

# Forensic application of foot dimensions in ethnic differentiation among Ghanaians

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**Abstract.** *Background and aim:* Foot dimensions are known parameters for height estimation and personal identification in most developed countries but there appears to be dearth of information about their utilization in developing countries. Therefore, the present study sought to provide ethnic-specific baseline data on foot dimensions and bring to light the differences that exist between some ethnic groups in Ghana. *Methods:* One hundred and ninety-three undergraduate students consisting of Ashantis, Fantes and Ewes were recruited. Plantar surfaces were scanned and foot dimensions were taken. *Results:* The left 1<sup>st</sup>, right 2<sup>nd</sup> and 3<sup>rd</sup> toe-pterion lengths and the right breadth at ball were the only dimensions that exhibited differences between the Ashanti and Fante ethnic groups. However, differences were recorded between the Ashanti and Ewe feet for all the measurements taken. Also, with the exception of the right 5<sup>th</sup> toe-pterion length, all the dimensions exhibited differences. *Conclusions:* Inter-ethnic differences exist for the dimensions of the foot between the ethnic groups that were involved in the present study. The present study has provided ethnic specific baseline data on foot dimensions for identification purposes. ([www.actabiomedica.it](http://www.actabiomedica.it))

**Key words:** inter-ethnic difference, foot dimensions, ethnicity, identification, plantar surface

## Introduction

According to forensic anthropologists, the ancestry (ethnicity) of an individual is one of the four important biological profiling features (ancestry, biological sex, age, height) (1). Therefore, devising means for determining and differentiating between the ethnic groups using the different parts of the body serves to minimize the scope of search in cases of natural disasters, road traffic accidents, wars etc. It is of optimum importance, in mostly developing countries where the DNA database of the citizens are yet to be set up for identification purposes, to be able to establish relationships between the parts of the human body and race (2). It is evident that the morphology of the foot shows variations in terms of race

and ethnicity (3). Therefore, a key feature that must be well-thought-out for population profiling, is the consideration of the reliability and efficiency of the biological profile. (4). In estimating the androgenic differences among ethnic groups, Manning (5) observed the differences among the ethnic groups to be statistically significant. According to Pheasant (6), the uniqueness in the various dimensions and measurements of the limbs among different ethnic groups could be attributed to hormonal, environmental and climatic effects. Currently, there appears to be no ethnic specific dimensions of the foot that could be used in differentiating between some major ethnic groups in Ghana. The present study therefore sought to provide information on the inter-ethnic differences existing for footprint dimensions.

## Materials and methods

A total number of 193 students at the School of Medicine and Dentistry (Kwame Nkrumah University of Science and Technology) consisting of 70 (36.3%) Ashantis, 61 (31.6%) Ewes and 62 (32.1%) Fantes were recruited for the study. Ethical approval was sought from the KSMD/KATH Committee of Human Research, Publication and Ethics (CHRPE/AP/396/21). The research and its protocol were explained to the understanding of the participants to obtain their informed consent. Individuals without any form of foot, hand and limb related deformities were recruited. Pregnant women and individuals whose parents (mother and father) were not from the same ethnic group were excluded. The sex, age, ethnic group, foot lengths related to toe I to V, breadth at heel, breadth at ball were recorded.

### Measurement of foot dimensions

A pilot study was done prior to the commencement of the study to compare the methodology being used in the present study (foot scan using Canoscan LiDE 120) to the direct or manual measurement method. No statistically significant differences ( $p=0.8$ ) existed between the measurements taken by these two methods. The intra-rater and inter-rater reliability were assessed using the intraclass correlation coefficient. The intra-rater reliability and inter-rater reliability were more than 97% and 96% respectively. The sole of the feet of each participant was washed and cleaned thoroughly with a dry towel. With a flexed left knee, the ipsilateral foot of the participant was then gently

placed on flatbed scanner (Canoscan LiDE 120) connected to an HP 15 laptop. The sole of the left foot was then scanned and the image produced was labelled and saved. The same procedure was repeated for the right foot. The foot dimensions were then measured using the parallel dimension tool of CorelDRAW X7 (64-Bit) software. Below are the definitions of the various foot dimensions measured.

### Breadth at ball

The breadth at ball measures the distance between the most projecting points on the medial and lateral sides at the ball of the foot. This spanned from the heads of the first to the fifth metatarsal taking its origin from the most medial aspect of the foot to the most lateral aspect of the foot (7) (Figure 1).

### Breadth at heel

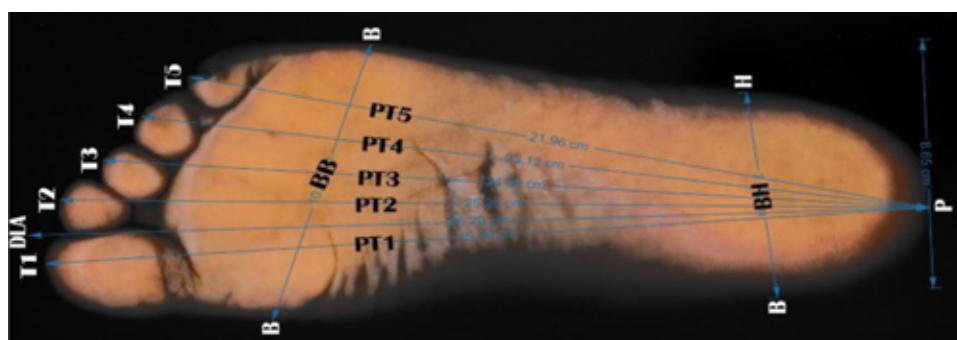
The breadth at heel was measured as the widest distance across the heel (Figure 1).

### Foot length

The lengths relating to I – V toes of the feet were measured from the mid-rear heel point (pternion) to the most anterior edge of each toe (Figure 1).

### Statistical analysis

The data obtained were documented in a log book and further recorded into Microsoft Office Excel 2013.



**Figure 1.** A scanned image of the right foot showing the dimensions measured ( $\times 0.2$ ). PT1-PT5 = pternion to toe lengths 1 to 5, BB = Breadth at ball, BH = breadth at heel.

The data were then analysed using the IBM Statistical Package for Social Sciences (SPSS) version 23.0 (SPSS, Inc., Chicago, Illinois, USA). In testing for normal distribution, one-sample Kolmogorov-Smirnov test and Shapiro-Wilk normality test were performed. Moreover, inter-ethnic differences in foot dimensions were determined using Multivariate Analysis of Variance (MANOVA).

## Results

### *Sample characteristics*

One hundred and ninety-three (193) consisting of 70 (36.3%) Ashantis, 61 (31.6%) Ewes and 62 (32.1%)

Fantes were included in the present study. The mean age of the participants was  $20.7 \pm 3.2$  years. The Ashanti, Ewe and Fante ethnic groups recorded mean ages of  $18.8 \pm 1.3$  years,  $22.1 \pm 3.4$  years, and  $21.4 \pm 3.5$  years respectively.

### *Inter-ethnic differences in foot dimensions*

There were significant inter-ethnic differences between the means of most of the foot measurements employed in this study. Inter-ethnic difference was exhibited by the left 1<sup>st</sup> toe to pternion length between the Ashanti and Fante ethnic groups. However, between the Ashanti and Ewe ethnic groups as well as the Ewe and Fante ethnic groups, all the measurements of the left foot exhibited statistically significant differences (Table 1). The Ashanti ethnic group

**Table 1.** Inter-ethnic differences in left foot dimensions.

Dimension	Ethnicity 1	Mean $\pm$ SD	Ethnicity 2	Mean $\pm$ SD	M. D	S. E	P
LT1	Ashanti	25.9 $\pm$ 1.5	Ewe	24.6 $\pm$ 1.5	1.3	0.3	<0.001
			Fante	25.3 $\pm$ 1.5	0.6	0.3	0.035
	Ewe	24.6 $\pm$ 1.5	Fante	25.3 $\pm$ 1.5	-0.7	0.3	0.034
LT2	Ashanti	25.4 $\pm$ 1.6	Ewe	24.0 $\pm$ 1.6	1.4	0.3	<0.001
			Fante	24.6 $\pm$ 1.6	0.6	0.3	0.052
	Ewe	24.0 $\pm$ 1.6	Fante	24.8 $\pm$ 1.6	-0.7	0.3	0.030
LT3	Ashanti	24.4 $\pm$ 1.5	Ewe	23.1 $\pm$ 1.6	1.4	0.3	<0.001
			Fante	23.8 $\pm$ 1.7	0.6	0.3	0.083
	Ewe	23.1 $\pm$ 1.6	Fante	23.8 $\pm$ 1.7	-0.8	0.3	0.018
LT4	Ashanti	23.2 $\pm$ 1.4	Ewe	22.0 $\pm$ 1.4	1.2	0.3	<0.001
			Fante	22.7 $\pm$ 1.5	0.5	0.3	0.160
	Ewe	22.0 $\pm$ 1.4	Fante	22.7 $\pm$ 1.5	-0.8	0.3	0.010
LT5	Ashanti	21.9 $\pm$ 1.3	Ewe	20.7 $\pm$ 1.3	1.2	0.2	<0.001
			Fante	21.4 $\pm$ 1.4	0.5	0.2	0.092
	Ewe	20.7 $\pm$ 1.3	Fante	21.4 $\pm$ 1.4	-0.7	0.2	0.007
LBB	Ashanti	9.8 $\pm$ 0.8	Ewe	9.3 $\pm$ 0.7	0.5	0.1	<0.001
			Fante	9.6 $\pm$ 0.7	0.2	0.1	0.187
	Ewe	9.3 $\pm$ 0.7	Fante	9.6 $\pm$ 0.7	-0.3	0.1	0.030
LBH	Ashanti	6.7 $\pm$ 0.7	Ewe	6.2 $\pm$ 0.5	0.5	0.1	<0.001
			Fante	6.5 $\pm$ 0.6	0.2	0.1	0.127
	Ewe	6.2 $\pm$ 0.5	Fante	6.5 $\pm$ 0.6	-0.3	0.1	0.019

S.E - Standard error, LT1 to LT5 – left pternion to anterior toes (T1-T5), LBB – left breadth at ball, LBH – left breadth at heel, M.D. - mean difference, p – probability, p < 0.05 = significant

recorded the highest left foot dimensions followed by the Fante and then the Ewe ethnic groups.

The mean differences between the Ashanti and Ewe ethnic groups for all the right foot dimensions were statistically significant. Also, between the Ewe and Fante ethnic groups, with exception of the right 5<sup>th</sup> pternion to toe length, all the dimensions of the right foot exhibited statistically significant differences (Table 2).

## Discussion

### *Inter-ethnic differences of foot dimensions*

Silventoinen *et al.* (8), Dubois *et al.* (9) and Moorthy and Sulaiman (7) suggested that no two individuals (twins inclusive) are genetically precisely

the same and the unique variability in an individual serves as the means of identifying that particular individual. Manning (5) found the androgenic differences among people of different ethnic groups to be statistically significant. According to literature, different races and ethnic groups have varying foot measurements (10). Pheasant (6) attributed the inter-ethnic differences to hormonal, environmental and climatic effects. Due to the fact that all the ethnic groups employed in the present study are in Ghana, although their geographical locations are different, similar and dissimilar parameters could be observed (8, 9, 11). The significant differences that were observed in this study can be attributable to the variations in the climatic, environmental, occupational, nutritional and hereditary factors of the ethnic groups involved (9, 12). The similarities in the dimensions of the foot could also

**Table 2.** Inter-ethnic differences of right foot dimensions.

Dimension	Ethnicity 1	Mean $\pm$ SD	Ethnicity 2	Mean $\pm$ SD	M. D	S. E	p
RT1	Ashanti	25.8 $\pm$ 1.6	Ewe	24.5 $\pm$ 1.5	1.4	0.3	0.000
			Fante	25.2 $\pm$ 1.6	0.6	0.3	0.071
	Ewe	24.5 $\pm$ 1.5	Fante	25.2 $\pm$ 1.6	-0.7	0.3	0.024
RT2	Ashanti	25.4 $\pm$ 1.6	Ewe	23.8 $\pm$ 1.8	1.6	0.3	0.000
			Fante	24.6 $\pm$ 1.7	0.8	0.3	0.025
	Ewe	23.8 $\pm$ 1.8	Fante	24.6 $\pm$ 1.7	-0.8	0.3	0.019
RT3	Ashanti	24.4 $\pm$ 1.6	Ewe	23.0 $\pm$ 1.5	1.4	0.3	0.000
			Fante	23.7 $\pm$ 1.6	0.7	0.3	0.036
	Ewe	23.0 $\pm$ 1.5	Fante	23.7 $\pm$ 1.6	-0.7	0.3	0.042
RT4	Ashanti	23.1 $\pm$ 1.4	Ewe	22.0 $\pm$ 1.4	1.1	0.3	0.000
			Fante	22.7 $\pm$ 1.6	0.5	0.3	0.161
	Ewe	22.0 $\pm$ 1.4	Fante	22.7 $\pm$ 1.6	-0.7	0.3	0.031
RT5	Ashanti	22.0 $\pm$ 1.8	Ewe	20.8 $\pm$ 1.4	1.2	0.3	0.000
			Fante	21.5 $\pm$ 1.4	0.6	0.3	0.101
	Ewe	20.8 $\pm$ 1.4	Fante	21.5 $\pm$ 1.4	-0.7	0.3	0.055
RBB	Ashanti	9.9 $\pm$ 0.6	Ewe	9.2 $\pm$ 0.7	0.6	0.1	0.000
			Fante	9.6 $\pm$ 0.7	0.3	0.1	0.042
	Ewe	9.2 $\pm$ 0.7	Fante	9.6 $\pm$ 0.7	-0.4	0.1	0.010
RBH	Ashanti	6.6 $\pm$ 0.5	Ewe	6.15 $\pm$ 0.5	0.4	0.1	0.000
			Fante	6.5 $\pm$ 0.5	0.09	0.09	0.572
	Ewe	6.2 $\pm$ 0.5	Fante	6.5 $\pm$ 0.51	-0.3	0.09	0.002

S.E - Standard error, p - probability, RPT1 to RPT5 - right pternion to anterior toes (T1-T5), RBB - right breadth at ball, RBH - right breadth at heel, M.D - mean difference, \* - the mean difference is significant at the 0.05 level.

be attributed to the increasing levels of inter-tribal marriages.

Age, gender, type of footwear and daily physical activities are some of the key elements that could affect the anatomy of the foot. It is however evident that the morphology of the foot shows variations in terms of race and ethnicity (13). The foot is an important human identification tool that shows uniqueness for different races and ethnic groups (14). The Ashanti and Fante groups are sub-groups of the Akan meta-ethnic group. Therefore, they may show similarities in some traits. Such traits may include the dimensions of the foot. The present study reported the left 1<sup>st</sup> toe to pternion length, right 2<sup>nd</sup> and 3<sup>rd</sup> toe to pternion length and the right breadth at ball to exhibit inter-ethnic differences between the Fante and Ashanti ethnic groups. However, between the Akan sub-ethnic groups and the Ewe ethnic group, most of the dimensions exhibited inter-ethnic differences. Fawehinmi and Paul (15) also reported inter-ethnic foot differences between the Igbos and Hausas. Chiroma *et al.* (16) reported interracial differences between the Nigerian Ga'anda people and Bangalees as well as Santhals. Moreover, the Caucasian footprint dimensions of males were significantly lower than Ga'anda tribe in Nigeria (16). According to Harris *et al.* (17) a possible explanation to the inter-ethnic differences of the footprint dimensions is the distinct use of the lower extremity among the different ethnic groups. The kind of manipulative skills displayed by a particular ethnic group could cause the lengthening and widening of the foot (18). Furthermore, McIntyre (19) suggested that differential prenatal exposure to androgens could also cause inter-ethnic and inter-racial differences of foot measurements. This androgenic explanation is backed by the findings of Kirchengast and Christiansen (20) among two Namibian ethnic groups; Kavango and Kung San. Chiroma *et al.* (16) also suggested that the inter-racial and inter-ethnic differences existing for the dimensions of the foot are attributed to climatic changes. Tobias *et al.* (21) reported that the individuals in the tropical regions have longer and wider foot to increase the area of the plantar surface of the foot to allow for loss of heat. Some people have very dense plantar pad and in weight bearing position, this pad spreads out causing the imprint to have a greater

surface area. In such cases, the greater surface area of the imprint is not due to a drop in the height of the longitudinal arches but the excess plantar pad (22).

## Conclusion

In the present study, the left 1<sup>st</sup> pternion to toe length, right 2<sup>nd</sup> and 3<sup>rd</sup> pternion to toe length and the right breadth at ball exhibited inter-ethnic differences between the Fante and Ashanti ethnic groups. Most of the dimensions employed in the study, exhibited differences between the Akan sub-ethnic groups and the Ewe ethnic groups. Foot dimensions therefore serve as a useful tool in differentiating between individuals with different ethnic backgrounds.

## Limitations

Unequal sample size for males and females as well as ethnic groups could result in sex and ethnic biases.

**Conflicts of Interest:** Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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