HEIGHT AND SEX DETERMINATION USING FOOT DIMENSIONS AND THEIR RELATION TO TRIBE

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INTRODUCTION

It is an undeniable fact that identification of a person plays a pivotal role during natural calamities, terror strikes, crime scenes and also in our day to day lives. The scientific basis for human identification dates back to the 19th century when Alphonse Bertillon, a French criminologist introduced the use of a number of anthropometric techniques to identify habitual criminals (Vijay *et al.,*2013). Forensic identification involving anthropometry is well known for identifying a suspect's gender, age, race, and even the body profile of the individual (Robertson, 2012; Robertson *et al.,* 2013).

The forensic study of the foot is a branch of anthropometry that has been well applied to aid the establishment of personal identity and serves as a kind of evidence at the crime scene and a potential relation between the crime and the perpetrator (Krishan *et al*., 2011; Ozaslan *et al.,* 2013).

Foot anthropometry can also serve a complement to deoxynucleic acid (DNA) techniques like polymerase chain reaction (PCR) in the analysis of the remains of victims of mass disasters (Ross, 2012). Different parameters of the feet studied by various researchers have successfully shown to correlate with the sex and stature of a person in the developed world. Yet, there appears to be very limited data about the use of foot dimensions for this purpose in Ghana.

AIM

This study was aimed at determining height and sex using foot dimensions and their relation to tribe.

MATERIALS AND METHODS

This was a cross-sectional study conducted at School of Medicine and Dentistry, KNUST, Kumasi from September 2018 to April 2019. Ethical clearance was sought from the Committee for Human Research Publications and Ethics. Informed participants' consent was sought prior to the study. By means of convenient sampling, 307 participants including 177 males and 130 females recruited for the study. Participants without any apparent foot-related disease and orthopaedic deformity were included in the study. Also, participants with lower limb amputations and pregnant subjects regardless of gestational stage were excluded from the study. Height (Stature) of the participants were measured in centimeters (cm) with the aid of a wall mounted Shahe height meter (Shanghai, China) as the vertical distance between the vertex of head and the sole of the foot. Footprint of the participants were obtained using Hp Scanjet scanner 300 (California, U.S.A) and Canon Canoscan LiDE 120 Colour Image scanner (Tokyo, Japan) connected to a computer. The measurements of the foot were done using the CorelDraw X7 software. Alternatively, ink method was also used to obtain the footprints of the participants. Measurements were done afterwards using a rule (figure 1).

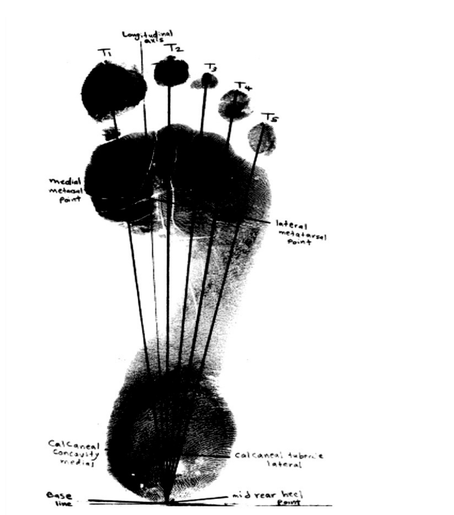

Figure 1*:* An image of the footprint showing the measurement of foot dimensions

The mid rear heel point (Pternion P), the distance between the calcaneal concavity medial and the calcaneal tubercle lateral-Foot breadth at the heel(BHEL); The distance between the medial metatarsal point and the lateral metatarsal point-Foot breadth at the ball (BBAL);T1-toe 1;T2-toe 2;T3-toe 3;T4-toe 4 and T5-toe 5 (Source; Fawzy and Kamal, 2010).

STATISTICAL ANALYSIS

Data was analysed using IBM statistical Package for social Sciences version 20.0. All the measurements were presented in descriptive statistics. Pearson's correlation coefficient (r) between various foot dimensions and height was also obtained. The linear regression analysis method was employed to derive regression equations for stature estimation from various foot measurements. Stepwise binary logistic regression equations were used to generate models for sex determination and the prediction accuracies of these models were also determined.

RESULTS AND DISCUSSION

Sample characteristics

A total of 307 participants including 177 males and 130 females with ages ranging from 16 to 34 years were recruited for this study. Out of the 307 participants recruited for the study, 240 (78.18%) of them were Akans. Aside the Akans, the Northerners, Ewes, Ga-Adangbes and those belonging to other tribes were 20 (6.51%), 16 (5.21%), 16 (5.21%) and 15 (4.89%) in number respectively. The tribes that made up the other tribes were; Nzemas, Kotokolis and Guans.

DISTRIBUTION OF HEIGHT

The height of the participants ranged from 145.90 to 192.50 cm with the overall mean height being 167.75 ± 8.07 cm. The Ga-Adangbes recorded the highest mean height (170.36 ± 8.48 cm) followed by those belonging to other tribes (170.10 ± 7.20), Ewes (168.99 ± 7.11 cm), Northerners (167.82 ± 6.33 cm) with Akans recording the lowest mean height of 167.34 ± 8.27 cm. When data was stratified by sex, males (171.50 ± 7.07 cm) were taller than females (162.63 ± 6.36 cm) and the difference was significant. This finding was consistent with studies conducted by Jasuja and Singh (2004), Fessler *et al.* (2005) and Nor *et al.* (2013)

DISTRIBUTION OF FOOT DIMENSIONS

From the present study, male participants recorded higher means for all the measured foot dimensions than the females and the differences were statistically significant ($p < 0.05$). This is in agreement with Krauss *et al.* (2008).

In males, PLT1 and PRT1 recorded the highest mean of 26.39 ± 1.38 cm and 26.32 ± 1.33 cm respectively. Also, it was observed that the mean left foot dimensions were higher than that of the right foot. In females, PLT1 (25.15 ± 1.48 cm) and PRT1 (25.17 ± 1.45 cm) had the highest mean as compared to the other measured indices. This was not consistent with a study conducted by Danborno and Elukpo (2008)

INTER-ETHNIC DIFFERENCES IN FOOT DIMENSIONS

For all the measured left and right foot dimensions, there were differences among the various tribes but these differences were not statistically significant ($p > 0.05$). This finding is in agreement with a study conducted by Phang *et al.* (2017) who also observed inter-ethnic variations that were not statistically significant in a Malaysian population.

RELATIONSHIP BETWEEN HEIGHT AND FOOT DIMENSIONS

There was statistically significant association between all the measured foot dimensions and height. Among males and females, breadth at ball on the left had the highest correlation with height (r=0.499 and r=0.353 respectively) however, this correlation was moderately strong. Also, the correlations were higher in males than females for most of the measured foot dimensions. This was consistent with Ozaslan *et al.* (2012).

TABLE 1: CORRELATION BETWEEN HEIGHT AND THE LEFT AND RIGHT FOOT DIMENSIONS AMONG MALES AND FEMALES

Measurement	LEFT r		RIGHT r	
	Males	Females	Males	Females
BHEL	0.238**	0.243**	0.201**	0.320**
BBAL	0.499**	0.353**	0.447**	0.352**
PT1	0.475**	0.219*	0.452**	0.226**
PT2	0.453**	0.222*	0.450**	0.232**
PT3	0.430**	0.226**	0.428**	0.201*
PT4	0.429**	0.241**	0.438**	0.231**
PT5	0.469**	0.247**	0.484**	0.195*

BHEL*=Foot breadth at heel;* ***BBAL****=Foot breadth at ball;* ***PT1*** *= Pternion- toe 1 length ;* ***PT2****=Pternion - toe 2 length;* ***PT3****= Pternion-toe 3 length ;* ***PT4****= Pternion-toe 4 length;* ***PT5****=Pternion-toe 5 length ;* ***P-Value*** *=Probability value; ** =correlation is significant at 0.01 level(2 tailed));* ***r*** *=correlation coefficient and* * *= correlation is significant at 0.05 level(2 tailed).*

ESTIMATION OF HEIGHT USING LEFT FOOT DIMENSIONS

For the left foot dimensions, the best parameter for estimation height in both males and females was BBAL (Adj.$R^2$of males and females= 0.244, 0.118 respectively). However, the Adj.R^2 was below 25%. Also, the regression equations developed from the right foot dimensions also had an adjusted R square value below 25% also confirming that for this population, the foot dimensions may not be a reliable determiner of height. making it not reliable for height determination (Table 2 and 3). This was consistent with Fawzy and Kamal, 2010.

Table 2: SIMPLE LINEAR REGRESSION EQUATIONS FOR HEIGHT ESTIMATION FROM LEFT FOOT DIMENSIONS

Parameter	Sex	Regression equation	SEE	R^2	Adj.R^2
BHEL	Male	151.532+3.293(BHEL)	6.884	0.057	0.051
	Female	146.693+2.844(BHEL)	6.196	0.059	0.052
BBAL	Male	110.704+6.307(BBAL)	6.147	0.248	0.244
	Female	129.135+3.732(BBAL)	5.975	0.125	0.118
PLT1	Male	107.321 + 2.432(PLT1)	6.237	0.226	0.221
	Female	138.140 + 0.942 (PTL1)	6.231	0.048	0.041
PLT2	Male	111.665 + 2.326(PLT2)	6.321	0.205	0.200
	Female	139.551 + 0.938(PLT2)	6.226	0.049	0.042
PLT3	Male	116.772 + 2.214(PLT3)	6.399	0.185	0.180
	Female	139.468 + 0.981(PLT3)	6.221	0.051	0.044
PLT4	Male	116.120 + 2.358(PLT4)	6.419	0.184	0.179
	Female	137.295 + 1.128 (PLT4)	6.198	0.058	0.051
PLT5	Male	111.847 + 2.704(PLT5)	6.261	0.220	0.215
	Female	136.693 + 1.225 (PLT5)	6.189	0.061	0.054

BHEL *=Foot breadth at heel(left);* ***BBAL*** *= Foot breadth at ball(left);* ***SEE*** *=Standard Error of the Estimate ;*R^2 *= Coefficient of determination;* ***Adj.R²*** *= Adjusted coefficient of determination,* ***PLT1*** *= Pternion- toe1 length (left);* ***PLT2****=Pternion – toe 2 length (left);* ***PLT3****= Pternion-toe 3 length (left);* ***PLT4****= Pternion-toe 4 length (left);* ***PLT5****=Pternion-toe 5 length (left).*

Table 3: SIMPLE LINEAR REGRESSION EQUATIONS FOR HEIGHT ESTIMATION USING THE RIGHT FOOT DIMENSIONS

Parameter	Sex	Regression equation	SEE	R^2	Adj.R^2
BHEL	Male	154.503+ 2.818(BHEL)	6.943	0.041	0.035
	Female	140.262+ 4.016(BHEL)	6.051	0.102	0.095
BBAL	Male	118.821+ 5.415(BBAL)	6.342	0.199	0.195
	Female	129.349+3.666 (BBAL)	5.977	0.124	0.117
PRT1	Male	108.374 + 2.399(PRT1)	6.234	0.204	0.199
	Female	137.710 + 0.990(PRT1)	6.221	0.051	0.043
PRT2	Male	113.214 + 2.272(PRT2)	6.330	0.202	0.198
	Female	138.591+ 0.979(PRT2)	6.212	0.054	0.047
PRT3	Male	117.045 + 2.210(PRT3)	6.405	0.183	0.179
	Female	142.601 + 0.849(PRT3)	6.256	0.040	0.033
PRT4	Male	114.759 + 2.422(PRT4)	6.372	0.192	0.187
	Female	139.088 + 1.048(PRT4)	6.213	0.054	0.046
PRT5	Male	107.363 + 2.907(PRT5)	6.204	0.234	0.229
	Female	142.257 + 0.963(PRT5)	6.263	0.038	0.031

BHEL *=Foot breadth at heel (right);* ***BBAL****= Foot breadth at ball(right);* ***SEE*** *=Standard Error of the Estimate;* R^2 *= Coefficient of determination;* ***Adj.R²*** *= Adjusted coefficient of determination;* ***PRT1*** *= Pternion- toe 1length (right);* ***PRT2****=Pternion - toe 2 length (right);* ***PRT3****= Pternion-toe 3 length (right);* ***PRT4****= Pternion-toe 4 length (right);* ***PRT5****=Pternion-toe 5 length (right).*

DETERMINATION OF SEX USING FOOT DIMENSIONS

Using stepwise binary logistic regression equation, three models were derived using foot dimensions. There was a significant prediction of sex by all these three models ($p < 0.05$) but the model with the highest prediction accuracy was;

Sex = -0.889 (right BHEL) -1.412 (left BBAL) -0.281(PLT1) + 25.224.

When the result of the equation is > 0.5 it indicates a male and when ≤ 0.5 it indicates a female. The sex prediction accuracy in males was 82.4% and 66.9% in females. The overall sex prediction accuracy was 75.8%. This was in agreement with a study conducted by Bindurani *et al.* (2017) but was not consistent with Zeybek *et al.* (2008).

CONCLUSION

Foot dimensions in the males were larger and broader than that of the females. Foot dimensions were not useful in the determination of tribe. The dimension that correlated best with height in both males and females were the left foot breadth at ball but the coefficient of determination was below 25% therefore was not a reliable index for height estimation. Sex was best determined using left foot breadth at ball, right breadth at heel and left pternion-toe 1 length.

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