Forensic appraisal of leg length as a predictor for determination of Nigerian students' body height

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ABSTRACT

Appraisal of body height (Bh) from leg length (LL) and other anthropometric parts of an individual is very important in the identification of human skeletal remains. The objective of this study was to develop a model for the estimation of Bh_{male}, Bh_{female} and $Bh_{combined}$. The study was conducted in three selected tertiary institutions in Southwest Nigeria with a total of 324 students (162 male and 162 female) using the snowball techniques where the Bh and LL of the students were measured using stadiometer and sliding caliper. The data were analysed statistically using statistical package for social sciences v 21 software. The result showed mean values of 168.49 ± 9.19 cm of Bh_{male}, 168.15 ± 8.66 cm Bh_{female} and 168.32±8.91 cm $Bh_{combined}$. Similarly, the mean values of 96.40±7.29 cm LL_{male}, 96.27±6.96 cm LL_{female} and 96.33 ± 7.12 cm $LL_{combined}$ were found. Furthermore, the coefficient of determination, R^2 was determined as 76.0%, 19.1% and 44.3%, respectively. Three regression models were formulated to determine the Bh_{male}, Bh_{female} and $Bh_{combined}$ with LL_{male}, LL_{female} and $LL_{combined}$ as the predictors. It was concluded that this formulated model could be a veritable tool for the development of forensic anthropological studies for Nigerian student population.

Keywords: Body height; Leg length; Anthropometric; Forensic; Regression; Student
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INTRODUCTION

The conventional tools in the investigation of forensic cases have been the observation and interpretation of physical evidences from remains. But, beginning from the last century, science and technology was introduced by advancing the manner in which case(s) were determined and evaluated with the improvement of the validation in the conclusion drawn from the results of the investigation from the responsible authority. Mansur *et al.* (2012) defined body height (Bh) as a very important measure of physical and stature identification. The need to identify a person from a mutilated or fragmented body has literally become necessary due to various disasters such as flood, terror attacks, bomb blast, ritual killings, mass accidents, etc. Chikhalkar *et al.* (2010) also described the Bh as a very important element in identifying skeletal remains.

Anthropometric parts such as leg length (LL), upper limb (UL), finger length, foot length (FL), foot breadth (Fb), knee length (K) etc. also played a major and vital role in the determination of body height (Bh) of an individual. Forensic anthropologists have been engaged in the recovery of skeletal remains from the scene of the crime using relevant information. This information includes the anthropometric parameters of the victims (Mansur *et al.*, 2012). Wherever the discovery of skeletal remains and body parts took place, a forensic investigator is required to ascertain the identity of recognition of the deceased (Ahmed, 2013).

Several studies been performed to determine the body height from different body parts such as knee length, tibia length, arm length, forearm length, hand and finger length, length of bone, foot and shoe length, head length, head circumference, distance between sterna notch and public symphysis, crown to rump and rump to heel ratio, etc. (Karaddi *et al.*, 2013; Moitra, 2019). Linear regression model is widely used to determine the Bh of individuals on the basis of their body parts (Karaddi *et al.*, 2013).

Moitra (2019) reported that there is a lot of variance and differences in the determination of Bh from limb measurements among individual of different nations and ethnicities. In view of this, there is an urgent need to conduct more studies among people of different nations and ethnicities so that Bh determination could be more reliable an identification of an individual is easily established.

Several researchers in the field of anthropological forensics have studied areas of foot print and skeletal remains (Vukotic, 2020) several times in road accidents; feet of the deceased remain unfragmented due to the shoe. Similarly, many researchers have also engaged in the study of anthropometric parts as a predictor of Bh (Ahmed, 2013) using simple linear regression to determine the model equation and

other parameters. This current study is necessary to establish the association between the Bh and LL of Nigerian tertiary institution students using simple regression analysis to determine the model equation which we presumed is yet to be done in the Nigeria.

MATERIALS AND METHODS

Subject selection

A total of three hundred and twenty-four (324) students of three tertiary institutions, i.e., 162 male and 162 female (Federal College of Education Abeokuta, Moshood Abiola Polytechnic Abeokuta and Adegbenro ICT Polytechnic Itori) in Ogun State Southwest Nigeria were selected using snowball techniques. The students' age group ranged between 16 – 26years.

The study was conducted between January and March 2022 with nine (9) research assistants who assisted in the area of anthropometric measurement. All the research assistants were trained on the modality of the measurement. The anthropometric data obtained includes Bh and LL. All the measurements were recorded in centimeters (cm). The Bh was measured using a stadiometer in a standing position bare footed with head in Frankfort plane. The LL was measured from iliac crest to the floor in standing posture as a direct distance using metal tape.

Exemption criteria

Subjects having malformed limb(s) were exempted from participating in the study.

Data analysis

Data obtained were statistically analyzed using statistical package for social sciences (SPSS) v 21 to determine the descriptive statistics mean, standard deviation (SD), maximum and minimum, correlation coefficient (R), coefficient of determination (R^2) and linear regression for the estimation of model. The linear regression analysis was used to determine and predict Bh from the LL successfully at a significance level of $P<0.05$ and their connection was presented in the form of a scatter plot diagram.

RESULTS AND DISCUSSION

Statistical analysis was carried out in three phases to check the normality of the study to determine correlation analysis and mathematical models for the

development of regression equations. The present study included 324 students, age 16 to 26years (mean 22.29 ± 2.71 cm).

Descriptive analysis

The result of the anthropometric parameters obtained shows that the mean age of the participants was 22.29 ± 2.71 cm. The body height (Bh) was minimum and maximum ranged of 150 - 190 cm with a mean of 168.49 ± 9.19 cm and 168.15 ± 8.66 cm for male and female, respectively. Similarly, leg length (LL) was also reported as 72.0 – 110.50 cm and 66.30 - 109.50 cm with average mean values of 96.40 ± 7.29 cm and 96.27 ± 6.96 cm for male and female participant, respectively (Table 1).

Table 1. Descriptive Statistics of the participants (n = 324).

Parameters	**Age (years) (n =324)**	**Male (n= 162)**		**Female (n =162)**		**Combined (n = 324)**	
		Bh_{male} (cm)	**LL_{male} (cm)**	**Bh_{female} (cm)**	**LL_{female} (cm)**	**$Bh_{combined}$ (cm)**	**$LL_{combined}$ (cm)**
Mean	22.3	168.5	96.4	168.2	96.3	168.3	96.3
SD	2.7	9.2	7.3	8.7	7.0	8.9	7.1
Min	16.0	150.0	72.0	150.0	66.3	150.0	66.3
Max	26.0	190.0	110.5	190.0	109.5	190.0	110.5

The result also shows the analysis of total sample (male and female together) tagged as "combined". The average mean values of $Bh_{combined}$ and $LL_{combined}$ for were 168.32 ± 8.91 cm and 96.33 ± 7.12 cm with minimum and maximum range of 150.00-190.00 cm and 66.30–110.50 cm of $Bh_{combined}$ and $LL_{combined}$ respectively (Table 1). Below is the histogram for the distribution of $Bh_{male,}$ Bh_{female} and $Bh_{combined}$ (Figure 1).

Correlation analysis

Table 2 shows R significantly correlated with Bh as dependent variable and LL as predictor. The result shows the correlated R of LL_{male}, LL_{female} and $LL_{combined}$ with the dependent variable (Bh) as 0.875, 0.437 and 0.668 with p-value less than 0.001 ($P<0.001$). The result shows that there are no significant changes in the values of LL_{male}, LL_{female} and $LL_{combined.}$ The differences in R value of male and female, shows that there is a stronger bond of correlation between these parameters in males than females.

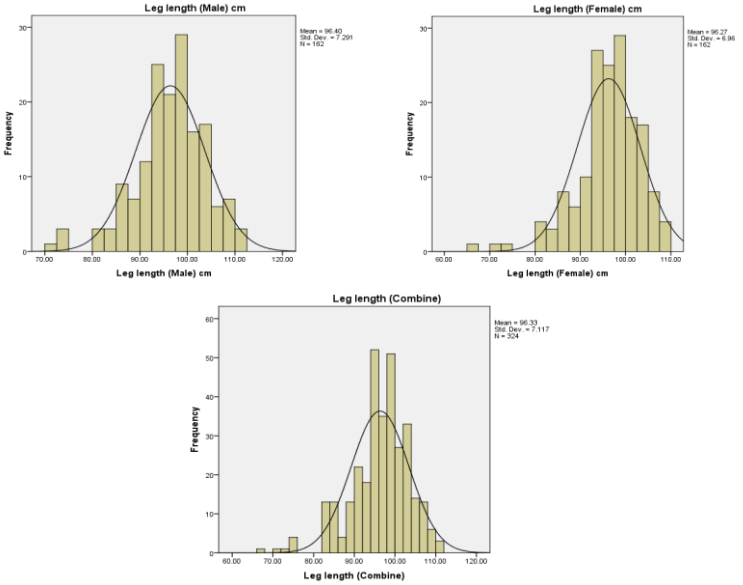

Figure 1. The histogram for the distribution of $LL_{male,}$ LL_{female} and $LL_{combined}$

Table 2. Pearson correlation coefficient analysis

Variables	R	P-Value	95% Confidence Interval	
			Lower	Upper
LL_{Male}	0.875	0.000	1.003	1.196
LL_{Female}	0.437	0.000	0.396	0.718
$LL_{Combined}$	0.668	0.000	0.732	0.937

However, the 95% Confidence Interval (CI) shows that LL_{male}, LL_{female} and $LL_{combined}$ were 1.003cm, 0.396 cm and 0.732 cm for lower limit and 1.196cm, 0.718cm and 0.937cm for upper limit, respectively (Table 2). The CI displays the probability that a parameter will fall between a pair of values around means. The difference in the LL_{male}, and LL_{female} could arise from the Bh of the male and female.

Regression analysis

Table 3 shows the result of multiple linear regression analysis for the participants with the model equations used for the determination of Bh_{male}, Bh_{female} and $Bh_{combined}$ respectively. The result also shows the Coefficient of determination (R^2) as 0.760,

0.191 and 0.443, respectively. Standard Error of Estimation (S.E.E) were 4.51, 7.82 and 6.66, respectively.

The general formula for the regression model is

$$\gamma = k + b\beta \quad (1)$$

Where, γ = dependent variable (Bh), k = constant, β = predictor (LL).

From equation 1, the values of Bh are therefore determined as predicted model (Table 3).

Table 3. Regression Analysis for the participants.

	Predicted Model ($\gamma = k + b\beta$)	R^2	Adjusted R	P-value	S.E.E	Constant (K)	B
1	Bh_{male}, = 62.53 + 1.10LL_{male}	0.760	0.753	0.000	4.513	62.53	1.099
2	Bh_{female}=115.83 + 0.54LL_{female}	0.191	0.186	0.000	7.815	115.83	0.543
3	$Bh_{combined}$= 87.94 + 0.83$LL_{combined}$	0.443	0.442	0.000	6.664	87.94	0.834

Model 1, Model 2 and Model 3 were compared favourably with general formula of Duyar *et al.* (2006) and are therefore assent that the Bh of Nigerian students are to be reconstructed using their LL. The established formula could be used as specific for Nigeria tertiary institution students. Figure 2 shows the scatter plots between Bh and LL of the participants.

The current study was developed for the prediction of Bh of tertiary institution student from LL measurement. The study was conducted among 324 students (162 male and 162 female) in Abeokuta Southwest Nigeria with age group between 16 and 26 years. The LL was not strongly correlated ($P<0.05$) with Bh in this current study. The present study result shows R of LL_{male}, LL_{female} and $LL_{combined}$ with the dependent variable (Bh) as 0.875, 0.437 and 0.668 correlated with p-value less than 0.001 ($P<0.001$). This study was compared with Trivedi *et al.* (2014) who studied 540 students (270 male and 270 female) to determine the Bh from tibia length. The study reported correlation coefficients of R 0.417 in males and 0.442 in females (Trivedi *et al.*, 2014). Similarly, Bickes (2019) also conducted a study of 572 adult students (256 male and 286 female) of Debre Markos University, northwest Ethiopia. The study result showed an R of 0.634 and 0.632 of Bh and tibia length. The present study result also shows the Coefficient of determination (R^2) as 76.0%, 19.1% and 44.3%, respectively. The Standard Error of Estimation (S.E.E) were 4.51, 7.82 and 6.66, respectively. The determined values from the regression analysis were favourably compared with the measured values and evaluated the efficacy of the determination of Bh from LL measurement. The values of R^2 and standard error of estimation (S.E.E) was the statistical test used to measure the extent to which observed data matches the values expected and determined the effectiveness of the statistical models.

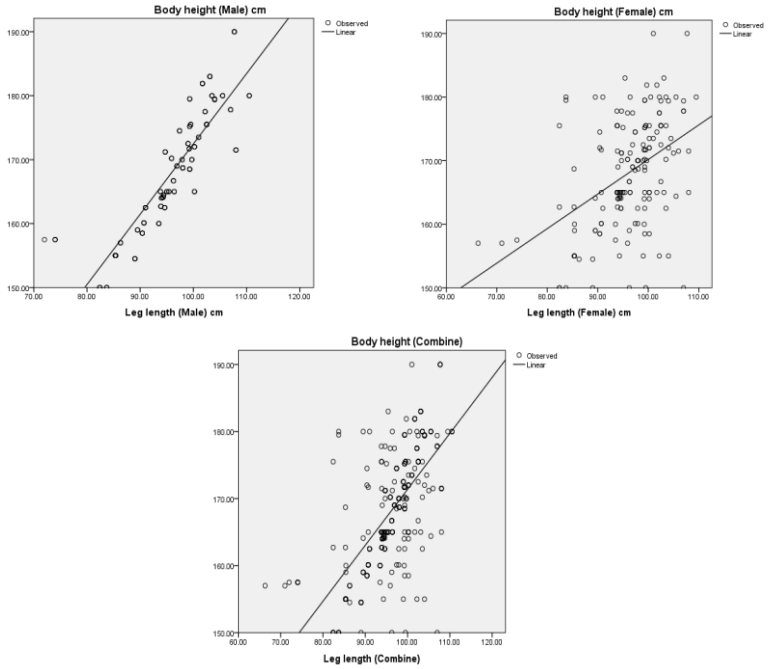

Figure 2. Scatter plot between Bh and LL of the participants

In the evaluation of the models, the values of R^2 and adjusted R was higher in male participants (76.0%, and 75.3%) than the female participants 19.1% and 18.6% and combined participants (44.3% and 44.2% (respectively with a minimum value of S.E.E (4.513, 7.815 and 6.664) for the model. The R^2 is said to measures the goodness of fit of a regression model. In view of this, higher R^2 indicates the model is a good fit while a lower R^2 indicated not a good fit. The values of R^2 are expected always to be 70% or above. The present study shows that R^2 of Bh_{female} and $Bh_{combined}$ is not a good fit for the model. This could be due to the inherent female data collected. However, the results of R^2 and S.E.E were compared to identify if the model is ideal and served the purpose of determination (Özaslan *et al.*2003; Ahmed, 2013).

Researchers on the Bh agreed that derivation of Bh from different formula as used are mere estimation and by no means exact, just as they assert that the formula for one population may not be adequate for another due to differential LL among the other sex and different populations (Özaslan *et al.*, 2003; Ahmed 2013).

Similarly, researchers also highlight that Bh can be determined by anatomical and mathematical method (Iscan and Steyn, 2013; Konigsberg *et al*., 2018). The anatomical method involves reconstituting the Bh by adding bone measurement of several skeletal remains between the head and leg while the mathematical uses regression equation based on the correlation between the anthropometric measurement of body parts. This present study was compared with several similar studies which reported the mean Bh and LL (Table 4).

Table 4. Comparison of the mean Bh and LL of similar studies

Study	Year of study	Bh (cm)	LL (cm)
Present study	2022	168.32	96.33
Arazi *et al.*	2011	181.10	104.50
Hanadan	2014	173.00	88.00
Ghazaleh *et al.*	2014	174.04	97.54
Krishan *et al.*	2010	172.54	96.09

Reference to the present study, the differential in the Bh and LL of individuals from different countries is due to the environmental condition of the region. Several researchers have recommended multiple linear regressions over simple linear regression due to the fact that the analysed data could not fulfill the desired assumption. Reference to other researchers, it was apparent that multiple regression could have capitulated more predictive models than using simple linear model and this was a better predictor of Bh (Özaslan *et al*., 2003; Khanapurkar and Radke, 2012; Ahmed, 2013). However, simple linear regression was adopted for this study due to the limited number of variables.

CONCLUSION

In this present study, gender differences in average mean values of Bh and LL were slightly higher in male than female and this may be attributed to sex chromosomal differences. Examination of LL provides evidence in criminal scene investigation as it helps determine Bh of a criminal. The objective initiated in this study was achieved, a regression model being developed to predict the Bh of a person based on the LL. In this study, it was observed that LL exhibits high values of correlation (R = 0.875 in male), female 0.437 and 0.668 for combined participants. The study is very important contribution to the field of forensic anthropology and useful in the medico-legal profession. Thus, this study establishes equations to derive the Bh of an individual merely by the measurement of LL. This equation is helpful when applied for disremembered or fragmented body parts as it is commonly encountered in disaster sites. The data used provided reliable results with huge applicability in the future for estimating the Bh from LL for student populations in Nigerian tertiary institutions. This study is good and veritable tool for the development of the forensic anthropology studies for Nigerian populations. The determination of Bh

and LL is easy, convenient and economical. There is no specialized equipment or training required. Anthropologists, forensic experts and investigating officers only need the use of this method to their added advantage. An attempt was made to compare the findings with similar or relevant studies of Nigerian students proved abortive because authors could not find any related studies. Future studies can be done with large sample size and embarked based on the measurement of more anthropometrical parts and also from computer scans. It is recommended that a specific regression equation be derived for Nigeria students and every other population due to the differential in LL and environmental condition of the region.

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Data and materials
Data sharing was declined so as to protect the participants' confidentiality.

Conflict of Interests
Authors declare that there is no conflict of interest(s).

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