivers State. The findings in Table 1 demonstrate variation in angular measurements between anatomical levels and sides. This variation is consistent with the complex morphology of the tibiofibular joints, whose articular orientations and supporting structures differ between the proximal knee region and distal ankle region. Hayashi *et al.,* (2023), using three-dimensional computed tomography and anatomical dissection, demonstrated substantial structural detail in the proximal tibiofibular joint, including variation in ligament attachment sites and an inverse relationship between joint surface area and inclination angle. This provides an anatomical explanation for why tibiofibular angles may vary among individuals rather than conform to one uniform configuration.

The proximal and distal measurements also differed in the number of available observations. The more limited distal measurements mean that the estimated distal means are more sensitive to individual anatomical differences. This is important when interpreting the range of measurements in Table 1, because a small number of observations may not adequately represent the full anatomical variability of the population. Furthermore, the present measurements describe angles formed by longitudinal anatomical axes, whereas much of the existing literature reports linear distances, joint spaces, and syndesmotic areas. Consequently, the results contribute a different type of radiographic reference information to the existing literature.

In a study of normal distal tibiofibular anatomy among Indian adults, Bhagat *et al.,* (2024) documented variation in syndesmotic dimensions and incisura morphology. These differences reinforce the importance of population-specific anatomical investigations. The present study extends this area of research by examining proximal and distal angular relationships in Nigerian adults, for whom comparable radiographic reference information remains limited.

Relationship Between Age and Tibiofibular Angles

The second objective examined the relationship between age and the four tibiofibular angles. As presented in Table 2, age was significantly associated with the right proximal angle, with a negative relationship, but no statistically significant association was demonstrated for the other three angles measured. This indicates that the relationship between age and tibiofibular anatomy was not uniform across the measured sites.

A possible explanation is that age-related anatomical changes affect specific dimensions of the tibiofibular relationship rather than producing equivalent changes throughout the lower leg. In a systematic review and meta-analysis, Raheman *et al.,* (2022) found that syndesmotic volume decreased with increasing age. The authors suggested that age may influence the spatial relationship between the tibia and fibula. Although syndesmotic volume is different from the longitudinal-axis angle assessed in the present study, the finding supports the possibility that age-related changes may be detectable in selected anatomical measurements.

Similarly, Yüzügüldü *et al.,* (2024) found associations between age and selected syndesmotic measurements. These findings support the biological plausibility of age-related variation but also indicate that the direction and strength of the association depend on the parameter being examined. The significant relationship in the present study was confined to the right proximal angle, suggesting that the observed association may be related to local joint orientation rather than a general alteration of tibiofibular alignment.

The lack of significant associations for the remaining angles may reflect genuine differences between anatomical sites, but the small distal samples are also relevant. With fewer observations, individual measurements exert greater influence on the estimated correlations, reducing the ability to detect modest relationships. Therefore, the present results suggest a site-specific age association rather than a consistent relationship between age and all tibiofibular angles.

Sex-Related Differences in Tibiofibular Angles

The third objective compared the proximal and distal tibiofibular angles between male and female participants. Table 3 shows that none of the four comparisons was statistically significant. Although some descriptive differences were observed, these did not provide sufficient evidence of a consistent sex-related association with the angles measured.

This finding contrasts with Bejarano-Pineda *et al.,* (2025), which identified significant sex differences in syndesmotic area and volume. The authors reported larger measurements among males for several parameters. Their findings suggest that sex-related anatomical differences can occur in the distal tibiofibular

region, particularly in dimensions reflecting overall joint size.

The difference between that study and the present findings may be explained by the measurement methods. Syndesmotic area and volume reflect three-dimensional joint dimensions, whereas longitudinal-axis angles describe the orientation of anatomical structures. Differences in bone size may produce larger linear or volumetric measurements without necessarily resulting in significant differences in angular orientation. In addition, the smaller distal samples in the present study reduced the statistical power available to detect sex-related differences.

Eceviz *et al.,* (2026), in a CT-based study of patients with ankle fractures, also reported sex differences in selected distal syndesmotic parameters, although not all measurements differed significantly. Their results further demonstrate that sex-related variation is dependent on the specific anatomical parameter assessed. Thus, the present study's nonsignificant comparisons may indicate that sex has a limited relationship with these particular angles, even though it may influence other aspects of tibiofibular morphology.

Right–Left Differences in Proximal Tibiofibular Angles

The fourth objective compared right and left proximal tibiofibular angles among participants with paired measurements. The findings in Tables 4 and 5 demonstrate a significant bilateral difference, with the right proximal angle tending to be higher than the left. This indicates that the proximal angular measurements were not identical between sides in the paired sample.

One possible explanation is natural anatomical asymmetry arising from differences in articular-surface inclination and the relative orientation of the tibia and fibula. Hayashi *et al.,* (2023) demonstrated that proximal tibiofibular joint inclination is related to joint surface morphology, providing a plausible anatomical basis for variation in angular measurements. However, that study did not establish a consistent right-sided predominance, so it cannot directly explain the direction of the difference observed in the present study.

Research on the distal syndesmosis has produced contrasting findings. Patel *et al.,* (2019) reported no significant right–left differences in the parameters examined. More recent evidence from Yüzügüldü *et al.,* (2024) similarly found no significant side differences in the commonly used tibiofibular overlap and clear-space measurements. This differs from the present proximal-angle finding, potentially because the studies assessed different anatomical regions and measurement parameters.

Radiographic positioning may also contribute to the observed asymmetry. Differences in limb rotation and the identification of anatomical axes can influence calculated angles, particularly when measurements are obtained retrospectively from existing images. Nevertheless, the paired statistical result indicates that the difference was systematic within the available observations. Further investigation using standardized imaging and repeated measurements would help establish whether the right-sided predominance is reproducible in Nigerian adults.

CONCLUSION

The study concludes that proximal and distal tibiofibular angles vary among adults in Port Harcourt, with a significant negative association between age and the right proximal angle and a significant right–left difference in proximal angles. However, the absence of significant sex-related differences and the limited distal measurements highlight the need for further studies to establish reliable population-specific radiographic reference values.

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