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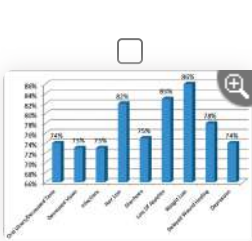
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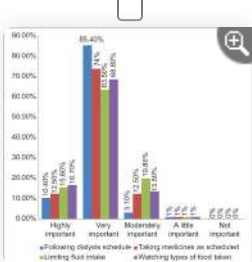
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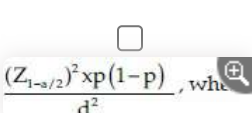
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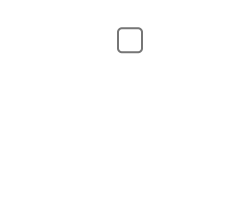
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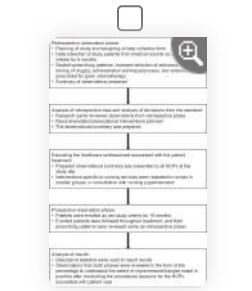
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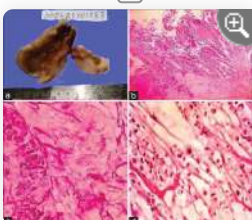
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Radiological assessment of the calcaneal angles of Kwara populace: A retrospective study

Ade S. Alabi, Bilikis E. Mohammed, Susan Folashade Lewu, Richard O Neku¹, Bidemi S Kareem, Oyetunji A Oyewopo, Foyeke M Adigun

Abstract:

INTRODUCTION: Estimation of sex from different dimensions has considerable forensic value, for the identification of human remains, in the estimation of sex at disaster sites and in corroborating reports from scientists. This study evaluated calcaneal angles of Kwara populace and estimated sex using X-ray (Bohler's angle [BA], crucial angle of Gissane [CG], Fowler–Philips angle [FPA], calcaneal inclination angle [CIA], and calcaneal compression angle [CCA]).

MATERIALS AND METHODS: One hundred and ten lateral radiographs consisting of 59 males and 51 females (unilateral) were used in this study. The study was carried out on randomly collected lateral calcaneal radiographs of adults in several hospitals in Kwara state. Standard anthropometric methods were used to measure the right and left calcaneal angles: BA, GA, FPA, CIA, and CCA. Data were analyzed using SPSS version 23 (IBM® Armonk, New York, USA) statistical software. Confidence level was set at 95% as $P \leq 0.05$ was considered statistically significant.

RESULTS: For right and left calcaneus in both sexes, the calcaneal angles were not significant. The P value was >0.05 ($P > 0.05$), indicating a nonstatistically significant values for the calcaneal angles. This present study, following measurements of calcaneal parameters in determining the sex of the right and left foot, showed no significant statistical difference across all five parameters.

CONCLUSION: The findings showed that the measured calcaneal parameters cannot be used for determining sex.

Keywords:

Calcaneal angles, discriminant function analysis, Kwara populace, radiography

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Introduction

The evolution of the foot to attain the human type has occurred over many millions of years. The foot is made of 28 bones and 31 articulations, which helps the body attain stamina even with up to 3–7 times the body weight.^[1] Sexual dimorphism is the expression of secondary sexual characteristics that are defined after puberty and during adolescent years.^[2]

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The calcaneus, also known as the heel bone, is the largest of the tarsal bones. It articulates with the talus, which lies superiorly and the cuboid lying anteriorly. It is a rectangular block of bone, characterized by the sustentaculum tali, which is a shelf that projects from the upper border of its medial surface. This joint is important to attain normal foot function. The calcaneus is often compared to a hard-boiled egg, because it is composed of a thin, hard shell on the outside and softer, spongy bone on the inside. When the outer shell is broken, the

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bone tends to collapse and become fragmented. For this reason, calcaneal fractures are severe injuries.^[3] Fracture of the calcaneus is highly common in fall from heights and slipping from stairways.^[1] Calcaneal fractures characterize 2% of all fractures and approximately 60%–70% of tarsal fractures.^[1] Several angles can be derived from the calcaneus which has been proven various times to have a characteristic variation which are important in determining the degree of deformity and quality of reduction, and can thus help to predict the morbidity after calcaneal fractures.^[4]

Materials and Methods

Anthropometric measurement

A total of 110 calcaneal radiographs (unilateral) consisting of 59 males and 51 females were used in this study. The sample size was determined by the availability of X-ray films. The lateral radiographs of the normal calcaneus were collected randomly from some hospitals and the needed angles were taken with other necessary parameters in place (sides and sex). The lines of intersections were taken from its appropriate boundaries by a measuring rule and its angles were measured using a protractor.

Tuber or Bohler's angle

The first line is drawn from the highest point of the anterior process to the highest point of the posterior facet and the second line runs tangential to the superior edge of the tuberosity. It ranges from 25° to 40°, with an average of 30° [Figure 1].^[5]

Gissane's angle

The calcaneus has two thick and strong cortical struts that extend from the front of the bone to the posterior facet. These struts are angled and support the lateral process of the talus. This angle was termed "the crucial angle" by Gissane. It ranges from 120° to 140° with an average of 130° [Figure 2].^[6]

Fowler–Philip angle

It is formed between the line tangent to the anterior tubercle and the medial process of the plantar tuberosity as well as the line tangent to the posterosuperior prominence at the insertion of the Achilles tendon. It ranges from 44° to 69°, with an average of 75° [Figure 3].^[7,8]

Calcaneal compression angle

It is derived from a line in the plane of the inferior surface of the calcaneus, whereas the other line is identical to the first line of the Bohler's Angle (BA) (Bohler, 1931). It ranges from 18° to 42°, with an average of



Figure 1: Right Bohler's angle



Figure 2: Right Gissane's angle



Figure 3: Fowler–Philip angle

36° [Figure 4].^[5,6] Measurements were taken twice and the average was tabulated as the value for the calcaneal angle.

Calcaneal inclination angle

It is subtended by two lines originating at the lowest point on the calcaneus, one joining it to the head of the fifth metatarsal bone and the other to the lowest point of the calcaneocuboid joint. It ranges from 15° to 44°, with an average of 28°.^[6]

Ethical consideration

Ethical standard as prescribed in the Declaration of Helsinki (2000) was duly observed in data collection. In addition, proper ethical approval measures were sought for the purpose of this study.

Statistical analysis

Statistical Package for the Social Sciences version 23 (IBM® Armonk, New York, USA) was used in analyzing the data. *T*-test was used in evaluating sex difference, whereas discriminant function analysis (DFA) was used to assess the possibility of classifying the data into male and female groups. Only statistically significant variables or close to significant variables were selected for DFA. The confidence level was set at 95%; hence, $P < 0.05$ was considered statistically significant.

Result presentation

The results were presented based on the anthropometric measurements of the calcaneal angles of the left and right feet of the studied population. The values were reported as mean (standard deviation) and Wilks' Lambda unidimensional test of equality of the means of the groups [Tables 1a and 2a]. The DFA was presented in tables 1b, 1c, 2b and 2c using calcaneal angle parameters.



Figure 4: Calcaneal compression angle

Results

The random radiological study of the calcaneal angle of individuals living in Kwara state is represented in Table 1, which shows the characteristics of the right calcaneal angle measured as it relates to sex. The mean right BA for both males and females was statistically insignificant. The mean right Gissane's angle (GA) for both males and females showed insignificant statistical difference. Similar observation was found in the right Fowler-Philip angle (FPA), showing insignificant differences; however, common to these three indices, it was observed that the mean values of the males were slightly higher than that of the females. On the other hand, though the mean right calcaneal compression angle (CCA) and right mean calcaneal inclination angle (CIA) for males were slightly lower compared to that of the female, their differences were also insignificant. Table 1c which predicted the accuracy of the work to be 11.90% has proven not useful in determining sex.

Table 2a shows the characteristics of the left calcaneal angle in both sexes. The mean values of the left BA in males compared with females were slightly increased, however statistically insignificant. Similar outcomes were obtained in the mean left GA, the mean left CCA, the left mean CIA, and the mean left FPA, though, in the latter, slightly increased values were observed in the females than in males.

Table 2b which predicted the accuracy of the work to be 4.08% has proven insignificant in determining sex.

Discussion

The knowledge of calcaneal angles (GA, FPA, CIA, BA, and the CCA) helps in the diagnosis and treatment of calcaneal fractures^[1] and the knowledge of the normal range in a given population is necessary not to have high percentage of abnormal cases of calcaneal fracture.^[9] In the present study, considering the right and left GA for both males and females, it was discovered that

Table 1a: Descriptive characteristics of the right calcaneal measured and Wilks' Lambda unidimensional test of equality in group means

Parameters	Mean±SD			Wilks' Lambda test of group mean			
	Male (n=34)	Female (n=23)	Total (n=57)	Wilks' Lambda	Fisher's value	Significance (P)	Inference
R_BA	34.12±7.36	30.67±6.46	32.73±7.15	0.943	3.311	0.074	NS
R_GA	64.15±20.14	63.62±21.68	63.94±20.58	0.974	1.447	0.234	NS
R_FPA	109.51±21.72	107.09±18.88	108.54±20.48	0.997	0.189	0.665	NS
R_CCA	27.45±4.92	28.54±5.80	27.89±5.27	0.989	0.59	0.446	NS
R_CIA	13.89±6.47	15.56±5.34	14.57±6.05	0.981	1.047	0.311	NS

Box's M within class covariant matrices ($P=0.880$). There is no significant statistical difference in determining the sex of the right calcaneus using the abovelisted calcaneal parameters. S=Signifint, NS=Not significant, R_BA=Right Bohler's angle, R_GA=Right Gissane's angle, R_FPA=Right Fowler-Philips angle, R_CIA=Right Calcaneal Inclination angle, R_CCA=Right Calcaneal Compression angle, SD=Standard deviation, $P>0.05$, n=Sample size

there was no significant difference between the sexes and the sides of the foot ($P > 0.05$), which means that this result cannot be used to differentiate male from female calcaneus neither can it be used to identify the right foot from the left.

The right and left FPA for both males and females was discovered to also have no significant difference, meaning that it cannot be used to determine sexual dimorphism and the sides of the foot ($P > 0.05$); this is in correlation with the study done^[9] in Nigeria. The right and left CCA for both males and females was

also seen to have no significant difference, which also brings us to a conclusion that this angle cannot be used to determine sexual dimorphism or even the sides of the foot ($P > 0.05$), which is also in correlation with the study^[10] done in Egypt.

Therefore, the mean values for all the calcaneal dimensions of the studied population and the test of equality in mean values of groups (male vs. females) were presented, with no significant difference in any of the five parameters (BA, GA, FPA, CCA, and CIA) ($P > 0.05$) for both the right and left foot.

Table 1b: Wilks' Lambda test of equality in mean vector between the predicting groups (right calcaneal measurement)

Wilks' Lambda Test	Values
λ	0.881
χ^2	6.661
DF	5
P	0.247

$P > 0.05$, therefore the parameters entered into the model cannot significantly predict sex. λ =Lambda, χ^2 =Chi square, DF=Discriminant function, P=Probability

Table 1c: Model canonical correlation and accuracy in prediction

Function	Eigen value ^a	r_c	R_c^2
F1	0.135	0.345	11.90%

^a $P > 0.05$. Table 1c shows evaluation of sex-associated differences from radiologic measurement of the right calcaneus which predicts accuracy of the factors measured to be 11.90%. F1=First 1 canonical discriminant functions were used in the analysis, r_c =Canonical correlation, R_c^2 =Prediction model accuracy

Conclusion

Calcaneal angles of both feet (GA, FPA, CIA, BA, and CCA) cannot be used for the intent of determining the sex.

Recommendation

Studies using other parameters in a larger population should be carried out on the establishment of sex from calcaneal angle parameters of the left and right foot.

Financial support and sponsorship

Nil.

Conflicts of Interest

There are no conflicts of interest.

Table 2a: Descriptive characteristics of the left calcaneal measured and Wilks' Lambda unidimensional test of equality in group means

Parameters	Mean±SD			Wilks' Lambda test of group mean			
	Male (n=34)	Female (n=23)	Total (n=57)	Wilks' Lambda	Fisher's value	Significance (P)	Inference
L_BA	29.16±6.26	28.31±7.06	28.71±6.65	0.996	0.211	0.648	NS
L_GA	82.47±26.69	78.22±26.99	80.23±26.68	0.994	0.332	0.567	NS
L_FPA	100.13±30.47	100.53±29.59	100.34±29.72	1.000	0.002	0.962	NS
L_CCA	27.64±5.11	26.12±4.74	26.84±4.93	0.976	1.257	0.267	NS
L_CIA	18.81±6.51	17.59±6.04	18.16±6.23	0.99	0.499	0.483	NS

Box's M within class covariant matrices ($P=0.880$). There is no significant statistical difference in determining the sex of the right calcaneus using the abovelisted calcaneal parameters. S=Significant, NS=Not significant, L_BA= Left Bohler's angle, L_GA= Left Gissane's angle, L_FPA= Left Fowler-Philips angle, L_CIA= Left Calcaneal Inclination angle, L_CCA=Left Calcaneal Compression angle, SD=Standard deviation, $p > 0.05$, n= sample size

Table 2b: Wilks' Lambda test of equality in mean vector between the predicting groups

Wilks' Lambda Test	Values
λ	0.959
χ^2	2.022
DF	5
P↓	0.846

$P > 0.05$, therefore the parameters entered into the model cannot significantly predict sex. λ =Lambda, χ^2 =Chi square, DF=Discriminant function, P=Probability

Table 2c: Model canonical correlation and accuracy in prediction

Function	Eigen value ^a	r_c	R_c^2
F1	0.043	0.202	4.08%

^a $P > 0.05$. Table 2c shows evaluation of sex-associated differences from radiologic measurement of the left calcaneus which predicts accuracy of the factors measured to be 4.08%. F1=First 1 canonical discriminant functions were used in the analysis, r_c =Canonical correlation, R_c^2 =Prediction model accuracy

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