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Research

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Lower Extremity Measurements in the Prediction of Body Height of the Igbos

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ABSTRACT

Body height prediction is one of the biological profiles used in the identification of individuals in cases of natural and man made disasters, and in crime investigations. In the present study, an attempt was made to derive regression formula to determine Body Height (BH) from lower extremity dimensions. 123 females and 88 males belonging to the Igbo population of Nigeria who gave informed consent were studied. BH was measured using standard protocols and measurements of the lower extremity segments were taken using measuring tape cutaneously. The mean observed BH of the studied population was 167.55±9.10 cm. In sexing the population, all the variables obtained were statistically significant, $p<0.0001$ except Thigh Length (TL). All the lower limb segments measured, showed positive significant correlation with body BH except Leg Length (LL) in the females. The multiple linear regression models generated using Lower Leg Length (LLL), LL and Trochanteric height (TROCH) in the overall population, and using LL and TL in the males performed better than the simple linear regression models because of the values of 'R' used in testing model adequacy. In females, LLL performed better than the other lower limb segments.

KEYWORDS: Lower limb; Igbos; Measurements; Model adequacy.

ABBREVIATIONS: BH: Body Height; TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower Leg Length.

INTRODUCTION

The human body may be subject to fragmentations by both natural and manmade disasters. Such conditions have lead researcher to continue to estimate Body Height (BH) using available human body parts. The documented results are used by Scientist either in the identification exercise or for body height reconstruction.

In humans, estimation of BH is also applied to check for normal or abnormal growth especially in the young individuals.[1-4]

The lower limb extends from the lower part of the trunk to the foot. An understanding of its sub-segments provides a good knowledge of the landmarks required in the measurement for BH prediction using lower limb segments.

The bones of the lower extremity are: the hip bone in the gluteal region/segment, the femur in the thigh, the patella in the knee, the fibular and tibia in the leg, the tarsals, metatarsals, and the phalanges in the foot.[5]

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The long bones of the body have been used to estimate stature[6-14] and results obtained were reliable.

In this study, we attempted to investigate which of the sub-segments of the lower extremity will predict BH best in the overall population as well as in the males and females.

MATERIALS AND METHODS

Subjects were randomly selected from a pull of 211 persons[15] and attention was paid on the measurements of some of the sub-segments of the lower extremity after obtaining informed consents.

Demographics

Information on age, sex, and state of origin were collected.

Exclusion criteria

Individual with limb length discrepancies and other musculo-skeletal disorder affecting body height were excluded from this study. Pregnant women were also excluded.

Inclusion criteria

Subjects from the Igbo ethnic states who were apparently healthy were included in the study.

ANTHROPOMETRICS

Body height (BH): The height was measured to the nearest 0.1 cm using an Anthropometer with subjects standing without shoes with the heels held together, toes apart, and the head held in the Frankfort plane.[16]

The following lower extremity measurements were taken (see illustration of landmarks, figure 1 below)

Trochanteric height (TROCH) was measured from the lateral bulging of the greater trochanteric protrusion to the floor.

Thigh length (TL) was measured as the distance between greater trochanter and the knee joint.

Lower leg length (LLL): is the distance from the tibia to the floor.

Leg Length (LL): is the distance from the lateral supracondyl of the tibia to the distal part of the lateral malleolus. All the

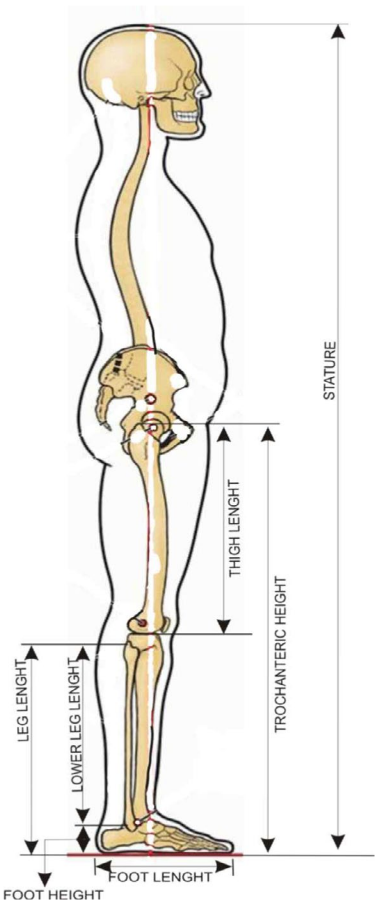

Figure 1: Landmarks for measurement of lower extremity segments.[5]

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lower extremity measurements[13] were taken cutaneously using measuring tape.

DATA PRESENTATION AND ANALYSIS

In this study, analysis of data was carried out using statistical package for social sciences (SPSS 17.0 software). In summarizing the data, the Minimum, Maximum, Mean and Standard deviations were estimated and presented. A comparison of difference of variable in females and males was also carried out. To test the relationship between BH and lower extremity dimensions, Pearson correlation was performed. The prediction function was derived through linear regression for each of the measurement with BH for the overall population, males and females separately. Finally the predicted/estimated values of BH were compared with that of observed/actual values.

RESULT

Table 1 shows the descriptive statistics of the overall population, females and males for the lower extremity anthropometry. The mean value for the dependent variable (BH) of the population under study was 167.55±9.10 while those of the explanatory variables are as in table 1.

Table 2 represents a comparison of difference of variables in females and males. It reveals that TROCH, TL, LL, LLL are highly significant in males than in females, P<0.0001, while TL is not significant.

The Pearson correlations (r) between the dependent variable and the explanatory variables for the overall population, females and males are given in table 3. In the overall population,

Variables	Overall population					females					males				
	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
AGE(YEARS)	211	16	45	23.58	4.95	123	16	45	23.74	5.36	88	18	43	23.35	4.34
BH(CM)	211	149.00	190.00	167.55	9.10	123	149.00	190.00	163.17	7.64	88	156.00	190.00	173.66	7.30
TROCH	198	55.90	107.00	89.93	6.38	117	55.90	104.00	88.65	6.48	81	71.00	107.00	91.79	5.762
TL	198	33.00	59.00	43.11	4.36	117	35.00	55.00	42.88	4.40	81	33.00	59.00	43.44	4.32
LL	198	33.00	56.00	46.55	4.14	117	33.00	55.00	45.48	3.49	81	36.00	56.00	48.10	4.53
LLL	198	31.00	57.00	42.98	4.01	117	31.00	51.00	42.00	3.77	81	34.00	57.00	44.41	3.94

BH: Body Height; TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower Leg Length.

Table 1: Descriptive statistics of the overall population, females and males, for lower extremity anthropometry (cm).

VARIABLES (CM)	Paired Differences					T	Df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
TROCH (F) - TRLOCH (M)	-4.25641	6.55555	.74227	-5.73446	-2.77836	-5.734	77	.000
TL (F) - TL (M)	-.83333	5.60593	.63475	-2.09727	.43061	-1.313	77	.193
LL (F) - LL (M)	-3.14872	5.60980	.63518	-4.41353	-1.88390	-4.957	77	.000
LLL (F) - LLL(M)	-2.92564	5.21438	.59041	-4.10130	-1.74998	-4.955	77	.000

BH: Body Height; TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower Leg Length. Variables are significant at p<0.05.

Table 2: Comparison of variables between females and males in lower extremity anthropometry.

Variables	Overall population			Females			Males		
	N	Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)
TROCH	198	.454**	.000	117	.328**	.000	81	.515**	.000
TL	198	.253**	.000	117	.189*	.041	81	.385**	.000
LL	198	.365**	.000	117	.092	.322	81	.427**	.000
LLL	198	.500**	.000	117	.507**	.000	81	.296**	.007

BH: Body Height, TROCH: Trochanteric height, TL: Thigh Length, LL: Leg Length, LLL: Lower Leg Length.
*.Correlation is significant at the 0.05 level (2-tailed).
**.Correlation is significant at the 0.01 level (2-tailed).

Table 3: Correlation coefficients between body height (Dependent variable) and lower extremities variables (Explanatory variables) in overall population, females and males.

ISSN 2473-4772 Open Journal http://dx.doi.org/10.17140/ANTPOJ-1-104

all the four explanatory variables were significantly correlated with BH. The correlation between body height (Y_{BH}) and Lower Leg Length (X_{LLL}), r=0.500 was better than that between Y_{BH} and trochanteric height ($X_{LLLTROCH}$) r=0.454. The least significant correlation was observed in TL (r=0.253) in in the overall population.

The correlation between female's body height (Y_{FBH}) and female's lower leg length (X_{FLLL}) i.e. r=0.507 was better than that between Y_{FBH} and females trochanteric height (X_{FTROCH}), r=0.328; but the least significant correlation was observed in TL, r=0.189. LL in the females did not show any significant correlation with BH, as such LL could not be used to construct regression equations in the females. In the males, the correlation between males BH, (Y_{MBH}) and males trochanteric height (X_{MTROCH}), r=0.515 was better than that between Y_{MBH} and males leg length (X_{MLL}), r=0.481.

Table 4 shows the constant, regression coefficient and the variation explained of lower extremity variables with the BH in the overall population. Twenty-Five percent of the variation in BH is inherent by lower leg length (LLL) while the combination of LLL, LL, and TROCH contributed 33.4% to the variation in the dependent variable.

The regression coefficients (see Table 5) for the variables used for BH prediction in the females and males were highly significant, indicating that they contributed positively for the prediction of BH in the females as well as in the males. The variation explained ($R^2 \times 100$) showed that it ranges from 3.6% to 25.76% in the females while it ranges from 8.7% to 31.6% in the males. The best prediction power was observed in LLL in female while it was the combination of TL and LL in the males.

The computed values of the multiple correlation coef-

	Constant	Regression Coefficient	R^2	*p* value
TROCH	108.969	.651	.206	.000
TL	144.632	.530	.064	.000
LL	130.030	.805	.133	.000
LLL	118.569	1.138	.250	.000
LLL LL, TROCH	88.969	.265 .405 .833	.334	.015 .007 .000

BH: Body Height; TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower Leg Length.

Table 4: Constant, Regression coefficient and Variation explained (R^2) of lower extremity variables with BH (dependent) variables in the overall population.

	Females					Males			
Variables	Constant	Regression Coefficient	R^2	*p* value	Variables	Constant	Regression Coefficient	R^2	*p* value
TROCH	128.336	.393	.107	.000	TROCH	114.567	.644	.265	.000
TL	148.858	.334	.036	.041	TL	145.809	.642	.148	.000
LLL	119.239	.166	.257	.000	LL	140.980	.680	.182	.000
					LLL	149.694	.540	.087	.007
					LL, TL	115.859	.609 .652	.316	.000 .000

BH: Body Height; TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower Leg Length.

Table 5: Constant, Regression coefficient and Variation explained (R^2) of lower extremity variables with BH (dependent) variables in females and males.

Variables	R	R^2	Adjusted R^2	SEE
TROCH	.454	.206	.202	8.165
TL	.253	.064	.059	8.864
LL	.365	.133	.129	8.532
LLL	.500	.250	.246	7.937
LLL, LL, TROCH	.578	.334	.323	7.518

BH: Body Height; TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower Leg Length; R: Multiple correlation coefficient; R^2: Coefficients of determinations; SEE: Standard error estimate.

Table 6: R, R^2, Adjusted R^2, and SEE in overall population in lower limb anthropometry.

ISSN 2473-4772 Open Journal http://dx.doi.org/10.17140/ANTPOJ-1-104

Females					Males				
Variables	R	R^2	Adjusted R^2	SEE	Variables	R	R^2	Adjusted R^2	SEE
TROCH	.328	.107	.100	7.380	TROCH	.515	.265	.256	6.218
TL	.189	.036	.027	7.671	TL	.385	.148	.137	6.695
LLL	.507	.257	.251	6.732	LL	.427	.182	.172	6.559
					LLL	.296	.087	.076	6.929
					LL, TL	.562	.316	.298	6.040

BH: Body Height; TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower Leg Length.

Table 7: R, R^2, Adjusted R^2, and SEE of lower extremities variables in females.

ficients R, of the coefficients of determinations R^2 and $R^2_{adjusted}$, and the standard errors of the estimates (SEE),[17] of all possible and multiple linear regression equations for each of the variables were tested for the best model (Table 6 and 7). The multiple linear regression model was found to be the best model with the highest values for multiple correlation coefficient 'R' as 0.578, coefficient of determination R^2 as 0.334 and $R^2_{adjusted}$ as 0.323 and with lower SEE as 7.518 in the overall population.

The multiple linear regression model was also found to be the best model to predict BH in the males (R=0.562), while single linear regression model performed better in the females (R=0.507)

Considering all possible simple and multiple linear regression analysis, the best multiple linear equation to estimation BH from lower extremity dimensions in males is Y_{MBH}=115.859 +.609(LL)+.652(TL).

When the explanatory variables were considered one after the other, the best linear equation used to regress BH for the females is Y_{FBH}=119.239+.166(LLL), while that of the males is Y_{MBH}=114.567+.644(TROCH) however stature could also be estimated from any of the dismembered parts or sub-segments of the lower extremity using the formula constructed in the tables (Table 8).

The mean predicted value of BH through the regression function was similar to the mean observed value; however the minimum and maximum value indicated that there were differences in the predicted and observed value (Table 9).

The mean predicted value of BH through the regression function was similar to the mean observed value; however the

Regression equation (overall population)	±SEE	Regression equation (females)	±SEE	Regression equation (males)	±SEE
BH=108.969+.651(TROCH)	8.165	BH=128.336+.393(TROHT)	7.380	BH=114.567+.644(TROCHT)	6.218
BH=144.632+.530(TL)	8.864	BH=148.858+.334(TL)	7.671	BH=145.809+.642(TL)	6.695
BH=130.030+.805(LL)	8.532	BH=119.239+.166(LLL)	6.732	BH=140.980+.680(LL)	6.559
BH=118.569+1.138(LLL)	7.937	BH=127.775+1.401(FL)	7.443	BH=149.694 +.540(LLL)	6.929
BH=88.969+.265(LLL) +.405(LL) +.833(TROCH)	7.518			BH=115.859 +.609(LL)+.652(TL)	6.040

BH: Body Height: TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower; SEE: Standard error of stimates.

Table 8: Regression Equations for BH in the overall population, females and males lower extremity measurements.

OBSERVED VALUE FOR BH		Minimum	Maximum	Mean	Std. Deviation	N
		149.00	**190.00**	**167.5460**	**9.1027**	**211**
PREDICTED VALUE	TROCH	145.3409	178.5899	167.4859	4.14785	198
	TL	162.1269	175.9106	167.4859	2.31359	198
	LL	156.5823	175.0888	167.4859	3.33295	198
	LLL	153.8482	183.4376	167.4859	4.56587	198
	LLL, LL, TROCH	146.7266	183.3746	167.4859	5.27892	198

BH: Body Height; TROCH: Trochanteric height; TL: Thigh Length; LL: Leg Length; LLL: Lower; Std: Standard deviation.

Table 9: Minimum, Maximum, Mean and standard deviations of the predicted Values of BH by regression functions using the lower extremities parameters in overall population.

ISSN 2473-4772 Open Journal http://dx.doi.org/10.17140/ANTPOJ-1-104

OBSERVED VALUE FOR BH		Min	Max	Mean	SD	N
		149	**190**	**163.172**	**7.643**	**123**
PREDICTED VALUE	TROCH	150.314	169.225	163.189	2.549	117
	TL	160.555	167.239	163.189	1.470	117
	LLL	151.680	172.609	163.189	3.946	117

Table 10: Minimum, Maximum, Mean and standard deviations of the predicted Values of BH by regression functions with lower extremity variables in females

OBSERVED VALUE FOR BH		Min	Max	Mean	SD	N
		156.00	**190.00**	**173.660**	**7.296**	**88**
PREDICTED VALUE	TROCH	160.300	183.488	173.693	3.7115	81
	TL	166.992	183.682	173.693	2.774	81
	LL	165.466	179.069	173.693	3.079	81
	LLL	168.069	180.499	173.693	2.132	81
	LL, TL	163.142	187.024	173.693	4.049	81

Table 11: Minimum, Maximum, Mean and standard deviations of the predicted Values of BH by regression functions with lower extremity variables in males.

minimum and maximum value indicated that there were differences in the predicted and observed value; the minimum predicted value overestimates the minimum observed value and in both sexes while the maximum predicted value underestimates the maximum observed value in both sexes except the maximum predicted value from LL (Tables 10 and 11).

DISCUSSION

Four lower extremity measurements including BH of the subjects were taken. The prediction function was derived through linear regression and multiple regressions for each of the measurement with BH, for the general population and for the males and females separately.

In sexing the lower extremity parameters, all the variables were highly significant ($p<0.0001$) except TL. These values were higher in the males than in the females. This agrees with the popular phenomena that most anthropometric variables are significantly higher in the males than in the females.[15,18-25]

In this study, the value of coefficient of determination R^2 for the multiple linear regression equations with BH as the dependent variable and LLL, LL and TROCH as explanatory variables in overall population was 0.334. The value of R^2 with BH as the dependent variable and LL and TL as explanatory variables in males was 0.316. This means that 33.4% of the total variation in BH is explained by the explanatory variables LLL, LL and TROCH put together in the in overall population, while 32% of the total variation in BH is explained by the explanatory variables LL and TL in males. The values of multiple correlation coefficient R for the multiple linear regression equations for the overall population and males were 0.578 and 0.562 respectively, while the SEE were 7.518 and 6.040 respectively. This means that the multiple linear regression models for the overall population as well as for the males fits very well to the observed value (compare tables 6, 7, 8 with 9, 10 and 11) unlike the linear regression models.

The findings above are not congruent with the report by Ozaslan A, et al[13], who carried out similar work by measuring seven lower extremity variables on adult Turks (203 males and 108 females). Five (TROCH, LL, TL, Foot length, and Foot height) out of the seven variables were significantly correlated with stature. The highest value of coefficient of determination R^2 was associated with TROCH (58%) and LL (56%) in the males while in females it was LLL (65%) and LL (63%).

The R, R^2, Adjusted R^2 and SEE obtained in this study were lower than that obtained by.[6,13] This means that the error arising from the predicted BH is minimal in the present study.

Using a Polish sample, Hauser R, et al[8] were able to determine that the longest measurement of femur was the most useful for correlating with living height, atleast in males. Similarly[26] reported that the femur was the most useful for estimating stature in a sample of adult Portuguese while[27] indicated that the femur and tibia were the best predictors of stature in a Mesoamerican population. This is at variance with the result of this study because in the overall population the combination of TROCH, TL and LLL performed better than any of the independent lower extremity segments; this also applies to the males using LL and TL. However the independent/explanatory variables that ranks first in the prediction of BH in our study was LLL in the overall population as well as in the females while TROCH performed better than the rest of the other lower extremity seg-

ISSN 2473-4772 Open Journal http://dx.doi.org/10.17140/ANTPOJ-1-104

ment for prediction of BH in the males.

CONCLUSION

The multiple regression model generated using LLL, LL and TROCH put together provided the best/highest accuracy of determination in the overall population while LL and TL gave that of the males.

CONFLICTS OF INTEREST: None.

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