جامعة نايف العربية للعلوم الأمنية
Naif Arab University for Security Sciences

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Arab Journal of Forensic Sciences & Forensic Medicine
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الجمعية العربية لعلوم الأدلة الجنائية والطب الشرعي
Arab Society for Forensic Sciences and Forensic Medicine

Original article

Sexual Dimorphism and Estimation of Height from Body Length Anthropometric Parameters among the Hausa Ethnic Group of Nigeria

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Received 19 Jul. 2017; Accepted 27 Dec. 2017; Available Online 31 Dec. 2017

Abstract

The relationships between dimensions of the parts of the human body and the whole body have drawn the attention of anatomists, anthropologists and scientists for many years. The purpose of this study was to investigate sexual dimorphism in some body lengths and other anthropometric parameters. It also aimed to generate formulae for height estimation using anthropometric measurements of some length parameters among the Hausa ethnic group of Kaduna State, Nigeria.

A cross sectional study was conducted among 500 secondary school students between the ages of 16 and 26 years. Anthropometric measurements were obtained using standard protocols.

The results showed significant sexual dimorphism in all the parameters, except for body mass index. In all the body length anthropometric parameters considered in this study, males had significantly ($p < 0.05$) higher mean values, except in biaxillary distances. Height showed positive and strong correlations with demispan length with good correlation of determination, indicating a stronger estimation ability than other parameters. A combination of two parameters tends to give better estimations, as explained by the adjusted R^2; and, therefore, combining the three parameters gives better estimation accuracy.

In conclusion, Hausa males tend to have larger body proportions compared to females. Height showed strong positive correlation with demispan length. Body length an-

Keywords: Forensic Sciences, Height Estimation, Anthropometry, Hausa Population, Nigeria.

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doi: 10.26735/16586794.2017.009

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thropometric measurements proved to be useful in estimation of stature among the Hausa ethnic group of Kaduna state, Nigeria.

الاختلافات بين الجنسين وتقدير الطول من خلال أطوال الجسم والمعايير الأنثروبومترية في مجموعة هوسا العرقية في نيجيريا.

المستخلص

لقد شدّت العلاقة بين أبعاد أجزاء الجسم وأبعاد الجسم ككل انتباه أخصائيي التشريح والأنثروبولوجيا والعلماء لسنوات عديدة، وهدفت هذه الدراسة إلى التحقق من الاختلافات بين الجنسين في بعض أطوال الجسم والمعايير الأنثروبومترية الأخرى. كما هدفت إلى التوصل لعلاقات رياضية لتقدير الطول باستخدام قياسات أنثروبومترية لبعض معايير الطول في مجموعة الهوسا العرقية من ولاية كادونا في نيجريا. وأجريت دراسة مقطعية شارك فيها ما مجموعه 500 شخص من طلاب المدارس الثانوية من الفئة العمرية بين 16-27 سنة، وتم الحصول على القياسات الأنثروبومترية باستخدام البروتوكولات القياسية. ولوحظ وجود اختلاف ذو دلالة إحصائية بين الجنسين في جميع المعايير المدروسة باستثناء مؤشر كتلة الجسـم. وكان لدى الذكور قيم أعلى في جميع متوسـطات معايير الطول الأنثروبومترية ($p < 0.05$) باستثناء المسافات الإبطية. ولقد أظهر ارتفاع الجسم علاقة ارتباط ايجابية وقوية مع طول نصف الباع، وعلاقة ارتباط جيدة مع عملية التقدير تشير إلى قابلية قوية للتقييم مقارنة مع غيره من المعايير.

ويميل الجمع بين معيارين إلى إعطاء تقديرات أفضل وفق ما هو موضح بالنسبة لمعامل الارتباط R^2 المضبوط، وبالتالي فإن الجمع بين ثلاثة معايير يعطي تقديرات أفضل مع صحة أعلى. ونستنتج من هذه الدراسة أن ذكور الهوسا تميل إلى امتلاك نسب جسم أكبر مقارنة مع الإناث. وأن ارتفاع الجسم ذو علاقة ارتباط إيجابية وقوية مع طول نصف الباع، وقد أثبتت قياسات طول الجسم الأنثروبوميترية أنها مفيدة في تقدير القامة بين مجموعة الهوسا العرقية في ولاية كادونا نيجيريا.

الكلمات المفتاحية: علوم الأدلة الجنائية، الطول، التقدير، القياسات البشرية، مجموعة الهوسا السكانية.

1. Introduction

Alphonse Bertillon was a French criminologist who was the first to develop a system of criminal identification using anthropometric measurements [1]. The correlation between specific body measurements and proportions will help narrow down the process of establishing personal identity when complete evidence is unavailable [2]. For instance, some studies proved that height can be estimated using imprints of the hand and foot or even shoeprints left at a crime scene [3]. The long bones of the limbs are more preferably used [4, 5] to estimate stature than any other evidence left at the disaster scene. A more scientific way of height prediction using anthropometric measurement has been recommended [6].

The relationships in the dimensions of the parts of the human body and the whole body have drawn the attention of anatomists, anthropologists and biologists for many years. However, this relationship between body parts has been used to investigate variations between sexes or ethnic groups and link them to their lifestyle, the pattern of their locomotion as well as energy expenditure [2]. Measurements such as hand dimensions, leg length and arm span have been used for height estimation in cases when complete evidence of height estimation is not available at the accident scene [8-11]. It is an established fact that relationships between body measurements do occur on account of variation in population and ethnic origin, which could be linked to differences in nutrition and physical activity [12].

There is a scarcity of literature regarding the estimation of height for the Hausa ethnic group of Nigeria. The estimation of height can serve as an additional way of ascertaining the identity of victims using the available body fragments found at accident scenes or even decomposed and mutilated body parts. This is paramount, especially in recent times, due to increased cases of natural and man-made disasters like earthquakes and bomb blasts, among others. Thus, developing ways of making proper identification of victims using predictive equations is of great importance. Since height can be considered as one of the key elements in the identification, the objectives of the current study were to research sexual dimorphism in height and other anthropometric parameters. The study also aimed

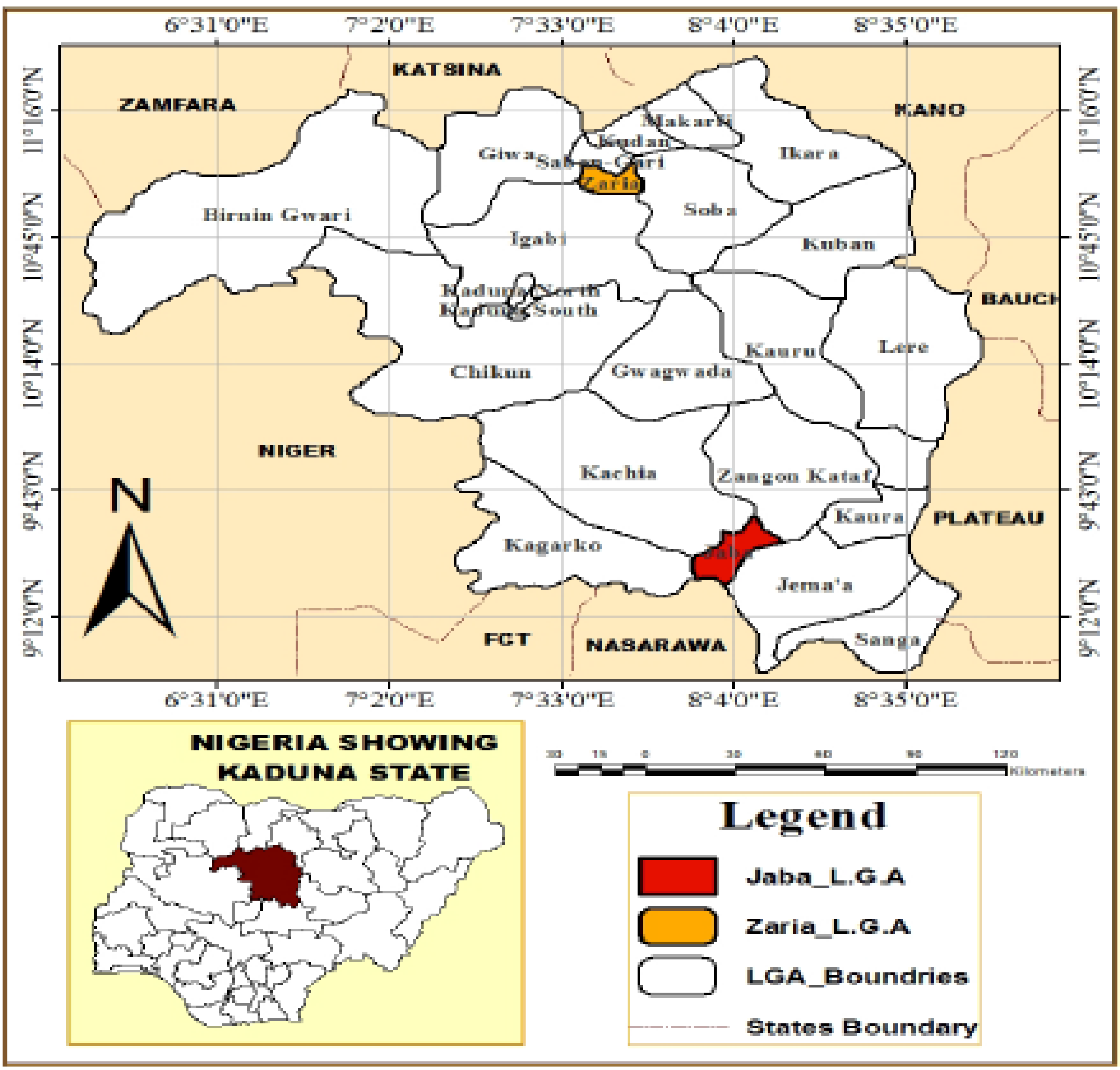

Figure 1- *Map of Kaduna State indicating location of the study.*

Table 1- *Procedures and instruments involved in the measurement of anthropometric parameters in this study.*

Variables	Measurements	Instrument
Height	The Subject's head was in the Frankfort Plane; arms relaxed at sides. The subject was instructed to inhale and stretch up. The measurer slidesthe headboard of the stadiometer down to the vertex and recorded the measurement to the nearest 0.1 cm.	Stadiometer
Weight	The subject was barefooted and lightly dressed. Weight was taken to the nearest 0.1kg.	Weighing Balance
Body Mass Index	Calculated as the weight (kg) divided by the square of the body height (m), and is universally expressed in units of kg/m^2.	Formula
Demispan Length	The subject sits in the anthropometric sitting position with shoulder in full extension. Measurements were made using a harpenden anthropometer at ventral surface, starting from mid manubrium passed over shoulder, elbow and wrist to tip of third finger laterally.	Harpenden Anthropometer
Humeral Length	The subject is in the anthropometric sitting position with arm bent 90 degrees at the elbow. Standing at the right side of the subject, vertical distance was measured using a harpenden anthropometer between the acromion landmark on the tip of the right shoulder and the bottom of the flexed elbow (olecranon bottom)	Harpenden Anthropometer
Sitting Height	The subject is in the anthropometric sitting position with the head in the Frankfort plane. Standing at one side of the subject, vertical distance was measured between the sitting surface and the top of the head (vertex). The blade of the anthropometer was across the top of the head and firm pressure was used to compress the subject's hair. Measurement was taken at the maximum point of quite inspiration.	Anthropometer
Thigh Length	Subject sits in the anthropometric sitting posture with 90 degree flexion of knee and 30-45 degree of the hip. Using a harpenden anthropometer, vertical distance was measured between trochanterion landmark on the thigh and the lateral femoral epicondyle landmark.	Harpenden Anthropometer
Knee Height	Sitting position with 90 degree flexion of knee and ankle neutral on the surface. Standing at the right side of the subject using a harpenden anthropometer, vertical distance was measured between the surface and the marked standing lateral femoral epicondyle landmark on the outside of the right knee.	Harpenden Anthropometer
Forearm Length	Subject sits in the anthropometric sitting posture with the arms bent 90 degrees at the elbow (palms facing medially). Standing on the right side of the subject using a harpenden anthropometer, the distance was measured between the posterior olecranon landmarks to the styloid process of radius on the right wrist. The beam of the caliper was parallel to the long axis of the lower arm. The fixed blade was placed on the posterior olecranon landmark. Enough pressure was exerted to attain contact between the caliper and the skin.	Harpenden Anthropometer
Neck Length	Subject sits in the anthropometric sitting position with full neck extension, using an elastic measuring tape at posterior, measurement at the external occipital protuberance to the tip of spinous process of 7th cervical spine (vertebral prominence at the root of neck) was taken.	Inelastic Tape

Continued on the next page

Table 1- *(continued)*

Biaxillary Length	Subject stands in anthropometric standing position with arm adduction close to the body. At ventral surface, the distance was measured with the fixed blade of a harpenden anthropometer placed side to side at the junction of the deltopectoral groove and anterior axillary fold.	Harpenden Anthropometer
Hand Length	Subject sits with hand placed on a hard surface. Using a harpenden anthropometer, distance was measured at palmar surface, starting at the last crease of the wrist to the tip of mid finger (3rd finger).	Harpenden Anthropometer
Foot Length	Subject sits with neutral position of the ankle joint. Using a harpenden anthropometer, measurement from the tip of heel at posterior to tip of first toe was taken.	Harpenden Anthropometer

to generate formulae for the estimation of height from anthropometric parameters of some body parts in the Hausa ethnic group of Kaduna state, Nigeria.

2. Materials and Methods

2.1. Study setting

The study was carried out among the Hausa population of Zaria city, Kaduna state, Nigeria. The neighborhoods of Tudun Wada and Danmagaji are predominantly occupied by indigenous Hausa [13].

2.2. Study population

This is a cross-sectional study; a total of 500 healthy secondary school students (247 male and 253 female) between the ages of 16-26 participated in this study. Informed consent was obtained from the students and parent or guardian before commencement of data collection. In order to encourage more candidates and reliable responses, participants were made to complete a self-administered questionnaire. Only subjects belonging to the Hausa ethnic group with no obvious physical deformities were included. Participants who were less than 16 years of age or older than 30 years of age were excluded. Any participants with amputated limb(s) or diseases that affect the desired measured parameters like edematous limbs, grossly deformed limbs or vertebral bone deformities like kyphosis or lordosis were also excluded.

2.3 Anthropometry

Relevant data were collected using protocols described by the previous studies [6, 14]. Table-1 shows procedures involved in the measurement of anthropometric parameters.

2.4 Statistical analysis

The data were expressed as mean ± standard deviation. Differences in means between male and female were obtained using student's t-test. Relationships between anthropometric measurements were investigated using the Pearson's correlation coefficient. Simple and multiple linear regression analyses were used to estimate height from other anthropometric parameters. SPSS statistical software was used for all the analyses. $p < 0.05$ was set as level of significance.

3. Results

Table-2 shows the differences in study variables among the Hausa population according to sex. A significant sexual

Table 2- *Student's t-test for sex differences in anthropometric variables*.

	Males ($n = 247$)	Females ($n = 253$)		
Parameters	**Mean± S.D.**	**Mean± S.D.**	**t**	***p - value***
Age (Years)	18.99±2.03	17.74±1.10	8.57	0.001
Height (cm)	166.59±7.51	158.57±6.42	12.85	0.001
Weight (cm)	56.19±9.75	51.11±9.39	5.94	0.001
Body Mass Index (kg/m^2)	20.16±2.79	20.31±3.36	-0.53	0.597
Demispan Length (cm)	89.00±4.79	82.61±4.40	15.55	0.001
Neck Length (cm)	14.79±1.78	12.83±1.99	11.58	0.001
Biaxillary (cm)	31.89±2.49	32.33±2.58	-1.92	0.055
Sitting Height (cm)	82.79±4.37	79.09±3.25	10.74	0.001
Thigh Length (cm)	42.99±3.01	39.94±2.96	11.42	0.001
Knee Height (cm)	53.50±3.24	49.91±2.80	13.28	0.001
Foot Length (cm)	26.03±1.63	24.36±1.27	12.77	0.001
Humeral Length (cm)	33.33±1.97	32.30±2.31	5.35	0.001
Forearm Length (cm)	29.63±1.89	28.44±2.09	6.62	0.001
Hand Length (cm)	19.61±1.16	18.51±1.13	10.72	0.001

dimorphism was observed in all the parameters, except for body mass index and biaxillary distance. In all the parameters, males tend to have significantly ($p < 0.05$) higher mean values than females.

Height was observed to have more positive and stronger correlations with demispan length than the other body length anthropometric parameters. The least correlation was observed between height and neck length (Table-3).

The demispan length showed a strong correlation coefficient with a better estimation ability. A strong correlation was also observed between height with sitting height, thigh height, and knee height (Table-4).

Table-5 shows equations for height estimations from length anthropometric parameters among Hausa males. In all the parameters, height correlated strongly with demispan length, sitting height, thigh height, knee height, forearm length and humeral length with height. Table-6 shows equations for height estimations from length anthropometric parameters among Hausa females. In all the parameters, height correlated strongly only with demispan length.

Tables-7 and 8 show the single and multiple regressions with the parameters that had the highest correlation coef-

Table 3- *Pearson's correlation (r) of anthropometric variables of Hausa ethnic group (n=500).*

Variables	Height (cm)		
	All	Male	Female
Weight (cm)	0.56**	0.63**	0.37**
Body Mass Index (kg/m^2)	0.03	0.18**	-0.08
Demispan Length (cm)	0.84**	0.83**	0.71**
Neck Length (cm)	0.33**	0.14*	0.13*
Biaxillary (cm)	0.21**	0.42**	0.17**
Sitting Height (cm)	0.72**	0.70**	0.57**
Thigh Length (cm)	0.73**	0.74**	0.55**
Knee Height (cm)	0.77**	0.74**	0.63**
Foot Length (cm)	0.68**	0.56**	0.61**
Humeral Length (cm)	0.62**	0.75**	0.47**
Forearm Length (cm)	0.57**	0.70**	0.33**
Hand Length (cm)	0.69**	0.67**	0.53**

** $p < 0.05$; **$p < 0.01$; The cut-off point of strong correlation is 0.7*

Table 4- *Linear regression equations for estimations of height from anthropometric length parameters of Hausa tribes (n=500).*

Parameters	Regression Equation	R	R^2	*SEE*	*F*	*p - value*
Age (Years)	HT=1.826*AGE+129.014	0.396	0.157	7.395	92.436	0.001
Weight (kg)	HT=0.453*WT+138.232	0.557	0.310	6.687	224.212	0.001
Body Mass Index (kg/m2)	HT=0.074*BMI+161.021	0.029	0.001	8.049	0.407	0.524
Demispan Length (cm)	HT=1.200*DS+59.566	0.835	0.698	4.426	1150.613	0.001
Neck Length (cm)	HT=1.251*NL+145.264	0.331	0.109	7.600	61.073	0.001
BiaxillaryLengh (cm)	HT=0.675*BL+140.857	0.214	0.046	7.867	23.817	0.001
Sitting Height (cm)	HT=1.363*SH+52.198	0.722	0.522	5.568	543.732	0.001
Thigh Length (cm)	HT=1.741*TL+90.395	0.725	0.526	5.546	551.867	0.001
Knee Height (cm)	HT=1.763*KH+71.397	0.771	0.595	5.124	731.839	0.001
Foot Length (cm)	HT=3.269*FL+80.208	0.683	0.467	5.880	436.125	0.001
Humeral Length (cm)	HT=2.273*HRL+87.952	0.623	0.389	6.296	316.722	0.001
Forearm Length (cm)	HT=2.196*FRL+98.794	0.569	0.324	6.621	238.558	0.001
Hand Length (cm)	HT=4.381*HL+79.049	0.691	0.477	5.824	453.948	0.001

HT, height; WT, weight; BMI, body mass index; DL, demispan length; NL, neck length; BL, biaxillary length; SHT, sitting height; THL, thigh length; KHT, knee height; FT, foot length; HRL, humeral length; FRL, forearm length; HL, hand length; SEE, standard error of the estimate; The cut-off point of strong correlation is 0.7

Table 5- *Linear regression equations for estimations of height from anthropometric length parameters of Hausa males (n=247).*

Parameters	Regression Equation	R	R^2	*SEE*	*F*	*p - value*
Age (yrs.)	HT=1.270*AGE+142.468	0.344	0.118	7.064	32.878	0.001
Weight (kg)	HT=0.485*WT+139.317	0.630	0.397	5.841	161.456	0.001
Body Mass Index (kg/m2)	HT=0.482*BMI+156.860	0.179	0.032	7.402	8.124	0.005
Demispan Length (cm)	HT=1.301*DL+50.792	0.706	0.498	4.558	540.924	0.001
Neck Length (cm)	HT=0.584*NL+157.946	0.139	0.019	7.451	4.816	0.029
BiaxillaryLength (cm)	HT=1.253*BL+126.611	0.417	0.174	6.838	51.580	0.001
Sitting Height (cm)	HT=1.205*SH+66.788	0.702	0.492	5.360	237.651	0.001
Thigh Length (cm)	HT=1.832*TL+87.828	0.735	0.540	5.105	287.054	0.001
Knee Height (cm)	HT=1.718*KH+74.676	0.741	0.549	5.050	298.742	0.001
Foot Length (cm)	HT=2.558*FL+100.010	0.556	0.309	6.254	109.520	0.001
Humeral Length (cm)	HT=2.865*HRL+71.087	0.750	0.563	4.975	315.303	0.001
Forearm Length (cm)	HT=2.771*FRL+84.501	0.700	0.490	5.371	235.651	0.001
Hand Length (cm)	HT=4.335*HL+81.563	0.672	0.451	5.575	201.199	0.001

HT, height; WT, weight; BMI, body mass index; DL, demispan length; NL, neck length; BL, biaxillary length; SHT, sitting height; THL, thigh length; KHT, knee height; FT, foot length; HRL, humeral length; FRL, forearm length; HL, hand length; The cut-off point of strong correlation is 0.7

Table 6- *Linear regression equations for estimations of height from anthropometric length parameters of Hausa females (n=253).*

Parameters	Regression Equation	R	R^2	*SEE*	*F*	*p - value*
Age (yrs.)	HT=0.739*AGE+145.452	0.127	0.016	6.380	4.092	0.044
Weight (kg)	HT=0.256*WT+145.500	0.374	0.140	5.965	40.786	0.001
Body Mass Index (kg/m2)	HT=0.148*BMI+161.578	0.078	0.006	6.412	1.522	0.218
Demispan Length (cm)	HT=1.028*DL+73.630	0.706	0.498	4.558	248.732	0.001
Neck Length (cm)	HT=0.405*NL+153.373	0.125	0.016	6.381	3.992	0.047
Biaxillary Lengh (cm)	HT=0.416*BL+145.107	0.167	0.028	6.341	7.232	0.008
Sitting Height (cm)	HT=1.125*SH+69.613	0.569	0.324	5.287	120.443	0.001
Thigh Length (cm)	HT=1.180*TL+111.420	0.545	0.297	5.393	105.925	0.001
Knee Height (cm)	HT=1.441*KH+86.629	0.630	0.397	4.996	164.979	0.001
Foot Length (cm)	HT=3.097*FL+83.114	0.614	0.377	5.075	152.062	0.001
Humeral Length (cm)	HT=1.313*HRL+116.150	0.473	0.224	5.666	72.350	0.001
Forearm Length (cm)	HT=1.012*FRL+129.782	0.331	0.109	6.070	30.812	0.001
Hand Length (cm)	HT=3.047*HL+102.159	0.534	0.285	5.437	100.243	0.001

HT, height; WTl, weight; BMI, body mass index; DL, demispan length; NL, neck length; BL, biaxillary length; SHT, sitting height; THL, thigh length; KHT, knee height; FT, foot length; HRL, humeral length; FRL, forearm length; HL, hand length; The cut-off point of strong correlation is 0.7

Table 7- *Multiple and simple linear regressions for predictions of height from body length variables of Hausa ethnic groups (n=500).*

Parameters	Regression Equation	R	R^2	Adjusted R^2	*SEE*	*F*	*p - value*
DL	HT=1.200*DS+59.566	0.835	0.698		4.426	1150.613	0.001
KH	HT=1.763*KH+71.397	0.771	0.595		5.124	731.839	0.001
TL	HT=1.741*TL+90.395	0.725	0.526		5.546	551.867	0.001
DL+KH	HT=.847*D+.741*K+51.588	0.862a	0.742	0.741	4.090	716.498	0.001
DL+KH+TL	HT=.715*D+.569*K+.519*T+50.246	0.874a	0.765	0.763	3.914	537.387	0.001

HT, Height; D, Demispan length; DS, Demispan length; K, Knee height; T, Thigh length; D+K, Demispanlength and knee height; D+K+T, Demispan length, knee height and thigh length; The cut-off point of strong correlation is 0.7

ficients. It was noted from the equations that combining the two parameters tends to give better estimation strength as explained by the coefficient of determination; therefore,also combining the three parameters gives better estimation accuracy than the two parameters combined. Parameters with higher correlation coefficient were selected in order to have a better precision of the equations.

4. Discussion

Height is one of the parameters used most frequently in clinical and forensic practices; however, in some situations, it is unobtainable. This has led to finding alternatives by using anthropometric measurement, and a lot of formulas have been reported. However, ethnic differences, gender and age are considered as variables for application and external validation in different populations. The objectives of the study were to investigate sexual dimorphism and to develop prediction models using body length anthropometric parameters among the Hausa ethnic group.

This study confirmed sexual dimorphism, as males showed higher mean anthropometric values than females. The same has been reported in previous studies [15-18]. This supports the fact that males tend to have larger body proportions and builds compared to females. The findings of this study revealed that height is significantly related to anthropometric parameters. This is in line with the report of previous studies on stature estimation in Nigeria [14-16, 19-25]. This further explained the validity and reliability of body length parameters in estimating statures.

The highest correlation of height with demispan length compared to the other parameters is in agreement with the previous study [26], which reported that arm span correlated more strongly with height than knee and sitting height. This finding is also in line with the study performed in elderly females in south India [27], which showed that the arm span correlated more strongly with height than sitting height or leg length. Contrary to the present study, it was reported that knee height or leg length had the highest correlations in the single parameters and higher predictions than other parameters. This is followed by sitting height,

Table 8- *Multiple and simple linear regressions for predictions of height from body length variables of Hausa ethnic groups with the parameters that has a highest correlation coefficient in males (n=247) and females (n=253).*

Parameters	Regression Equation	R	R^2	Adjusted R^2	*SEE*	*F*	*p -value*
Males							
DL	HT=1.301*DL+50.792	0.706	0.498		4.558	540.924	0.001
HR	HT=2.865*HRL+71.087	0.750	0.563		4.975	315.303	0.001
KH	HT=1.718*KH+74.676	0.741	0.549		5.050	298.742	0.001
DL+HR	HT=0.955*D+1.128*HR+43.973	0.853	0.727	0.725	3.940	324.661	0.001
DL+HR+KH	HT=0.713*D+.931*HR+.641 *K+37.838	0.875	0.765	0.762	3.664	263.425	0.001
Females							
DL	HT=1.028*DL+73.630	0.706	0.498		4.558	248.732	0.001
KH	HT=1.441*KH+86.629	0.630	0.397		4.996	164.979	0.001
FL	HT=3.097*FL+83.114	0.614	0.377		5.075	152.062	0.001
DL+KH	HT=0.746*D+.719*K+61.072	0.748	0.559	0.555	4.280	158.367	0.001
DL+KH+FL	HT=0.597*D+.598*K+1.071 *F+53.279	0.764	0.584	0.579	4.164	116.610	0.001

HT, Height; DL, Demispan length; KH, Knee height; HR, Humeral length; DL+HR, Demispan length and Huemral length; DL+HR+KH, Demispan length; humeral length and Knee height and FL, Foot length; DL+KH, Demispan length and Knee height; DL+KH+FL, Demispan length, Knee height and Foot length

foot length, thigh length, hand length, humeral length and forearm length, respectively [6].

Standard error of estimate (SEE) obtained in this study was used to estimate the precision of the method. Males showed better precision than females. This is in line with the previous findings in Nigerian [14], Turkish [28, 29] and Indian [30, 31] populations. Therefore, higher predictive ability was observed in males than females in the Hausa ethnic group.

The degree of correlations in the present study proved that different body lengths could be used in height estimation in Nigeria. The study will help medical and legal practitioners to properly identify individuals in situations where body parts like hands or legs are available in accidents, crimes or disaster scenes. The present study intends to establish these equations as an addition to building anthropological baseline data for Nigerians.

5. Conclusion

Hausa males tend to have larger body proportions compared to Hausa females. The strongest correlations were observed between height and demispan length in the over-all population, the most reliable linear regression equation was Height = 1.20*demispan length + 59.566 (r = 0.835, p = 0.000, and R^2 = 0.698), which shows that demispan length in height estimation of Hausa ethnic groups is more accurate and reliable than the other anthropometric parameters in this study.

Acknowledgments

I would like to thank, Auwal Falalu Kabir, Abdulkarim Musa, M. Z, Yusuf, Muhammad Mubashir, Ibrahim Elladan, Abel Solomon Yashim and Monday Nwankwo, and to all those who participated in making this work great.

Conflict of Interest: The authors declare no conflict of interest.

Funding: None

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