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Original Article

Stature Prediction using Shoe Print Dimensions of an Adult Nigerian Population

التنبؤ بطول القوام باستخدام أبعاد طبعة الحذاء لدى سكان نيجيريين بالغين

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Abstract

This study aimed to derive predictive equations for stature estimation using shoe print dimensions of adult Nigerian medical students in the University of Lagos.

A sample of 230 volunteers (100 males and 130 females) of Nigerian parentage, aged 18 – 36 years comprised this cross-sectional study. Stature and 460 bi-lateral shoe prints were obtained from the participants using a stadiometer and ink pads. Data analysis was performed using SPSS version 20.

Sexual dimorphism in stature and shoe print dimensions were found to be highly significant ($p < 0.05$), with the males having greater values than the females. Paired t-test revealed statistically significant bi-lateral differences in shoe print dimensions for the females and the pooled sample ($p < 0.05$). The right shoe print length (RSPL) exhibited the highest correlation with stature in the males, females and the pooled sample, with values of 0.483, 0.607 and 0.772, respectively. The shoe print breadths in the males, females and the pooled sample were significantly correlated with stature, except the left shoe print breadth (LSPB) in the females (r = 0.148).

This study has demonstrated that shoe print dimensions are significantly correlated with stature, with the shoe print length showing more reliability in stature prediction than the shoe print breadth.

Keywords: *Forensic sciences, Forensic anthropology, Stature, Shoe prints, Correlation*

المستخلص

تهدف هذه الدراسة لاشتقاق المعادلات التنبؤية لتقدير طول القامة باستخدام أبعاد طبعة الحذاء لطلاب الطب النيجيريين البالغين في جامعة لاغوس. شملت هذه الدراسة المستعرضة عينة مكونة من ٢٣٠ متطوع (١٠٠ من الذكور و١٣٠ من الإناث) من النيجيريين الذين تتراوح أعمارهم بين ١٨ و٣٦ سنة.

أجريت الدراسة بناء على تصريح من لجنة أخلاقيات البحث العلمي ، وتم الحصول على طول القامة وأبعاد٤٦٠ طبعة ثنائية للحذاء خاصة بالمشاركين، وذلك باستخدام مقياس قائم لقياس الطول ومنصات وقوف حبرية على التوالي. وأجري تحليل البيانات باستخدام الإصدار ٢٠ من برنامج الحزم الإحصائي SPSS. ووجد أن أبعاد طول القامة والأحذية المطبوعة لكل الجنسين ذو دلالة إحصائية كبيرة ($p < 0.05$)، حيث أن للذكور قيم أكبر من الإناث. وكشف اختبار (t-test) لعينتين مرتبطتين عن فروق ثنائية مزدوجة ذات دلالة إحصائية في أبعاد طبعة الحذاء للإناث مقارنة بالعينة المجمعة (الذكور والاناث) ($p < 0.05$). قياس طول طبعة الحذاء الأيمن (RSPL) أظهر معامل ارتباط أعلى مع طول القامة عند الذكور والإناث والعينة المجمعة، مع قيم ٠,٤٨٣ و٠,٦٠٧ و٠,٧٧٢ على التوالي. يرتبط عرض طبعة الأحذية لدى الذكور والإناث والعينة المجمعة بشكل ملحوظ مع طول القامة، باستثناء عرض طبعة الحذاء الأيسر (LSPB) عند الإناث (r = 0.148).

لقد أثبتت هذه الدراسة أن أبعاد طبعة الحذاء ترتبط ارتباطًا وثيقًا بطول القامة، وأن طول طبعة الحذاء يظهر موثوقية أكبر في التنبؤ بطول القامة مقارنة بعرض طبعة الحذاء.

الكلمات المفتاحية: علوم الأدلة الجنائية، علم الأنثروبولوجيا الجنائي، طول القامة، طبعات الحذاء، معامل الارتباط.

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1. Introduction

There are various methods by which personal identification can be performed which include anthropometry, bite marks, lip prints, finger prints, footprints and shoe prints [1,2]. When examining a crime scene, many variables are usually not known about the suspect. There may be few, if any, witnesses and the perpetrators seldom leave behind specific identifying information (e.g., driver's license, identity card, etc.) Information about the perpetrator's identity is therefore deduced from the evidence left at the scene, and a person's stature is one identifying characteristic that is often used [3]. Evidence that a suspect leaves at a crime scene is likely to include foot or shoe prints, and because foot length has a biological correlation with stature, the latter can be estimated from foot or shoe print dimensions [4-10]. This evidence may provide the best,or only, opportunity to predict that aspect of a suspect's physical description, which can also be used to corroborate height estimates obtained from witnesses [11,12].

It has been reported that more than 30% of all burglaries provide usable shoeprints that can be recovered from crime scenes [2]. Analysis of shoe prints can reveal very important clues, which can be used as forensic evidence in crime scene investigations [13,14]. Previous studies have been conducted on stature estimation using shoe [12,15,16] and shoe print dimensions [2,11,17,18] in different populations. However, inter-populational differences in anthropometric characteristics, which include stature and foot dimensions relative to shoe size, have been reported to exist due to geographical distribution, genetic variation and primary racial traits. This necessitates the establishment of population specific stature prediction models in different climes [19]. Apart from giving idea about barefoot morphology and individualistic characteristics, shoe prints are also indicative of a person's height [16]; hence, the present study attempts to predict stature from shoe print dimensions.

There is paucity of data and forensic literature on stature estimation using shoe prints in Nigeria, and to the best of our knowledge, there is currently no existing literature on stature prediction from shoe print dimensions in a Nigerian population. Hence, it is very pertinent to evaluate the relationship between stature and shoe print dimensions, aimed at establishing predictive equations for stature reconstruction using shoe print length and breadth of an adult Nigerian population.

2. Materials and Methods

2.1 Study Population

The study population comprised randomly selected Nigerian medical students of the College of Medicine, University of Lagos. The various Nigerian ethnic nationalities were represented in the study, which included the Yoruba, Igbo, Hausa-Fulani, Edo, Ijaw, Ibibio, Efik, Igala, Nupe, Tiv and Annang.

2.2 Sample Size

A total of 230 participants (100 males & 130 females) with an age range of 18 – 36 years were recruited for this cross-sectional research work by simple random sampling. Participation of the research subjects was voluntary. Inclusion criteria required the participants to be within the age range, have both parents of Nigerian ancestry, and be free from any apparent musculoskeletal, dermatological or congenital deformity that might affect the measurements.

2.3 Ethical Approval

Ethical clearance to conduct this study was sought and obtained from the Health Research Ethics Committee, College of Medicine, University of Lagos, with reference no: CM/ HREC/12/16/084.

2.4 Informed Consent

The prerequisite for commencement of measurement was obtained after taking consent from the research subjects. The consent forms explained the measurement procedures and guaranteed the confidentiality of subjects' information.

2.5 Demographics

Sampling variables including gender, age, stature and shoe print dimensions were recorded on a data collection sheet.

2.6 Sample Collection

2.6.1 Measurement of stature

Stature was measured with a stadiometer. This instrument, a SECA 220 stadiometer (Germany), has a convenient eye-level read in case of measurement of very tall subjects. It has a measuring range of 60 – 200 cm, and the measuring rod is calibrated in millimeters (mm). The anthropometric protocol adopted for stature measurement is recommended by the International Society for the Advancement of Kinanthropometry (ISAK) [20].

For stature measurement, which represents the maximum vertical distance between the vertex of the head and the floor / base of the stadiometer, the subject was required to stand with the feet together, with the heels, buttocks and the upper part of the back touching the scale of the stadiometer. The head was held in the Frankfort plane and this was achieved when the Orbitale (lower edge of eye socket) was in the same horizontal plane as the tragion (the notch superior to the tragus of the ear). With the hands of the measurer placed far enough along the line of the jaw of the subject to ensure that upward pressure is transferred through the mastoid process, the subject was instructed to take and hold a deep breath. The head board of the stadiometer was then placed firmly down on the vertex (Figure-1). The stadiometer was read and recorded to the nearest 0.1 cm.

Figure 1- *Measurement of stature*.

2.6.2 Shoe prints

A total of 460 bi-lateral shoe prints were obtained from the sample population (Figure-2). For both males and females, the foot wears were recorded as 187 pairs of low-cut shoes and 43 pairs of rubber sole shoes. The only types of footwear considered were flat soled and well fitted shoes, to provide a basis for standardization and to prevent excess length and breadth margins. With the shoes on, the participants were instructed to step onto the ink pad, which already contained delible endorsing ink. They were then directed to step with the inked shoe sole firmly onto the white A2 duplicating papers attached to the flat wooden board lying on the ground.

a) Landmarks:

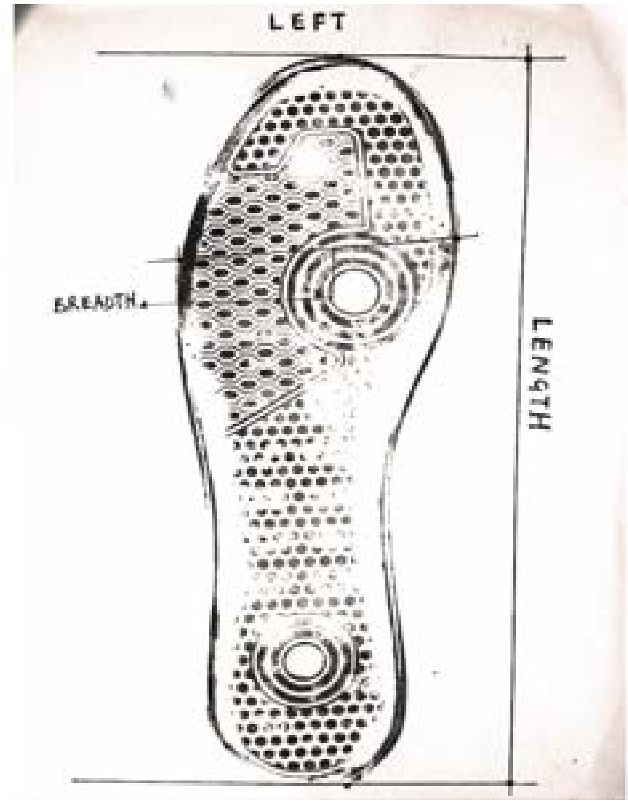

Figure 2- *A male left shoe print and its dimensions.*

- Top of the tip and the lower margin of the heel of the shoe.
- Most lateral and medial point of the shoe where the breadth of the print is at its maximum.

b) Measurement:

Instrument used: A transparent meter rule.

Following the method employed by Othman [18], shoe print length was measured as the direct distance between the top of the tip and the lower margin of the heel of the shoe. Shoe print breadth was measured as the straight distance between the most lateral and medial point of the shoe where the breadth of the print is at its maximum. The values obtained were recorded to the nearest 0.1 cm.

Each measurement was repeated twice and taken by one observer in order to avoid inter-observer bias.

2.7 Statistical Analysis

After the collation of data, it was then analyzed using statistical package for the social sciences (SPSS) for windows, version 20.0 (Armonk, New York: IBM Corporation). Kolmogorov-Smirnov test was employed to test the normality of the sample. Mean, standard deviation, standard errors of estimate, independent and paired t-tests were used as statistical tools to analyze the data. Comparisons were made of stature, shoe print length and shoe print breadth between the males and females using the Student's (independent) t-test to ascertain if sexual dimorphism exists in the study. Also, comparisons made between corresponding right and left parameters of each subject to determine if bilateral asymmetry exists, and this was carried out using the Paired t-test. The differences were considered statistically significant at 95% confidence level (i.e., when $p < 0.05$). Correlation coefficients (r), the standard measure of association between stature and the various parameters were determined for the male and female subjects, and also for the whole population. Coefficients of determination (R^2), which is the statistical method that explains how much of the variability of a dependent variable can be caused or explained by its relationship to another factor, were also derived. Linear regression equations were also derived using the variables, and this served as the predictive models for stature estimation.

3. Results

The results were summarized using the tables and graphs. The Kolmogorov-Smirnov test indicated normal distribution of the data, with the test statistics found not to be statistically significant ($p > 0.05$) for all the parameters.

Males have consistently greater values than the females for all the investigated parameters. The values of the pooled sample are lesser than that of the males, and greater than the values obtained for the females. This is because the pooled sample consists of the whole study population irrespective of gender (Table-1).

From Table-2, it can be observed that sexual dimor-

Table 1- *Summary of the descriptive and inferential statistics of age, stature, shoe print length and breadth in males, females and the pooled sample.*

Descriptive and Inferential Statistics						
	Measurement (cm)	**Mean**	**± SD**	**Range**	**Minimum value**	**Maximum value**
Males (*n* = 100)	Age (years)	25.48	3.18	18.00	18.00	36.00
	Stature	176.44	6.47	31.30	159.90	191.20
	RSPL	27.67	1.34	7.40	23.70	31.10
	LSPL	27.78	1.19	6.30	24.50	30.80
	RSPB	8.88	0.96	3.90	7.10	11.00
	LSPB	8.95	0.97	4.40	7.10	11.50
Females (*n* = 130)	Age (years)	24.75	2.87	18.00	18.00	36.00
	Stature	164.71	6.70	30.70	148.00	178.70
	RSPL	24.51	1.44	9.70	20.40	30.10
	LSPL	24.68	1.31	9.30	20.80	30.10
	RSPB	8.04	0.76	3.50	6.50	10.00
	LSPB	8.13	0.73	3.10	6.60	9.70
Pooled Sample (*n* = 230)	Age (years)	25.12	3.02	18.00	18.00	36.00
	Stature	169.80	8.79	43.20	148.00	191.20
	RSPL	25.88	2.10	10.70	20.40	31.10
	LSPL	26.03	1.99	10.00	20.80	30.80
	RSPB	8.41	0.94	4.50	6.50	11.00
	LSPB	8.48	0.94	4.90	6.60	11.50

SD, Standard deviation; RSPL, Right shoe print length; LSPL, Left shoe print length; RSPB, Right shoe print breadth; LSPB, Left shoe print breadth.

phism exists in the study, because the males have greater values than the females in all the investigated parameters (except age). The table shows that the difference in age between the males and the females is not statistically significant ($p < 0.05$), while the gender differences for stature and the shoe print dimensions were observed to be highly significant ($p < 0.05$).

Table-3 shows the existence of bi-lateral asymmetry in shoe print length and breadth of the females and the pooled sample ($p > 0.05$). For the males, it was observed that bi-

Table 2- *Gender differences in age, stature, shoe print length and shoe print breadth of the study population.*

Measurement (cm)	Gender differences			
	t - stat	***p* - value**	**± Mean difference**	**± Standard error of difference**
Age (years)	1.78 (ns)	0.075	0.73	0.40
Stature	13.41*	0.000	11.73	0.87
RSPL	17.11*	0.000	3.16	0.18
LSPL	18.59*	0.000	3.09	0.16
RSPB	7.19*	0.000	0.84	0.11
LSPB	7.03*	0.000	0.82	0.11

**(p<0.05); ns, not significant; RSPL, Right shoe print length; LSPL, Left shoe print length; RSPB, Right shoe print breadth; LSPB, Left shoe print breadth.*

Table 3- *Bi-lateral differences (right – left) in shoe print length and breadth dimensions of the males, females and the pooled sample.*

	Paired parameter	**t - stat**	**Sig. level (2 tailed)**	**Paired differences**	
				Mean (cm)	**± SEM (cm)**
Males (*n* = 100)	RSPL - LSPL	- 1.48	0.141	- 0.10	0.07
	RSPB - LSPB	- 1.60	0.111	- 0.06	0.04
Females (*n* = 130)	RSPL - LSPL	- 3.34*	0.001	- 0.17	0.05
	RSPB - LSPB	- 2.56*	0.011	- 0.08	0.03
Pooled sample (*n* = 230)	RSPL - LSPL	- 3.35*	0.001	- 0.14	0.04
	RSPB - LSPB	- 2.98*	0.003	- 0.07	0.02

**(P<0.05); SEM, Standard error of mean; RSPL, Right shoe print length; LSPL, Left shoe print length; RSPB, Right shoe print breadth; LSPB, Left shoe print breadth.*

lateral differences in shoe print length and breadth was not statistically significant ($p > 0.05$). The negative sign (-) for all the parameters indicated left shoe print preponderance, with the differences being statistically significant only in the females and the pooled sample.

From Table-4, it can be observed that the right shoe print length (RSPL) in the males, females and the pooled sample exhibited greater correlation coefficient values than the left shoe print length (LSPL). The right shoe print breadth (RSPB) in the females and the pooled sample showed higher correlation coefficient values than the left shoe print breadth (LSPB); while in the males, the LSPB exhibited higher correlation coefficient value than the RSPB. The LSPB in the females did not show a significant correlation with stature, and the shoe print lengths in the males, females and the pooled sample were more strongly correlated with stature than the shoe print breadth, which indicate stronger association between stature and the shoe print length. The pooled sample exhibited the highest correlation of stature with shoe print dimensions than when both genders were considered separately.

From Table-5, it can be observed that the linear regression equation for stature estimation from RSPL in the females exhibited the lowest standard error of estimate (SEE) value, hence indicating that it has the highest reliability in stature prediction using the investigated parameters. The left shoe print breadth in the pooled sample exhibited the highest SEE value, which shows that it has the least reliable equation for stature prediction from shoe print dimensions in the males, females and the pooled sample. The RSPL in the males, females and the pooled sample exhibited lower SEE values than the LSPL, hence indicating that the RSPL

Table 4- *Pearson's correlation coefficients of stature with shoe print length and breadth of the males, females and the whole study population.*

	Parameters	**Correlation coefficient (r)**	***p* - value**
Males (*n* = 100)	RSPL	0.483*	0.000
	LSPL	0.361*	0.000
	RSPB	0.257*	0.010
	LSPB	0.279*	0.005
Females (*n* = 130)	RSPL	0.607*	0.000
	LSPL	0.590*	0.000
	RSPB	0.205*	0.020
	LSPB	0.148	0.092
Pooled sample (*n* = 230)	RSPL	0.772*	0.000
	LSPL	0.748*	0.000
	RSPB	0.445*	0.000
	LSPB	0.430*	0.000

**($p<0.05$); SEM, Standard error of mean; RSPL, Right shoe print length; LSPL, Left shoe print length; RSPB, Right shoe print breadth; LSPB, Left shoe print breadth.*

Table 5- *Linear regression equations for stature estimation from the shoe print length and breadth in males, females and the pooled sample.*

	Linear Regression Equations			
	Measurement (cm)	**Linear regression equations**	**± SEE**	**R^2**
Males (*n* = 100)	RSPL	111.80 + 2.335 (RSPL)	5.700	0.233
	LSPL	122.20 + 1.952 (LSPL)	6.071	0.130
	RSPB	161.00 + 1.730 (RSPB)	6.293	0.066
	LSPB	159.80 + 1.854 (LSPB)	6.253	0.077
Females (*n* = 130)	RSPL	95.70 + 2.815 (RSPL)	5.349	0.368
	LSPL	90.55 + 3.004 (LSPL)	5.433	0.348
	RSPB	150.20 + 1.801 (RSPB)	6.587	0.041
	LSPB	153.70 + 1.346 (LSPB)	6.655	0.022
Pooled Sample (*n* = 230)	RSPL	86.12 + 3.233 (RSPL)	5.607	0.595
	LSPL	83.70 + 3.308 (LSPL)	7.896	0.560
	RSPB	135.10 + 4.124 (RSPB)	5.848	0.198
	LSPB	135.70 + 4.020 (LSPB)	7.962	0.184

**($p < 0.05$); SEE, Standard error of estimate; RSPL, Right shoe print length; LSPL, Left shoe print length; RSPB, Right shoe print breadth; LSPB, Left shoe print breadth.*

is more reliable for stature prediction in this study than the LSPL. There was also a striking observation in the pooled sample, where the RSPB exhibited a lower S.E.E value than the LSPL, which indicates that stature prediction from the right shoe print breadth is more reliable for stature estimation than the left shoe print length when both genders were considered together.

From Table-6, it can be observed that stature can be estimated from shoe print dimensions, with the shoe print lengths showing more reliability than the shoe print breadths. The mean actual stature values lie in very close approximation with the estimated stature values, hence indicating the usefulness of shoe prints in prediction of human height.

Figures-3–6 depict significant linear relationships between stature, shoe print length and shoe print breadth (right and left) in the males and females, represented using scatter graphs. It can be observed that the shoe print length in the male and female sample showed more linearity with stature than the shoe print breadth.

4. Discussion

Table 6- *Estimated stature values using the linear regression equations from shoe print length and breadth in males, females and the pooled sample.*

	Measurement (cm)	Estimated stature (cm)			
		Minimum	**Maximum**	**Mean**	**±SD**
Males (*n* = 100)	RSPL	167.16	184.45	176.40	3.13
	LSPL	170.04	182.34	176.42	2.34
	RSPB	175.35	180.10	176.36	1.66
	LSPB	173.01	181.16	176.39	1.80
	The minimum, maximum and mean actual stature values are 159.90cm, 191.20cm and 176.43cm, respectively.				

	Measurement (cm)	Estimated stature (cm)			
		Minimum	**Maximum**	**Mean**	**±SD**
Females (*n* = 130)	RSPL	153.15	180.43	164.69	4.06
	LSPL	153.04	180.99	164.68	3.95
	RSPB	153.04	180.99	164.68	3.95
	LSPB	162.65	166.82	164.64	0.99
	The minimum, maximum and mean actual stature values are 148.00cm, 178.70cm and 164.70cm, respectively.				

	Measurement (cm)	Estimated stature (cm)			
		Minimum	**Maximum**	**Mean**	**±SD**
Pooled sample (*n* = 230)	RSPL	152.07	186.66	169.79	6.78
	LSPL	161.94	180.50	169.80	3.91
	RSPB	152.51	185.59	169.78	6.58
	LSPB	162.23	181.93	169.78	3.78
	The minimum, maximum and mean actual stature values are 148.00cm, 191.20cm and 169.80cm respectively.				

SD, Standard deviation.

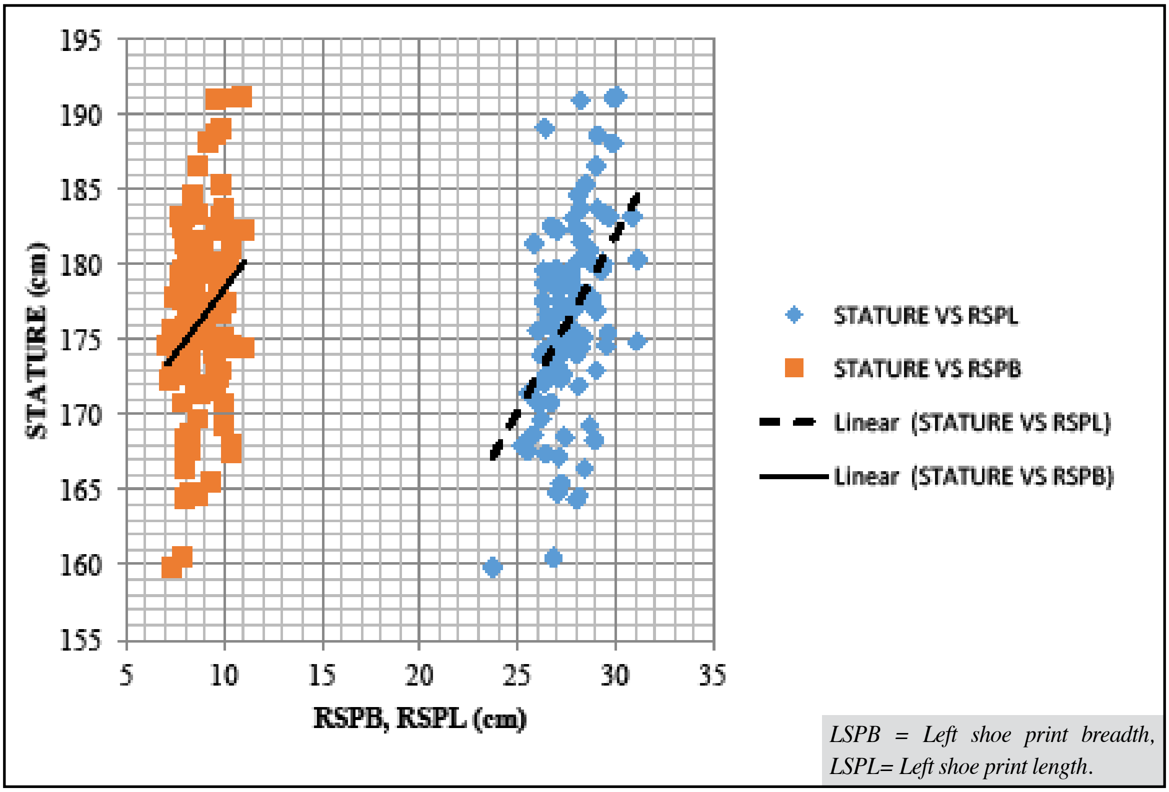

Figure 3- *Scatter plot of stature vs RSPB and RSPL in male subjects*.

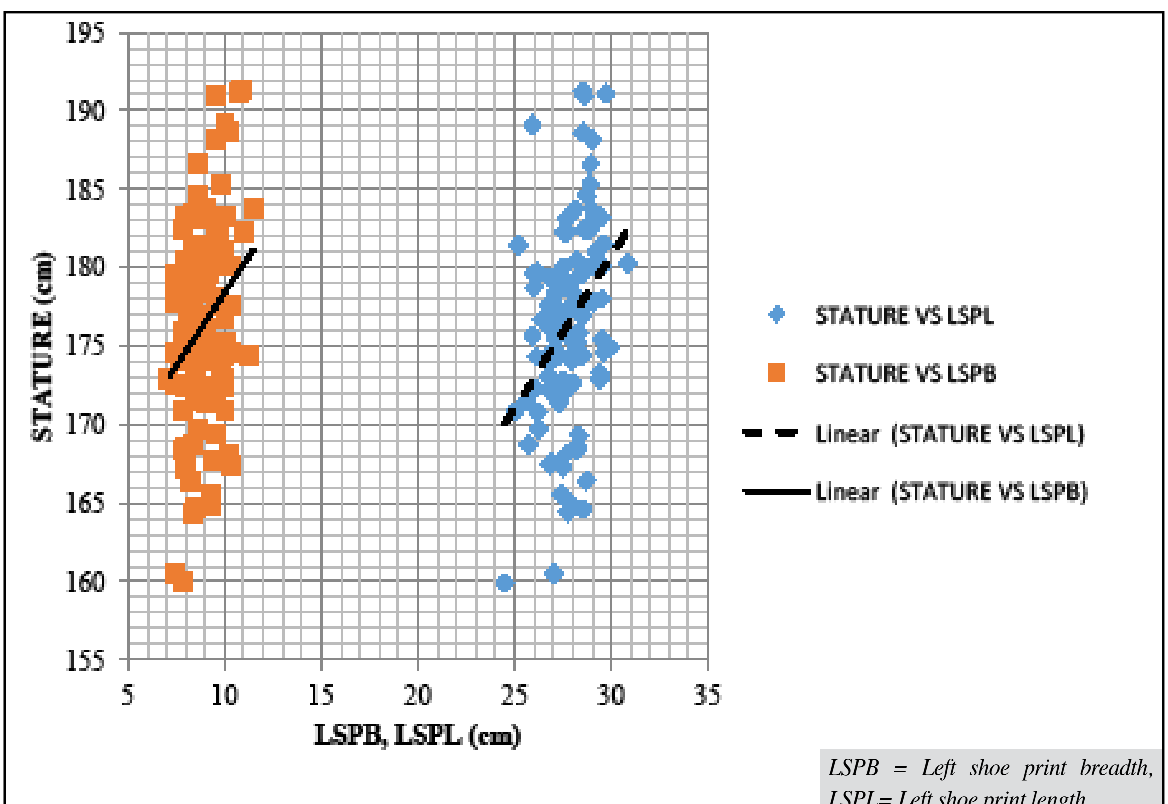

Figure 4- *Scatter plot of stature vs LSPB and LSPL in male subjects*.

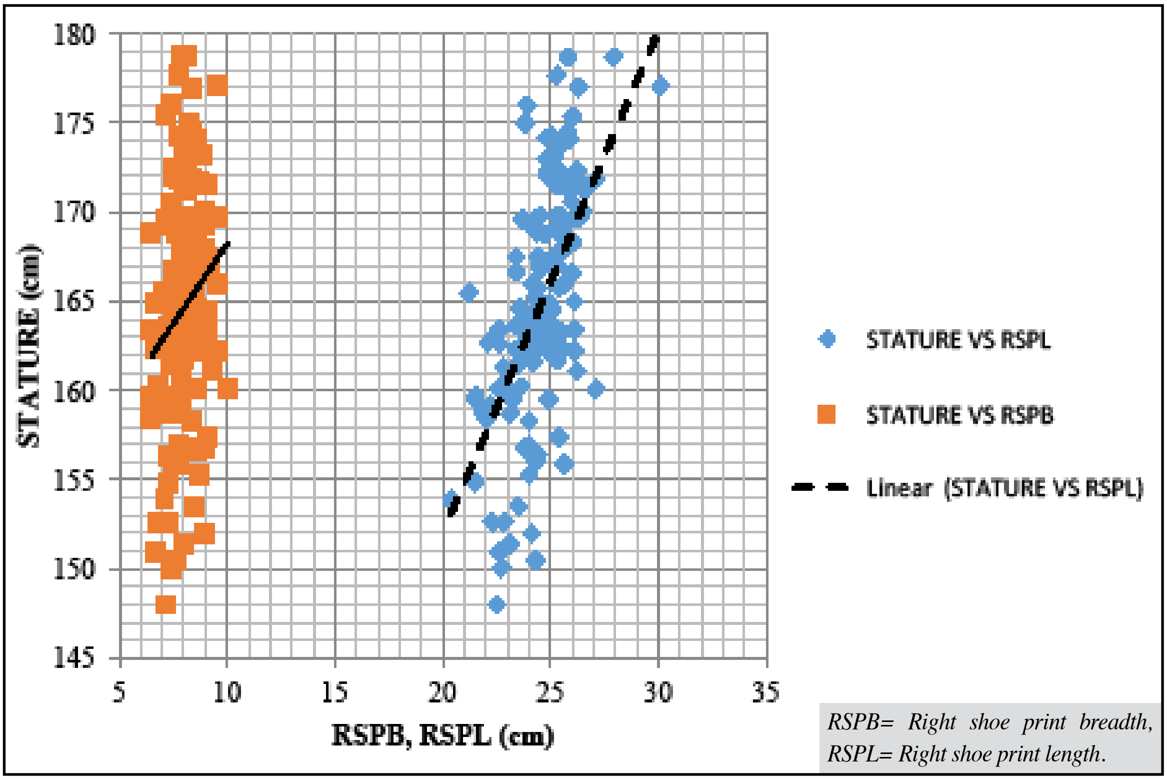

Figure 5- *Scatter plot of stature vs RSPB and RSPL in female subjects.*

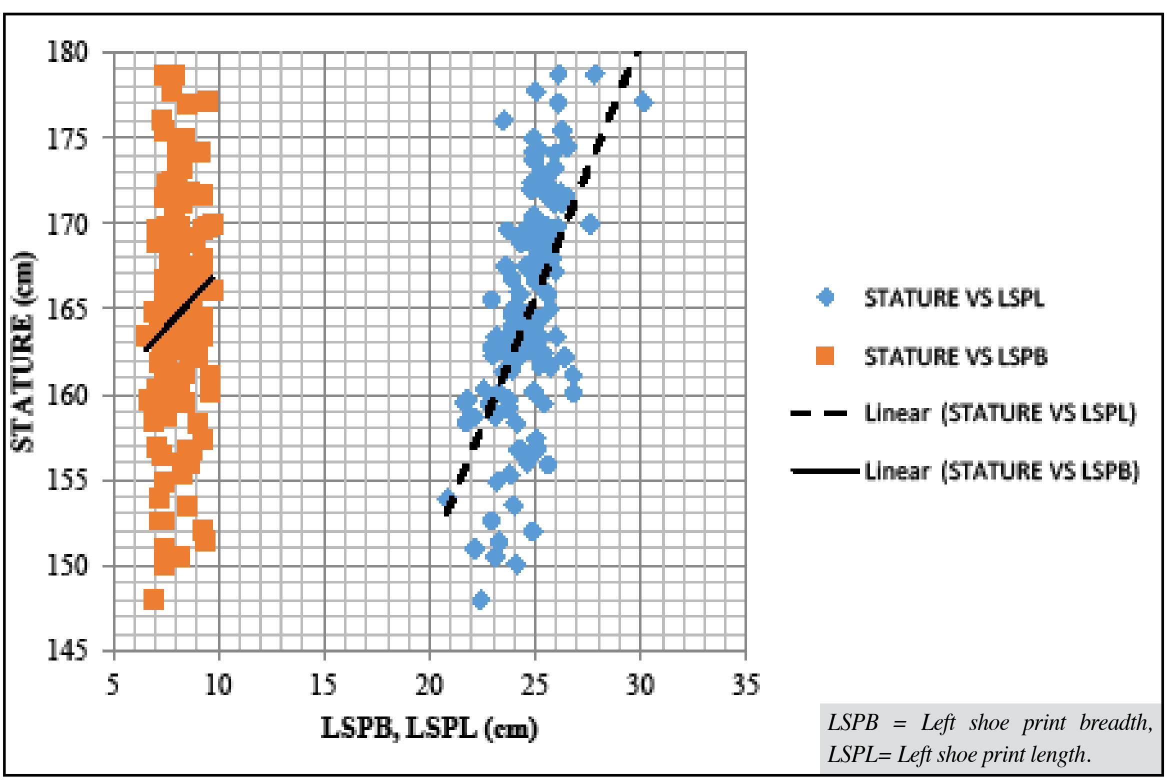

Figure 6- *Scatter plot of stature vs LSPB and LSPL in female subjects.*

After each violent crime, an examination of the crime scene will commence. Identifying the suspect is one of the most important tasks that have to be performed by crime investigators. In most crime cases, not much information is known about the suspect(s). Therefore, there must be optimum use made of available evidence at the scene of the crime, which is likely to include foot or shoe prints. While footprints represent impressions left by a bare foot on a surface, shoe prints in turn are also impressions left by a shoe on a surface [18].

In the present study, an attempt was made to predict stature using shoe prints in the males, females and the pooled sample of an adult Nigerian population. The mean ± SD values for stature and shoe print dimensions obtained from this study were recorded and tabulated. Mean values which lie in very close approximation with those of the present study have also been reported by Khairulmazidah et al. [2] in a Malaysian population, which considered only the shoe print length (right and left) for stature prediction. For the males, they reported mean values of 27.769 ± 1.31cm and 27.822 ± 1.32 cm for the right and left shoe print lengths, respectively. For the females, they reported mean values of 24.569 ± 1.35 cm and 24.605 ± 1.37 cm for the right and left shoe print lengths, respectively. However, they reported mean stature values of 166.56 ± 6.85 cm and 156.08 ± 5.83 cm for the males and females, respectively, which are lesser than the stature values recorded for the present study, which exhibited mean values of 176.44 ± 6.47 cm and 164.71 ± 6.70 cm in the males and the females, respectively. Raju et al. [17] carried out a study on stature estimation from shoe print length in Indian Karnataka females. For their study, only left shoe print length (LSPL) and the female population were considered. They reported stature and LSPL mean values of 165.87 ± 9.05cm and 24.12 ± 1.75 cm, respectively, which lies in very close approximation with the stature and LSPL values in the females of the present study. Higher mean values in shoe print dimensions (left side only) were found in the present study. Othman [18], similarly recorded LSPL and LSPB values of 28.61 ± 1.65 cm and 9.10 ± 1.13 cm, respectively, in the males, and 25.18 ± 1.70 cm for the LSPL in the females. For the LSPB, it was observed that the female population of the present study exhibited higher shoe print breadth, with a mean value of 8.13 ± 0.73 cm, as compared to a value of 7.93 ± 1.13 cm reported by Othman [18]. No two populations have the same average mean values for stature [21]. These populational differences can be attributed to variation in lifestyle, genetics, nutrition, primary racial characteristics and geographical distribution [19].

Gender differences in stature and shoe print dimensions were found to be highly significant in the present study ($p < 0.05$), with the males having greater values than the females. Similar views were expressed by Khairulmazidah et al. [2] and Othman [18] who reported the existence of statistically significant sexual dimorphism in stature and shoe print dimensions in their respective studies, with greater values being recorded for the males than the females. There was no report on gender differences by Raju et al. [17] as their study considered only a female population. Gender differences in stature and foot dimensions, and by implication, shoe prints can be ascribed to the fact that fusion of epiphyses of bones and cessation of growth occurs earlier in females in comparison to males, as males have two more years of bony growth than females [22].

The present study found the shoe print length and breadth of the females and the pooled sample to be bilaterally asymmetric ($p < 0.05$), with the left shoe print being preponderant. For the males, it was observed that statistically significant bilateral differences do not exist for the shoe print length and breadth ($p > 0.05$), although the minus (-) sign indicates greater left shoe print values. The report in the male sample is congruent with the finding of Khairulmazidah et al. [2] where bilateral asymmetry did not exist in the shoe print length of the males and females. There were no reports on bilateral asymmetry in the studies by Raju et al. [17] and Othman [18], as their studies considered only the left shoe print dimensions. The bi-lateral differences and left shoe print preponderance in the females and the pooled sample could be due to the effect of foot dominance, where the contralateral non-preferred side (left side) has always exhibited greater anthropometric values due to greater mechanical loads as a result of the postural and stabilizing support it offers [22]. The bilateral symmetry in shoe print dimensions for the male subjects in this study could be due to the fact that 80% admitted to playing football regularly, of which over 90% are right footed. This is likely to have led to an increase in the musculature of the right foot; thus reducing the preponderance of the contralateral side (left foot); hence, shoe prints of equal symmetry.

Correlation coefficient values for stature and shoe print dimensions were recorded for the present study, where there exists positive significant correlation for all the parameters in the males, females and the pooled sample, with the LSPB in the females being the only exception (r = 0.148). When compared with the correlation coefficient values reported by Khairulmazidah et al. [2] for the males, females and the pooled sample, it can be observed that the present study exhibited greater correlation coefficient values for RSPL and LSPL in the females and the pooled sample (0.59 – 0.74), while their study [2] recorded higher coefficient values for RSPL and LSPL in the males (0.50, 0.49) than was obtained in the present study. This indicates that there is stronger association between stature and shoe print length dimensions in the females and the pooled sample of the present study, while there exists stronger association between stature and shoe print length in their study [2], as regards the male population. The study by Raju et al. [17] on a female population reported a higher correlation coefficient value of 0.69 as opposed to the value of 0.590 recorded for the LSPL in the females of the present study. This indicates a stronger association between stature and shoe print length in their study than was obtained in the present study. Othman [18] reported statistically significant correlation between stature and LSPL in the males and the pooled sample, with values of 0.73 and 0.75, respectively, while the correlation in the female population was found not to be statistically significant. The report on the female population from the aforementioned study is not in tandem with the present study, which reported significant correlation between stature and LSPL in the females (0.590). The present study recorded lower correlation coefficient values in the males and the pooled sample than was obtained in the study by Othman [18], which also reported that the LSPB in the males and females were not significantly correlated with stature (r = 0.05 and -0.15, respectively). This is in keeping with the report on the LSPB in the females of the present study, where there exists no significant correlation with stature, and also contrasts the finding in the male population, where stature and LSPB was significantly correlated.

Standard error of estimate (SEE) values from the regression equations derived for stature prediction from shoe print dimensions in this study were recorded. When compared with the SEE reports by Khairulmazidah et al. [2], it was observed that their study exhibited lower SEE values in the pooled sample, females and the males (except RSPL). This indicates that stature prediction from shoe print lengths was more reliable in their study, except when the RSPL in the males was being considered. The study by

Khairulmazidah et al. [2] also provided a lower range of SEE values (± 4.991 - ± 5.928) than was recorded in the present study (± 5.349 - ± 7.962), which shows more reliability of the prediction models established in their study [2] than the present study. Gordon and Buikstra [12], for the development of their linear model for height estimation from foot and shoe measurement, showed a strong relationship between the calculation model with foot and shoe length and height. Works of Giles et al. [11], Robbins [23] and Quamra et al. [24] have also been conducted in the area of making height estimations from foot and shoe measurements by means of statistical methods.

5. Conclusion

The present study has demonstrated the usefulness of shoe print dimensions in stature estimation in Nigeria, which will be very pivotal in the identification of criminals. The shoe print length was found to be more reliable in stature prediction than shoe print breadth, with the RSPL in the females and the LSPB in the pooled sample being the most and the least reliable parameters for stature prediction in the present study, with SEE values of ± 5.349 cm and ± 7.962 cm, respectively. Further studies on stature prediction from shoe prints in Nigeria are recommended, which will employ greater sample size and a wider age range of participants.

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Abbreviations: International Society for the advancement pf Kinanthropometry (ISAK), Right shoe print length (RSPL), Left shoe print length (LSPL), Right shoe print breadth (RSPB), Left shoe print breadth (LSPB), Standard error of estimate (SEE).

References

1. Krishan K. Estimation of stature from footprint and foot outline dimensions in Gujjars of North India. Forensic Sci Int. 2008;175(2-3):93-101. https://doi.org/10.1016/j.forsciint.2007.05.014
2. Khairulmazidah M, Nadiah AN, Rumiza AR. Stature estimation using foot and shoeprint length of Malaysian Population. Int J Med Health Sci. 2013;21(29.5):24-663.
3. Sorg MH. Forensic Anthropology. In: James SH, Nordby JJ, editors. Forensic Science: an introduction to scientific and investigative techniques. Boca Raton, FL: Taylor & Francis 2005; 99-118.
4. Ozaslan A, Koc S, Ozaslan I, Tugcu H. Estimate of stature from upper extremity. Military Med. 2006; 171(4): 288-91. https://doi.org/10.7205/MILMED.171.4.288
5. Han TS, Lean ME. Lower leg length as an index of stature in adults. International journal of obesity and related metabolic disorders: Int J Obes. 1996;20(1):21-7.
6. Oommen A, Mainker A, Oommen T. A study of the correlation between hand length & foot length in humans. J Anat Soc India. 2005;54(2):55-7.
7. Saxena SK. A study of correlations and estimation of stature from hand length, hand breadth and sole length. Anthropologischer Anzeiger 1984; 42(4): 271-6.
8. Barker SL, Scheuer JL. Predictive value of human footprints in a forensic context. Med Sci Law. 1998; 38(4): 341-6. https://doi.org/10.1177/002580249803800411
9. Burke TR. Tell-tale footprints: Determination of stature from foot length in forensic cases. California State Science Fair, Project. 2002 Apr(J1003).

10. Fessler DMT, Haley KJ, Roshni DL. Sexual dimorphism in foot length proportionate to stature. Ann Hum Biol. 2005; 32(1): 44-59. https://doi.org/10.1080/03014460400027581
11. Giles E, Vallandigham PH. Height estimation from foot and shoeprint length. J Forensic Sci. 1991; 36(4): 1134-51. https://doi.org/10.1520/JFS13129J
12. Gordon CC, Buikstra JE. Linear models for the prediction of stature from foot and boot dimensions. J Forensic Sci.1992; 37(3): 771-82. https://doi.org/10.1520/JFS11989J
13. Vernon DW, Mc Court FJ. Forensic podiatry – a review and definition. British J Podiat. 1999; 2(2): 45-48.
14. Vernon W, Brodie B, DiMaggio J, Gunn N, Kelly H, Nuremberg M, Reel S, Walker J. Forensic podiatry: Role and scope of practice (in the context of forensic human identification). Int Asso for Identification, USA. 2009:1-7.
15. Jasuja OP, Singh J, Jain M. Estimation of stature from foot and shoe measurements by multiplication factors: a revised attempt. Forensic Sci Int. 1991; 50(2): 203-15. https://doi.org/10.1016/0379-0738(91)90152-9
16. Ozden H, Balci Y, Demirustu C, Turgut A, Ertugrul M. Stature and sex estimate using foot and shoe dimensions. Forensic Sci Int. 2005; 147(2-3): 181-4. https://doi.org/10.1016/j.forsciint.2004.09.072
17. Raju GM, Vijayanath V, Anitha MR. Estimation of stature from shoe print length while walking in females. J Indian Acad Forensic Med. 2012; 34(4).
18. Othman Z. Estimation of stature from foot, barefoot and shoe print dimensions. A research project, M.Sc. Forensic Science, University of Wolverhampton 2010.
19. Shukla RK, Lodha AS, Das S. Stature estimation from footprint: A study on Central Indian population. European J Forensic Sci. 2017; 4(2); 11-19. https://doi.org/10.5455/ejfs.228548
20. International Society for the Advancement of Kinanthropometry. International Standards for Assessment; ISAK, under dale, South Africa 2006; pp. 54-55.
21. Krishan K, Kanchan T Asha N. Estimation of stat¬ure from index and ring finger length in a north In¬dian adolescent population. J Forensic Leg Med. 2012; 19(5): 285-90. https://doi.org/10.1016/j.jflm.2011.12.036
22. Ewunonu EO, Egwu AO, Eleudo AN, Ajoku KI. Bilateral foot asymmetry and sexual dimorphism in young adult Igbo people of South Eastern Nigeria. European J Biotechnol Biosci. 2014; 1(4): 1-5.
23. Robbins LM. Estimating height and weight from size of footprints. J Forensic Sci.1986; 143-152. https://doi.org/10.1520/JFS11868J
24. Quamra SR, Deodhar SD, Inder J. A metric study of feet of north-west Indians and its relationship to body height and weight. Indian J Phys Anthropol Hum Genet. 1986; 131-138.