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Relationship between hand, foot, and mandibular measurements in stature prediction in Cross River State, Nigeria.

Koko Ottoh Arikpo, Barnabas Danborno, James Abrak Timbuak, Murdakai Tanko, Anozeng O. Igiri, Regina Alorye Beshel, Runyi Inyang Ofem, Emem Christopher Umor

[1]Department of Anatomy, Faculty of Basic Medical Sciences, College of Medical Sciences, Ahmadu Bello University, Zaria; [2]Department of Anatomy, Faculty of Basic Medical Sciences, Yusuf Maitama Sule University, Kano; [3]Department of Anatomy, Faculty of Basic Medical Sciences, University of Calabar, Calabar; [4]Department of Anatomy, Faculty of Basic Medical Sciences, University of Nigeria, Nsukka; [5]Department of Physiology, Faculty of Basic Medical Sciences, University of Cross River, Calabar.

***Corresponding Author:** Email: ottohezra@gmail.com,
Tel: +234 0806 267 9628

ABSTRACT

Stature estimation is a fundamental component of human identification in forensic anthropology, particularly in cases of fragmented remains, natural disasters, or mass casualties. Anthropometric methods provide a reliable means of predicting stature from body dimensions. This study examined the relationship between mandibular, hand, and foot measurements and human stature, with the aim of developing regression models for adult indigenes of Cross River State, Nigeria. A total of 600 participants (300 males and 300 females), aged 18 – 45 years and of Cross River parentage, were recruited through random sampling. Anthropometric parameters measured included height, mandibular arch length, hand length, hand breadth, wrist breadth, foot length, foot breadth, and ankle breadth. Data were analyzed using the XLMiner Toolpak (Google Sheets). Descriptive statistics, independent t-tests, ANOVA, Pearson correlations, and linear and multiple regression analyses were employed. Significant sexual dimorphism was observed in all parameters, including stature ($p < 0.01$). Hand length ($R = 0.603$) and foot length ($R = 0.582$) demonstrated the strongest correlations with stature. Regression models generated mean estimated statures ranging from 164.813 to 164.854 cm, closely approximating the mean actual stature of 164.831 cm. Therefore, mandibular, hand, and foot dimensions are reliable predictors of stature among adults in Cross River State. These findings provide population-specific regression models that can be applied in forensic anthropology, medico-legal investigations, and related anthropometric studies in Nigeria.

Keywords: anthropometry, stature estimation, hand, foot, mandibular arch, regression models,

INTRODUCTION

Stature estimation, the process of determining an individual's natural height, is the cornerstone of reconstructive identification of skeletonized and dismembered human remains, used in fields such as forensic anthropology, clinical medicine, physical anthropology, and bioarchaeology[1]. In forensic investigations, the ability to estimate an individual's stature from skeletal remains is important in narrowing down identities when the body is incomplete, heavily decomposed, or fragmented, particularly in cases of mass disasters, accidents, and crimes[2]. For instance, in mass mortality occurrences like the 2004 Indian Ocean tsunami, where an estimated 227,898 individuals perished and many bodies were fragmented, stature estimation was essential in the difficult task of victim identification[3]. Similarly, in bio-archeological research, stature estimation provides insights into the dietary status, health, and overall biological profile of previous populations, contributing to a comprehensive understanding of their lives [4].

Historically, stature estimation has relied primarily on measurements of long bones such as the femur, tibia, and humerus due to their strong and well-documented correlation with overall body height [5]. The use of these bones in the development of regression equations for estimating stature has been explored by Trotter and Glesser and is still frequently employed today [6]. However, recovery of these long bones is not always feasible. In dismemberment cases or severe trauma, only partial or fragmentary remains are available. This necessitates the exploration of alternative skeletal elements that can provide reliable stature estimates [7]. Over recent decades, research has expanded to include other body parts, such as the hands, feet, and skull, recognizing their potential as valuable predictors when long bones are absent or incomplete. Multiple studies have demonstrated a strong correlation between hand or foot dimensions and stature, with accuracies often within a few centimeters when population-specific regression models are applied [8]. These appendicular elements are not only accessible but are also often well-preserved in various postmortem conditions, making them practical alternatives in challenging recovery scenarios. Despite these advancements, a robust and frequently preserved part of the human skull, called the mandible, remains underutilized in stature estimation when compared to the use of long bones in Cross River State. While several studies have shown a statistically significant correlation between certain mandibular measurements and age and sex determination, its potential as a stature predictor, especially in comparison with other appendicular measurements like those of the hand and foot, is relatively underexplored. Current literature often examines these body parts in isolation or in limited combinations, leading to a fragmented understanding of their collective utility [1, 9-11].

This study, therefore, seeks to examine the relationship between stature and the measurements of the hand, foot, and mandible from indigenous adults of Cross River State. By analyzing these body parts individually and in combination, the research seeks to create a more complete model for stature estimation that is appropriate for a variety of forensic and anthropological contexts.

MATERIALS AND METHODS

Study design: This study adopted a descriptive cross-sectional design, with participants randomly selected from the indigenous population of Cross River State, Nigeria. The required sample size was determined using the formula described by Naing *et al*. [12].

$$n = \frac{Z^2 pq}{d^2}$$

Where: n = the desired sample size per ethnic group

Z = the standard normal deviation, usually set at 1.96 at a 95% confidence level
p = the proportion in the target population (50% = 0.5)
q = 1-p = 1-0.5 = 0.5
d = degree of accuracy desired (0.05)

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.05)^2} = 384.16$$

Based on this calculation, a total of 600 participants (300 males and 300 females) were recruited proportionately from the three senatorial zones of Cross River State.

Ethical considerations: The study protocol was reviewed and approved by the Health Research Ethics Committee on Human Subjects of Ahmadu Bello University, Zaria (Approval No: ABUCUHSR/2020/018). Ethical clearance and all procedures were consistent with the principles of the Belmont Report (1979) for research involving human subjects. Written and verbal informed consent was obtained from all participants before data collection.

Inclusion and exclusion criteria: This study involved only individuals whose both parents were indigenes of Cross River State, provided informed consent to participate, were within the specified age range, and presented with no physical deformities in any part of their bodies. Individuals who did not meet these requirements were excluded from the study. In particular, participants with any form of physical deformity affecting body structures relevant to anthropometric measurement were excluded to avoid confounding effects on the results.

Data collection: Data were collected from participants across the Central, Northern, and Southern senatorial zones of Cross River State to obtain a representative sample of the population. Anthropometric measurements were obtained using standard instruments, including a sliding caliper, anthropometric rod, measuring tape, and stadiometer. All measurements were conducted in accordance with the standard procedures and anatomical landmarks outlined by the International Biological Program (IBP). Trained male and female research assistants performed the measurements to ensure reliability and reduce observer bias. To minimize measurement error, each parameter was recorded twice independently, and the mean of the two readings was considered the final value. The anthropometric variables measured included stature (height), length of the mandibular arch (LOMA), hand length (HL), hand breadth (HB), wrist breadth (WB), foot length (FL), foot breadth (FB), and ankle breadth (AB).

Height was measured as the vertical distance from the soles of the feet to the vertex of the head, recorded to the nearest centimeter. Participants were instructed to stand barefoot on a horizontal platform of the stadiometer, with heels together, arms relaxed at the sides, palms facing inward, and fingers pointing downward, while maintaining an erect posture and the head oriented in the Frankfurt horizontal plane.

The length of the mandibular arch (LOMA) was measured using an inelastic measuring tape placed along the lower border of the mandible in the anterior view, extending from one mandibular angle to the opposite mandibular angle.

Hand length (HL) was measured with a calibrated non-stretchable tape as the linear distance from the distal wrist crease to the tip of the middle finger, with the hand fully extended.

Hand breadth (HB) was measured as the maximum transverse distance across the metacarpal heads, from the most prominent point on the radial side of the second metacarpal head (thumb side in adduction) to the corresponding point on the ulnar side of the fifth metacarpal head.

Wrist breadth (WB) was measured as the distance across the styloid processes of the radius and ulna, taken obliquely to the long axis of the forearm, using a sliding caliper with sufficient pressure applied to compress the overlying soft tissue.

Foot length (FL) was measured with a sliding caliper as the maximum distance from the most posterior point of the heel to the tip of the longest toe (either great or second toe, depending on which was longer).

Foot breadth (FB) was measured as the maximum transverse distance between the most prominent point on the medial aspect of the head of the first metatarsal and the most prominent point on the lateral aspect of the head of the fifth metatarsal.

Ankle breadth (AB) was measured with a sliding caliper as the distance between the medial and lateral malleoli, with sufficient pressure applied to minimize the effect of soft tissue thickness.

Figure 1: Measurement of standing height

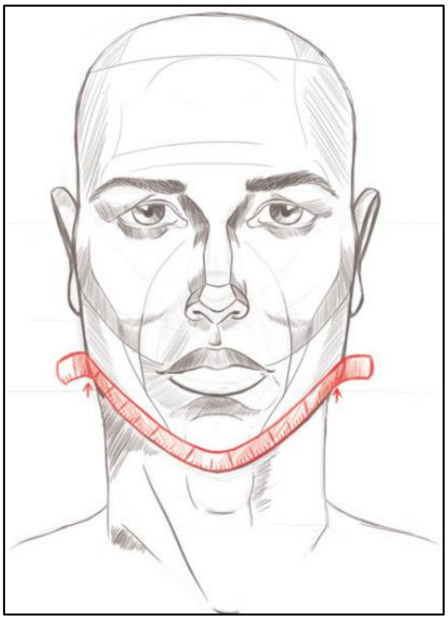

Figure 2: Measurement of length of the mandibular arch [9].

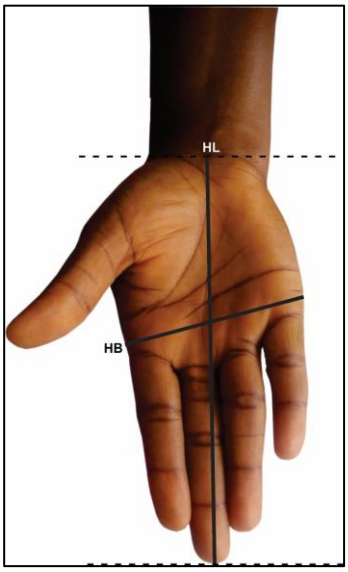

Figure 3: Measurement of hand length & breadth

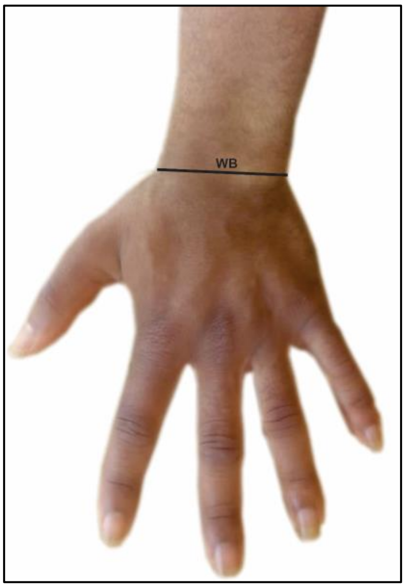

Figure 4: Measurement of wrist breadth

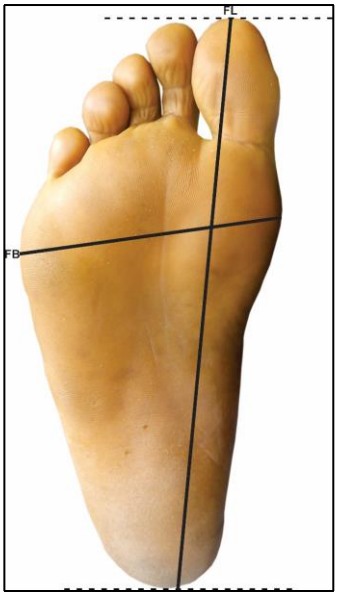

Figure 5: Measurement of foot length and breadth

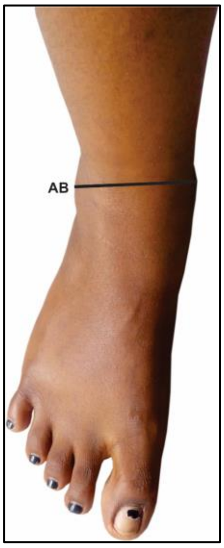

Figure 6: Measurement of ankle breadth

Data Analysis

Data were analyzed using the XLMiner Toolpak add-on in Google Sheets. Descriptive statistics, including means, standard deviations, and ranges, were computed to summarize the variables. Inferential analyses were conducted to assess group differences and relationships among variables: independent *t*-tests (assuming unequal variances) were used to examine gender differences, while one-way analysis of variance (ANOVA) was applied to assess regional differences across the three senatorial zones. Associations between stature and the measured anthropometric parameters were evaluated using Pearson's correlation coefficients. Simple and multiple linear regression models were developed to predict stature from individual and combined anthropometric variables. Regression analysis was employed because it provides more precise estimates and smaller average errors compared to the division factor method [8,9]. The predictive accuracy of the regression models was validated by comparing estimated stature values with actual measured stature. The standard error of estimate (SEE) was also calculated to assess the reliability of the developed equations.

RESULTS

The mean height for male and female adults was 170.484 ± 8.338 cm and 159.178 ± 6.194 cm, respectively (Table 1a), indicating that males were significantly taller than females ($t = 18.854$, $P < 0.01$). The mean values for all anthropometric parameters, including length of mandibular arch, hand length & breadth, wrist breadth, foot length & breadth, and ankle breadth, showed statistically significant differences between males and females ($P < 0.01$), indicating sexual dimorphism (Table 1a).

Table 1a: Descriptive statistics and sexual dimorphism in anthropometric parameters of subjects in Cross River State.

Variables	Male (N = 300)		Female (N = 300)		Total sample (N = 600)		t-Test
	Mean ± SD	Max. - Min.	Mean ± SD	Max. - Min.	Mean ± SD	Max. - Min.	t-value
Height	170.484 + 8.338	198 - 103	159.178 + 6.194	191 - 144	164.831 + 9.266	198 - 103	18.854**
LOMA	21.213 + 1.495	28 - 18	20.278 + 1.700	26 - 15	20.746+ 1.666	28 - 15	7.154**
HL	20.275 + 1.291	26 - 17	18.727 + 1.281	25 - 15.5	19.501 + 1.501	26 - 15.5	14.736**
HB	12.138 + 0.961	15 - 10	10.519 + 0.900	13 - 8	11.329 + 1.233	15 - 8	21.306**
WB	9.403 + 0.830	12 - 7	8.610 + 0.800	12 - 7	9.007 + 0.904	12 - 7	11.947**
FL	26.485 + 1.847	36 - 20	24.664 + 1.356	29 - 20	25.575 + 1.858	36 - 20	13.765**
FB	14.487 + 1.105	18 - 11	13.382 + 0.956	16 - 11	13.934 + 1.171	18 - 11	13.097**
AB	14.407 + 1.042	17 - 11	13.448 + 0.958	17 - 11	13.928 + 1.109	17 - 11	11.729**

LOMA = length of the mandibular arch; HL = hand length; HB = hand breadth; WB = wrist breadth; FL = foot length; FB = foot breadth; AB = ankle breadth.
"**" represents statistical significance at the 1% level

Table 1b: Descriptive statistics in anthropometric parameters according to senatorial zones

Variables	CSZ (N = 200)		NSZ (N = 200)		SSZ (N = 200)		ANOVA
	Mean + SD	Max. - Min.	Mean + SD	Max. - Min.	Mean + SD	Max. - Min.	F-value
Height	166.348 + 8.800	191 - 148	163.685 + 8.739	188 - 144	164.460 + 10.044	198 - 103	4.420*
LOMA	20.383 + 1.664	26 - 15	20.735 + 1.720	26 - 16	21.120 + 1.535	28 - 16	10.097**
HL	19.428 + 1.480	25 - 16.5	19.630 + 1.473	23 - 15.5	19.447 + 1.546	26 - 15.5	1.106
HB	11.489 + 1.143	14 - 9	11.470 + 1.151	15 - 8	11.028 + 1.345	15 - 8	9.212**
WB	8.890 + 0.825	12 - 7	9.195 + 0.843	12 - 7	8.935 + 1.008	12 - 7	6.755**
FL	25.841 + 1.963	35 - 20	25.390 + 1.677	30 - 20	25.493 + 1.900	36 - 20	3.263*
FB	14.113 + 1.263	18 - 11	14.048 + 1.162	18 - 12	13.643 + 1.027	16 - 11	9.732**
AB	14.110 + 1.142	17 - 11	14.038 + 1.122	17 - 12	13.635 + 1.003	16 - 11	11.006**

LOMA = length of the mandibular arch; HL = hand length; HB = hand breadth; WB = wrist breadth; FL = foot length; FB = foot breadth; AB = ankle breadth. CSZ = Central Senatorial Zone; NSZ = Northern Senatorial Zone; SSZ = Southern Senatorial Zone. “**” represents statistical significance at the 1% level; “*” represents statistical significance at the 5% level.

Comparing the average height of adults across the zones (Table 1b), the result of the one-way analysis of variance (ANOVA) revealed that adults from the northern senatorial zone (NSZ) are significantly taller when compared to subjects from CSZ and SSZ (F = 4.420, $P < 0.05$). Seven out of eight anthropometric parameters showed statistically significant differences across the three senatorial zones (Table 1b). Only hand length did not show any significant difference across the regions (F = 1.106; $P > 0.05$). This implies that there is significant variation amongst the zones and supports the development of region-specific stature prediction models.

Table 2a: Correlation matrix between height and anthropometric parameters of all subjects according to gender

	Total Sample (n=600)		Males (n=300)		Females (n=300)	
Variable	r	p	r	p	r	p
LOMA	0.318	<0.01	0.231	<0.01	0.160	<0.01
HL	0.603	<0.01	0.368	<0.01	0.510	<0.01
HB	0.558	<0.01	0.261	<0.01	0.268	<0.01
WB	0.394	<0.01	0.216	<0.01	0.127	<0.05
FL	0.582	<0.01	0.350	<0.01	0.516	<0.01
FB	0.463	<0.01	0.255	<0.01	0.246	0.180
AB	0.479	<0.01	0.324	<0.01	0.271	<0.01

LOMA = length of the mandibular arch; HL = hand length; HB = hand breadth; WB = wrist breadth; FL = foot length; FB = foot breadth; AB = ankle breadth.

The strongest association between height and anthropometric measurements among adults in Cross River State is with hand length ($R = 0.603$; $p < 0.01$), followed by foot length ($R = 0.582$; $p < 0.01$), and hand breadth ($R = 0.558$; $p < 0.01$) (Table 2a). The other anthropometric measurements showed moderate correlations, except the mandibular arch length (LOMA), which showed a weak correlation with height. All parameters show statistically positive relationships with height. However, hand and foot lengths were strongly more correlated in females than in males.

Table 2b: Correlation matrix between height and anthropometric parameters of all subjects according to senatorial zones

	CSZ (n = 200)		NSZ (n = 200)		SSZ (n = 200)	
Variable	r	p	r	p	r	p
LOMA	0.362	<0.01	0.371	<0.01	0.299	<0.01
HL	0.657	<0.01	0.747	<0.01	0.470	<0.01
HB	0.558	<0.01	0.651	<0.01	0.505	<0.01
WB	0.406	<0.01	0.424	<0.01	0.419	<0.01
FL	0.628	<0.01	0.675	<0.01	0.458	<0.01
FB	0.481	<0.01	0.560	<0.01	0.374	<0.01
AB	0.497	<0.01	0.581	<0.01	0.383	<0.01

LOMA = length of the mandibular arch; HL = hand length; HB = hand breadth; WB = wrist breadth; FL = foot length; FB = foot breadth; AB = ankle breadth. CSZ = Central Senatorial Zone; NSZ = Northern Senatorial Zone; SSZ = Southern Senatorial Zone. "**" represents statistical significance at the 1% level; "*" represents statistical significance at the 5% level

Generally, the highest correlation with height is shown in hand length, foot length, and hand breadth. The Northern Senatorial Zone (NSZ) has the strongest correlations among all the zones, followed by the Central Senatorial Zone, then the Southern Senatorial Zone (Table 2b).

The linear regression models presented in Tables 3a and 3b show how well each anthropometric variable predicts stature for each gender and region, respectively. The coefficient of /determination (R^2) shows the amount of variation in stature explained by the predictor variable, and the standard error of estimate (SEE) shows how accurately the model predicts height. The highest R^2 values for both genders were observed in foot length (FL) and hand length (HL), as they explain 26.7% and 26% for females and 12.3% and 13.6% for males, respectively. Other anthropometric predictors include ankle breadth (AB) and length of mandibular arch (LOMA). However, the standard error of the estimate is higher in males than in females, indicating greater variability in male height predictions.

The combined model explains 48.3% of the variation in stature, and the model is statistically significant, and the predictions deviating by ± 6.7 cm (SEE). Out of seven predictors examined in the model, the majority (4) showed statistical significance (HB, HL, FL, and LOMA), and only one (WB) showed a negative relationship. Hand length and breadth, and foot length emerged as the strongest and highly significant predictors of stature (R^2 = 1.615, 1.711, and 1.315, respectively).

Table 3a: Linear regression models for estimating stature according to gender

Variable	Gender	Model	R^2	SEE
LOMA	Males	H = 143.261 + 1.283(LOMA)**	0.053	8.128
	Females	H = 147.343 + 0.584(LOMA)*	0.026	6.124
	Total population	H = 128.069 + 1.772(LOMA)**	0.102	8.791
HL	Males	H = 122.285 + 2.377(HL)**	0.136	7.765
	Females	H = 113.037 + 2.464(HL)**	0.260	5.338
	Total population	H = 92.253 + 3.722(HL)**	0.363	7.400
HB	Males	H = 143.020 + 2.263(HB)**	0.068	8.063
	Females	H = 139.749 + 1.847(HB)**	0.072	5.977

	Total population	H = 117.368 + 4.190(HB)**	0.311	7.699
WB	Males	H = 150.104 + 2.167(WB)**	0.047	8.155
	Females	H = 150.662 + 0.989(WB)*	0.016	6.154
	Total population	H = 128.441 + 4.040(WB)**	0.156	8.523
FL	Males	H = 128.634 + 1.580(FL)**	0.123	7.824
	Females	H = 101.032 + 2.357(FL)**	0.267	5.314
	Total population	H = 90.647 + 2.900(FL)**	0.338	7.545
FB	Males	H = 142.594 + 1.925(FB)**	0.065	8.076
	Females	H = 137.900 + 1.590(FB)**	0.057	6.015
	Total population	H = 113.758 + 3.665(FB)**	0.215	8.219
AB	Males	H = 133.169 + 2.590(AB)**	0.105	7.903
	Females	H = 135.588 + 1.754(AB)**	0.074	5.972
	Total population	H = 109.110 + 4.001(AB)**	0.229	8.142
Combined predictors	Males	H = 92.520 + 0.593(LOMA) + 1.352(HL) + 0.397(HB) - 0.113(WB) + 0.836(FL) - 0.682(FB) + 1.523(AB)**	0.215	7.478
	Females	H = 87.548 + 0.171(LOMA) + 1.462(HL) + 0.515(HB) - 1.018(WB) + 1.463(FL) - 0.168(FB) + 0.766(AB)**	0.356	5.029
	Total	H = 65.753+ 0.479 (LOMA) + 1.615 (HL) + 1.711 (HB) - 0.745 (WB) + 1.315 (FL) + 0.129 (FB) + 0.687 (AB)**	0.483	6.700

LOMA = length of the mandibular arch; HL = hand length; HB = hand breadth; WB = wrist breadth; FL = foot length; FB = foot breadth; AB = ankle breadth. "**" represents statistical significance at the 1% level; "*" represents statistical significance at the 5% level

Table 3b: Linear regression models for estimating stature according to senatorial zones

Variable	Senatorial zone	Model	R^2	SEE
LOMA	CSZ	H = 127.322 + 1.915(LOMA)**	0.131	8.224
	NSZ	H = 124.630 + 1.884(LOMA)**	0.137	8.136
	SSZ	H = 123.088 + 1.959(LOMA)**	0.090	9.607
HL	CSZ	H = 90.491 + 3.905(HL)**	0.431	6.652
	NSZ	H = 76.726 + 4.430(HL)**	0.558	5.827

	SSZ	H = 105.138 + 3.050(HL)**	0.221	8.890
HB	CSZ	H = 117.019 + 4.294(HB)**	0.311	7.324
	NSZ	H = 107.008 + 4.941(HB)**	0.424	6.650
	SSZ	H = 122.844 + 3.774(HB)**	0.255	8.689
WB	CSZ	H = 127.881 + 4.327(WB)**	0.165	8.063
	NSZ	H = 123.282 + 4.394(WB)**	0.180	7.935
	SSZ	H = 127.113 + 4.180(WB)**	0.176	9.141
FL	CSZ	H = 93.544 + 2.817(FL)**	0.395	6.863
	NSZ	H = 74.447 + 3.515(FL)**	0.455	6.468
	SSZ	H = 102.721 + 2.422(FL)**	0.210	8.950
FB	CSZ	H = 119.058 + 3.350(FB)**	0.231	7.736
	NSZ	H = 104.527 + 4.211(FB)**	0.314	7.258
	SSZ	H = 114.566 + 3.657(FB)**	0.140	9.340
AB	CSZ	H = 112.336 + 3.828(AB)**	0.247	7.657
	NSZ	H = 100.194 + 4.523(AB)**	0.337	7.133
	SSZ	H = 112.155 + 3.836(AB)**	0.147	9.301

LOMA = length of the mandibular arch; HL = hand length; HB = hand breadth; WB = wrist breadth; FL = foot length; FB = foot breadth; AB = ankle breadth. CSZ = Central Senatorial Zone; NSZ = Northern Senatorial Zone; SSZ = Southern Senatorial Zone. "**" represents statistical significance at the 1% level; "*" represents statistical significance at the 5% level

The highest R^2 values can be observed with NSZ. The most reliable predictors were HL, FL, HB, and LOMA. Additionally, the models developed for SSZ have the lowest R^2, while CSZ models show moderate predictability. After comparing the mean actual stature and the estimated stature from the developed regression models, the differences are extremely small across all predicting variables and for both genders (± 0.03 m). However, the regression model with all the predicting variables shows the highest overall accuracy (Table 4a).

Table 4a: Comparison of mean actual stature and mean estimated stature derived from anthropometric parameters according to gender.

Estimated stature	All participants	Males	Females
LOMA	164.831	170.478	159.186

HL	164.836	170.479	159.181
HB	164.836	170.489	159.178
WB	164.828	170.481	159.177
FL	164.813	170.480	159.165
FB	164.827	170.481	159.177
AB	164.834	170.482	159.176
Combined predictors	164.854	170.471	159.184
Actual stature	164.831	170.484	159.178

LOMA = length of the mandibular arch; HL = hand length; HB = hand breadth; WB = wrist breadth; FL = foot length; FB = foot breadth; AB = ankle breadth. "**" represents statistical significance at the 1% level; "*" represents statistical significance at the 5% level

Table 4b: Comparison of mean actual stature and mean estimated stature derived from anthropometric parameters according to senatorial zones.

Estimated stature	CSZ	NSZ	SSZ
LOMA	166.354	163.695	164.462
HL	166.355	163.685	164.450
HB	166.353	163.681	164.462
WB	166.348	163.685	164.461
FL	166.338	163.693	164.464
FB	166.335	163.681	164.457
AB	166.349	163.686	164.459
Combined predictors	164.354	163.680	159.184
Actual stature	166.348	163.685	159.178

LOMA = length of the mandibular arch; HL = hand length; HB = hand breadth; WB = wrist breadth; FL = foot length; FB = foot breadth; AB = ankle breadth. CSZ = Central Senatorial Zone; NSZ = Northern Senatorial Zone; SSZ = Southern Senatorial Zone. "**" represents statistical significance at the 1% level; "*" represents statistical significance at the 5% level

The models developed for NSZ and SSZ show nearly exact predicted stature with negligible error (<0.01m) (Table 4b). However, the regression model using all the predicting variables for CSZ has a difference of approximately 2m. This may be due to the lower R^2 values for CSZ, indicating a weaker model fit compared to the other zones.

DISCUSSION

The present study investigated the relationship between selected anthropometric parameters and stature among adults in Cross River State, Nigeria, with participants aged between 18 and 45 years. This age range was deliberately chosen because maximum adult height is attained by approximately 18 years of age, and measurable decline in stature is not observed until the fifth decade of life [13]. The analysis revealed significant sexual dimorphism in stature, with males being consistently taller than females. This finding aligns with a wide body of anthropometric literature which has reported that males generally exhibit greater stature than females across populations, largely due to genetic, hormonal, and nutritional influences [10, 13-19].

Beyond overall stature, significant gender differences were observed in all measured variables, including length of mandibular arch, hand and foot dimensions, and wrist and ankle breadths. Males had consistently higher mean values than females, which is in agreement with earlier studies conducted in Nigeria and other populations [20]. However, some discrepancies were noted when compared with findings from other regions [10], which may be attributable to differences in environmental conditions, nutrition, genetic background, and methodological variations.

This study also demonstrated that all anthropometric parameters were significantly correlated with stature, with hand and foot lengths showing the strongest correlations. This is consistent with previous reports that identify linear dimensions of limbs as the most reliable predictors of height [21]. However, our findings differ from studies where breadth parameters exhibited stronger correlations with stature [8]. Such differences may reflect population-specific genetic variation, lifestyle factors such as occupational physical activity, or differences in sample size and analytical techniques. Interestingly, in the present study, foot and hand lengths of females showed stronger correlations with stature than those of males, a pattern not observed in some earlier Nigerian and non-Nigerian populations [10,16,22,23].

Regional variation in anthropometric dimensions was also evident, as statistically significant differences were observed across the three senatorial zones of Cross River State. These findings are consistent with reports of ethnic and regional variability in anthropometric traits documented in African and non-African populations [8,14,19,24-28]. The observed differences are likely due to underlying genetic heterogeneity, environmental influences, and long-standing cultural and nutritional practices within each region. Such variation reinforces the need for population- and region-specific databases in forensic and clinical applications of anthropometry.

The regression models developed in this study proved reliable in predicting stature from hand, foot, and mandibular dimensions, both in males and females. The multiple regression models, particularly in the southern senatorial zone, provided closer approximations of actual stature than individual predictors, highlighting the value of combined parameter models in enhancing predictive accuracy. The low standard error of estimate observed further confirms the robustness of the developed equations. These findings corroborate earlier reports which demonstrated that peripheral skeletal dimensions can be used to accurately estimate stature in different populations [29].

Overall, the present findings provide further evidence that stature can be reliably predicted from hand, foot, and mandibular anthropometric measurements. The observed gender and regional differences underscore the importance of using localized regression models rather than generalized equations derived from other populations. This has important implications for forensic identification, anthropological research, and clinical assessments in Nigeria and beyond.

Although this study provides important insights into the relationship between anthropometric parameters and stature in Cross River State, certain limitations should be acknowledged. First, the sample was limited to individuals aged 18 – 45 years, which excluded older adults in whom age-related decline in stature might affect regression outcomes. Second, the study was limited to three senatorial zones within a single Nigerian state. Therefore, the findings may not be directly generalizable to other regions or ethnic groups in Nigeria or beyond. Additionally, while anthropometric data were carefully collected, the study did not account for potential cofounders such as socioeconomic status, nutritional history, or levels of physical activity, all of which may influence body dimensions.

Further research should aim to include larger and more diverse populations across different Nigerian regions and ethnic groups to develop broader, population-specific databases. Longitudinal studies could also help track how anthropometric stature relationships change with age and lifestyle factors. Incorporating advanced imaging techniques and genetic analysis may further improve the accuracy and applicability of stature estimation models in forensic, medical, and anthropological contexts.

CONCLUSION

The regression models developed in this study demonstrate high accuracy in estimating stature from hand, foot, and mandibular measurements among adults in Cross River State, with hand and foot lengths proving most reliable. These multi-parameter models are therefore recommended for application in forensic, medical, and anthropological contexts, particularly in disaster-prone areas where complete bodies may not be available.

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