Stature Estimation using Footprint Dimensions among Ukwuani People of South-South Nigeria

*Eboh D.E. O[1], Ewamayinma A.R[2]

[1, 2] Department of Human Anatomy and Cell Biology, Delta State University, Abraka, Delta State, Nigeria

QR CODE

Website
http://ijfmi.com/

Doi:
https://doi.org/10.21816/ijfmi.v4i2

[1]corresponding author email:
drebohdennis@gmail.com

ABSTRACT

Introduction: Footprints usually reveal the different features of the foot, and can be left behind at crime scenes. A correlation exists between footprint measurements and stature. The aim of this study was to estimate stature from footprint dimensions among Ukwuani People of South-South Nigeria.

Materials and Methods: A descriptive cross-sectional study of 400 Primary and Secondary school teachers of Ukwuani ethnic group sampled systematically. Stature was measured in centimeter. The footprint was made on a clean white paper placed on a flat surface, and footprint length of all five toes, maximum and minimum footprint widths were measured in centimeter. Data analysis was done using SPSS 23. T-test, linear and multiple regression analyses were applied. Statistical significance was set at $p<0.05$.

Results: The dimensions were significantly higher in males compared to females only in the cases of height, big toe length print, second toe length print, maximum footprint width and minimum footprint width ($p<0.05$). The linear regression relationship of stature with footprint was significant in the cases of the big toe, third toe, fourth toe print in males and combined data; and second toe, maximum and minimum footprint width in combined data, but weak. Multiple regression relationship of stature with footprint was significant and poor with the big toe and the second toe print ($p<0.05$).

Conclusion: Footprint dimensions have a relationship with height, and can be used to derive stature in medico-legal setting in human identification.

Keywords: Anthropometry, Body height, Foot impression, Forensic, Nigeria, Ukwuani.

INTRODUCTION

Footprints are the impressions made by the foot of a person while standing, walking, running or climbing. Foot prints may reveal the different features of the foot such as deformities, Mortons toe, normal, flat or high arched foot, which are characteristics. Footprint can give evidence to the perpetrator of a crime and can be used to track same from the scene of crime to the hiding place. Criminals may go bare footed in order to avoid noise, or have a good grip when climbing walls, roofs, ceilings, and so forth to enter or exit the scene of crime 1,2. It has been noted that footprints can be left behind at crime scenes on surfaces with newly unset cement, moisture, dust, oil, paint, and blood 3,4.

The Ukwuani people are found in the Niger-Delta area, where kidnapping and killings occur due to youths demanding development of host communities by oil companies. Cases of sexual offenses, homicide, breaking and entering, etcetera, also abound. Notwithstanding, regression formulae for stature derived from footprints measurements indigenous to this people to track criminals who left footprints behind at crime scenes are lacking.

Various studies have been conducted on the stature estimation from footprint dimensions. Among them are those conducted in, Lagos, Nigeria 5; Sarawak, East Malaysia 1; Indian Tamils 6; Nnewi, Nigeria 7; Malaysian Chinese 3.

It has been published that a strong correlation exists between body height and foot size 8. More so, studies have also shown the presence of correlation between footprints and stature in different populations 5,7. It is known that 'people from different regions of a country possess different morphological features, based on their geographical distribution and primary racial characteristics' 1,9,10. It becomes imperative to provide a normative baseline study in this ethnic group, since are not available in the literature.

The purpose of this study was to estimate stature from footprint dimensions among Ukwuani People of South-South Nigeria. The findings of this study will provide population-based footprints data and regression equations for stature estimation using footprint dimensions for forensic application among Ukwuani People of South-South Nigeria

MATERIALS AND METHODS

Study Design, Population, Sample and Sampling Technique

The descriptive cross-sectional type of the quantitative design was adopted in this study.

All public primary and secondary school teachers, 20-45 years old, of Ukwuani ethnic group, in Ukwuani Local Government Area, formed the study population. The sample was 400 subjects based on the systematic sampling technique. Family pedigree status to ascertain parents were indigenous upto two generations was established before data collection.

Study Area

Armstrong 11 published that the Ukwuani people also referred to as Ndokwa Ethnic Nationality, are mainly farmers, located in Southern Nigeria, in the West of the Niger along other Igbo in the Region. The native language spoken is "Ukwuani". Armstrong 11 also reported that they lie between latitudes 50˚ 48′ N and 50˚ 60′ N and longitudes 60˚ 08′ E and 60˚ 32′ E. The author also stated that the Ukwuani people are the second largest ethnic group in Delta state and make huge oil contribution to the Nigerian Economy.

Ethical consideration

Informed consent was obtained from subjects prior to data collection in accordance with standard practice 12.

Also, the Research Ethics Committee of the Faculty of Basic Medical Sciences approved the methods for the study (reference number: REC/FMBS/DELSU/19/46).

Method of data collection

A prior pilot study conducted indicated that in all footprint parameters, no statistically significant side differences were recorded between paired samples ($p>0.05$). Hence, in the main study, only the right foot was measured. Only subjects without history of surgery and deformities of the feet were qualified for the study.

The stature was measured in cm with stadiometer as the linear distance from the vertex of the head to sole of the foot at the floor level, with the subject standing barefooted with the head held in the Frankfurt horizontal plane. It was ensured that both heels and buttocks were in contact with the wall during measurement.

The footprint was taken by using a roller to rub endorsing ink on the sole of the foot of the subject and made to step on a clean white A4 paper placed on a flat surface. The anatomical landmarks of the foot were marked on the paper with a sharp pointed pencil: posterior-most point of the heel (pternion) (P), medial-most point of first metatarsal bone (M), lateral-most point of fifth metatarsal bone (L), medial-most point of calcaneus (C) and lateral-most point calcaneus (T).

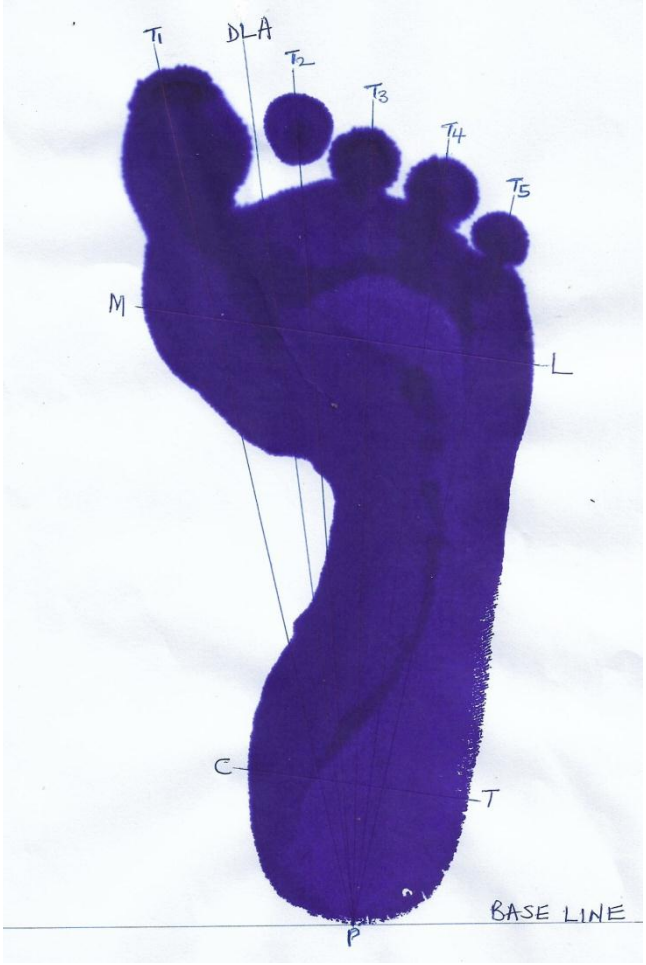

Figure 1. Footprint and measurements

$T_{1=}$ 1st toe, $T_{2=}$ 2nd toe, $T_{3=}$ 3rd toe, $T_{4=4}$ th toe, $T_{5=5}$ th toe, $P_{=}$ pternion, C= medial-most point of calcaneus, T = lateral-most point calcaneus , M= Medial-most point of first metatarsal bone. L= Lateral-most point of fifth metatarsal bone, DLA= designated longitudinal axis.

Measurements of footprints were based on established methods 10. A baseline drawn passes horizontally through the pternion (P). A perpendicular to the pternion that passes lateral to the side of the big toe was also drawn (see Figure 1).

- For footprint lengths, a diagonal was drawn from the pternion (P) to the anterior-most point of the respective toe (T1, T2, T3, T4 and T5) (Figure 1) .

• Maximum footprint width was measured in cm from the medial-most point of first metatarsal bone (M) to lateral-most point of fifth metatarsal bone (L) (Figure 1).

• Minimum footprint width was measured in cm from the medial-most point of calcaneus (C) to lateral-most point calcaneus (T) (Figure 1).

Statistical Analysis

The Statistical Package for the Social Science (SPSS) version 23 was used to analyze the raw data.. Independent samples t-test was used to determine significant mean differences in all measured parameters between males and females. Linear and multiple regression statistics were used to derive regression models for stature estimation from foot print dimensions. The value of $p<0.05$ was accepted as statistically significant

RESULTS

Demographic data showed 52.8% (211) and 47.3% (189) of study subjects were males and females respectively. The mean age of the participants was 26.10 ± 6.12 years.

Table 1. Comparison of footprint measurements in males and females.

Parameters	Data	Range	Mean ±SD	t	df	p value
Height (cm)	Combined	142.00 – 193.00	168.06 ± 8.60	-	-	-
	Male	156.00 – 193.00	173.16 ± 7.09	16.191	398	<0.001
	Female	142.00 – 184.00	162.36 ± 6.25			
Big toe length print (cm)	Combined	20.90 – 28.50	24.46±1.90	-	-	-
	Male	20.90 – 28.50	24.69±1.57	1.414	398	0.017*
	Female	21.00 – 28.30	24.32±1.51			
Second toe length print (cm)	Combined	19.80 – 28.10	24.08±2.17	-	-	-
	Male	24.00 – 28.10	25.38±0.94	19.566	398	<0.001*
	Female	21.70 – 25.00	22.75±1.68			
Third toe length print (cm)	Combined	19.40 – 27.70	23.27±1.55	-	-	-
	Male	19.40 – 27.70	23.37±1.62	1.500	398	0.134
	Female	20.40 – 26.30	23.14±1.45			
Fourth toe length print (cm)	Combined	18.30 – 26.10	22.08±1.45	-	-	-
	Male	18.30 – 26.10	22.16±1.51	1.228	398	0.220
	Female	19.20 – 25.00	21.98±1.37			
Fifth toe length print (cm)	Combined	22.90 – 24.50	20.55±2.39	-	-	-
	Male	17.20 – 24.50	20.57±1.88	0.608	398	0.544
	Female	17.80 – 23.40	20.47±1.27			
Maximum footprint width (cm)	Combined	6.40 – 19.30	9.21±0.91	-	-	-
	Male	7.40 – 19.30	9.32±0.10	2.419	398	0.016*
	Female	6.40 – 11.20	9.10±0.78			
Minimum footprint width (cm)	Combined	4.00 – 7.40	5.42±0.54	-	-	-
	Male	4.40 – 7.00	5.47±0.51	2.232	398	0.026*
	Female	4.00 – 7.40	5.35±0.56			

*Indicates values of significant difference. SD=standard deviation

Table 1 shows a comparison of height and footprint measurements in both sexes. In general, mean value of all parameters was higher in males than those of females. The dimensions were statistically significantly higher in males compared to females in the cases of big toe length print (p= 0.017), second toe length print (p< 0.001), maximum footprint width (p= 0.016) and minimum footprint width (p=0.026), while in third toe length print, fourth toe length print and fifth toe length prints, sex differences were not statistically significant (p>0.05) (also see Table 1).

Table 2. Linear Regression Equations for Footprint.

Parameters	Group	Constant	Slope	SEE	R	p- value	Equations
Big toe length print (cm)	Combined	148.74	0.79	8.56	0.142	0.004	H=148.74+0.79BP
	Male	155.17	0.73	7.01	0.161	0.019	H=155.17+0.73BP
	Female	163.54	-0.05	6.26	0.012	0.873	
Second toe length print (cm)	Combined	124.66	1.80	7.92	0.393	<0.001	H=124.66+1.80SP
	Male	186.02	-0.51	7.09	0.068	0.329	
	Female	171.19	-0.39	6.23	0.104	0.153	
Third toe length print (cm)	Combined	152.76	0.66	8.55	0.118	0.018	H=152.76+0.66TP
	Male	157.21	0.68	7.02	0.156	0.024	H=157.21+0.68TP
	Female	162.25	0.01	6.26	0.001	0.988	
Fourth toe length print (cm)	Combined	154.85	0.60	8.57	0.101	0.044	H=154.85+0.60FP
	Male	157.13	0.72	7.02	0.155	0.025	H=157.13+0.72FP
	Female	164.72	-0.11	6.26	0.024	0.748	
Fifth toe length print (cm)	Combined	159.83	0.40	8.58	0.075	0.132	
	Male	163.86	-0.07	7.05	0.120	0.083	
	Female	163.85	0.45	6.26	0.015	0.839	
Maximum footprint width (cm)	Combined	157.98	1.09	8.55	0.115	0.021	H=157.98+1.09MP
	Male	166.55	0.71	7.07	0.100	0.148	
	Female	164.37	-0.22	6.26	0.028	0.707	
Minimum footprint width (cm)	Combined	158.25	1.81	8.55	0.113	0.024	H=158.25+1.81MWP
	Male	169.07	0.65	7.09	0.053	0.440	
	Female	158.87	0.75	6.25	0.058	0.425	

H= stature, BP= big toe print length, SP= second toe print length, TP= third toe print length, FP= fourth toe print length, FTP= fifth toe print length, MP= Maximum print width, MWP= Minimum print width.

Table 2 shows the results of linear regression analysis of body height on footprint dimensions. It showed that in the combined data, statistical significant relationship existed between body height and big toe length print ($p= 0.004$), second toe length print ($p< 0.001$), third toe length print print ($p= 0.018$), fourth toe length ($p= 0.044$), maximum footprint width ($p= 0.021$), and minimum foot print width ($p= 0.024$); but not in fifth toe length print ($p>0.05$). In the male data, significant relationship ($p<0.05$) existed only in the cases of the big toe, third toe and fourth toe length prints. No relationship between body height and footprint in females ($p>0.05$). Consequently prediction models were derived only in cases where significant relationship existed between body height and parameter (Table 2).

Table 3: Multiple Regression

Parameters (cm)	Unstandardized coefficients (B)	Standard error of the estimate (SEE)	R	p-value
Constant	107.659			<0.001*
Big toe length print	0.535			0.398
Second toe length print	1.766			<0.001*
Third toe length print	0.727			0.422
Fourth toe length print	-0.872			0.378
Fifth toe length print	0.003	7.881	0.418	0.993
Maximum footprint width	0.306			0.578
Minimum footprint width	0.759			0.422
Multiple regression equation = H=107.66+ 1.766(SP)				

*statistically significant, H=stature, SP= second toe print length.

Table 3 shows the results of multiple regression analysis between height and footprint parameters. Regression correlation (R) was significant only for the " constant" component (p=0.000) and the second toe length print (p< 0.001). The regression model is shown in table 3.

DISCUSSION

In the present study, male were significantly taller than females. Previous studies had shown higher body height in males compared to females 1,3,5,7,13. This could be attributed to the fact that females attain puberty about 2 years earlier than males, affording the male gender extra time to grow; and also the relationship between Y chromosome and body height 14,15.

It is observed in this study that all the footprint dimensions were higher in males compared to females, but only in big toe, second toe print lengths, maximum and minimum foot print widths were the differences significant. Findings from related studies also reported higher dimensions in male than in females 1,3,5,7. It is well known that the bones of the human body are longer in males than in females. It is therefore extrapolated here that the higher dimensions of the feet imprints of males could be the result of the aforesaid.

On correlation between body height and footprint parameters, the data gave varied outcomes. In the some previous studies, it was reported that there were significant correlations between height and all toe print parameters measured 1,3,5,6. The result of the present study is in line with the aforementioned in the cases of combined and male data of big toe print, combined data of second toe print lengths, combined and male data of maximum and minimum foot print widths as they showed significant correlation with height. The result of the current study did not support the report by Okubike et al. 5 in the sense that female data of second toe print, maximum and minimum foot print widths showed no significant correlation with height. The difference could be present because the present study used a larger sample size of a specific ethnic group as against the former that recruited medical students generally.

In another study 7, they reported significant correlation between height and toe print dimensions in male data. The result of our study is similar to Ukoha et al. 7. With regards to the big toe print length, third toe print length and fourth toe print length, but also at variance as it concerns second and fifth toe's print length. Correlation of maximum and minimum footprint widths, with stature is not significant in the present study, which is congruent

with the result of a previous study 7. On the female data, correlation of all the footprint dimensions with height is not significant, different from the report of Ukoha et al. 7 who reported significant correlation.

The values of the correlation coefficient in the linear regression in the present study were lower than those of some prior studies 1,3,5, suggesting that the relationship may not be as strong as the latter. The multiple regression analysis showed that the correlation coefficient (R) is also low (R=0.42) though higher than those of the linear regression reported earlier, indicating a stronger relationship.

The values of the standard error of estimates (SEE) of the linear regression in the present study were moderate to high when compared with those of some previous studies 3,5,7, indicating elements of precision and accuracy of the regression models. In the multiple regression analysis, the SEE is not lower than those of the linear regression. These values recorded could be due to inherent factors, like genetic and the environment, peculiar to the ethnic group under consideration.

Based on the positive and significant correlation between footprint parameters and height, and the level of accuracy of the regression models, stature can be derived accurately from footprint measurements. Therefore, the study has established mathematical models for stature estimation using footprint parameters among Ukwuani; normative baseline values for foot anthropometry for indigenous Ukwuani people of South-South Nigeria. This study can be relevant in forensic human identification when the only evidence left at a crime scene is the footprint of a criminal or a victim. The applicability of the derived models will be more effective within the population.

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