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Predictive Modelling of Stature from percutaneous Anthropometric Hand Dimensions of Adolescent Nigerian School Children

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Abstract

Background: The literature on stature estimation by predictive regression modelling using percutaneous anthropometric dimensions in adolescent children in West Africa is sparse. This study evaluated the predictive relationships between hand anthropometric dimensions and stature in Nigerian adolescent school children in Lagos.

Methods: A randomized study sample of 483 (240 males and 243 females) volunteer Nigerian adolescent school children aged 10-17 years were recruited from the Nigeria Airforce Secondary School, Lagos. Stretch stature and eighteen anthropometric variables (right and left sides), including hand length, hand breadth, palm length, wrist width and the five digital lengths (D1-D5) were estimated according to standardized protocols. Statistical analysis of the data was carried out using SPSS version 25.0 and Microsoft Excel statistical packages. The dataset included descriptive and inferential statistics while the predictive models were generated by simple and multiple linear regressions and presented as tables, graphs and scatterplots.

Results: In this study the stature for boys at age 10 years was 142.57(± 6.69) cm, ranged 125.7-161.8cm, while for 10 years old girls, stature was 144.55 (±5.8) cm ranged 132.9-153.4cm. With a t=1.128 and p=0.2646. Pearson's product moment correlation coefficient and simple and multiple linear regression modelling showed varying levels of association between stature and hand dimensions with the strongest positive correlation being between stature and the male left hand length (r=0.853), while female right and left palm length and stature showed the weakest positive correlation (r=0.024 and 0.028).

Conclusion: These findings should be of benefit to anatomists and forensic scientists when considering cases of possible missing identities in disaster or crime scene scenario.

Keywords: Stature estimation, Percutaneous hand anthropometry, Regression, Adolescent nigerians

Introduction

Forensic scientists use different body segment bones of the human skeleton to estimate living stature with varying degree of accuracy [1-4]. A plethora of alternative methods of estimating stature for personal identification from the limbs or extremities are now available because of advances in technology [5,6]. However, nowadays, personal identification from the limbs has become most critical especially in the light of increasing frequency of unnatural mass disasters arising from air, rail and road traffic accidents, as well as blasts from explosive devices wherein the human remains have been dismembered with only segments such as the hands and feet being recovered [7]. In such instances, especially in the adult, several studies from around the world have attempted modelling the hand and feet anthropometry for living stature reconstruction [8-13]. Where juveniles (children and adolescents) have been suspected as possible victims of violent crime or mass disaster, stature estimation present a unique set of challenges necessitating a wider array of methodological options. Kimmerle [14] has canvassed the argument that identification of juvenile victims of violent crimes or mass disaster is a human rights issue which must be handled as top priority in any coroner's office [15,16]. The scientific literature describing studies on the estimation of stature from the extremities in juveniles is sparse and far-between [17]. Suggested that there is as yet no definitive estimation method recommended, because the most accurate means of estimating juvenile stature has remained a matter of speculation within the anthropological community in terms of comparisons of different skeletal elements as well as comparisons to adult studies, formulae, and populations [18-21]. Telkka [22] addressed the paucity of juvenile stature estimate formulae with their study of radiographs of 3,848 long bones (humerus, radius, ulna, femur, tibia, fibula) in juveniles from 1-9 years old. Other radiographic studies have also noted that the hand and wrist, among other limb bones and skeletal elements, often provide useful information about age since secondary centers of ossification may be identified under radiographic examination [23-28]. Aside the clinical radiological methods, [29] estimated stature from foot-length in adolescent girls from North India, with direct field anthropometric methods [30]. used the stature/femur ratio as a model for estimating stature in children and adolescents, suggesting that it was more reliable than the Trotter & Gleser [31] regression models developed from adult samples [32]. developed a clinically-robust protocol for predicting stature from arm-span in all age-groups stature from data acquired from across four continents, while [33] used the arm span as an index of pulmonary function in 6-10 years old children in Latin America. Arm-span data from [34] in the United States, [35] in North India, [36] in the United Kingdom, [37] in Indonesian Java and [38] in Nigerians suggests that arm- span to predict stature is probably more beneficial in the elderly. It has been suggested that juvenile stature modelling tends to be intertwined with those associated with adult formulae while studies on juvenile stature and body mass prediction rarely take account of skeletal maturity, the samples are simply divided into immature and mature groups (according to skeletal maturity). with the mature group being considered with adults. One problem with such studies was that they tended to overestimate stature in the older children and underestimate in the much younger groups [39]. However, Kimura [40]. While estimating stature by comparing single versus multiple dimensions as well as maturity status of second metacarpals in 552 boys and 542 girls aged 6 to 20 years, observed that combination of length and width measurements provided a more accurate estimate than each measurement been analyzed individually. Thus, by taking cog naissance of skeletal maturity (age), living stature could be readily estimated from the second metacarpal with significant degrees of accuracy in children, using a multiple linear model. In West Africa, there are only isolated reports on stature reconstruction from percutaneous measurements of hand dimensions in juveniles [41]. In Nigerians, the paucity of literature on stature prediction from anthropometry in Nigerian juveniles was highlighted in the study by [42]. Thus, in response to this obvious gap in our knowledge, the present study estimated nine hand anthropometric dimensions (right and left sides) to predict stature in Nigerian adolescent schoolchildren in urban Lagos.

Materials and Methods

Study description

The study was a cross-sectional survey conducted among 483 subjects, 240 male and 243 female volunteers adolescent Nigerian school children ranging from ages 10-17, resident in urban Lagos.

Sampling and demographics. Oral interview indicated that the participants in the study were from Christian, Muslim and traditional African religious and sociocultural backgrounds. Marriage laws in Nigeria do not restrict conjugal relationships across ethnic groups or social class nor the transmission of genetic traits from parent to offspring in any specifically defined manner. The study population was thus considered a heterogeneous Mendelian. The birthdates of participants were collected from the school registers and confirmed from the subjects individually. Decimal age of each subject was calculated by subtracting the date of birth from the date of data collection, using decimal age calendar [43-44]. All subjects between 13.51 and 14.50 years were classified in the age group 14 years, while those falling between 14.51 and 15.50 were included in the age group of 15 years. The same principle was applied throughout to classify subjects in appropriate age groups.

Inclusion criteria

A general physical examination was carried out to establish that each subject was in a satisfactory state of good health. School records and the response to individualized questioning established that the subjects were normally resident in metropolitan Lagos. The Nigerian ethnic groups represented in the sample included Yoruba, Ibo, Edo, Urhobo, Itsekiri, Ijaw, Ibibio, Efik, Annang, Igala, Hausa-Fulani, Nupe, Idoma and Tiv.

Exclusion criteria

The following categories of children were excluded from the current study: Pure-breed Caucasian, African and Near East Semitics (Jews and Arabs) and Far East Asian children; the acutely-ill and the physically challenged; children on any form of continuous medication; children with poor health conditions that manifested with overt signs of stunted growth or physical emaciation; grotesquely obese children to avoid potentially excessive errors in measurement and also for whom exposure before other children might cause undue embarrassment ISAK.

Informed consent

Consent was obtained from each subject that participated in the study and their parents. This was after the purpose and procedure of measurement had been carefully explained to them. A clear indication of full comprehension and acceptance to participate was received from them. Strict institutional rules regarding consent for every individual subject was ensured. All

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subjects received a guarantee of preservation of their personal space throughout the measurement exercise. Their right to withdraw- if so desired- at any stage of the study was also stated clearly to them. All measurements recorded belong to only those who gave full consent.

Research Materials

SECA Stadiometer calibrated in centimeters., Kipfer weighing scale, sliding caliper calibrated in centimeters. Digital Vernier caliper, Gloves, Permanent markers, Anthropometric proforma containing the students' demographic data.

Measurement protocol and training

The researchers undergo the basic level one practical training as recommended by ISAK under the tutelage of the research supervisor Dr. N.MIbeabuchi(an ISAKcertified Anthropometrism). Training was carried out in the anthropometry laboratory in the Department of Human Anatomy, University of Lagos. Protocols for direct measurements of stature and weight, was adopted from those established by the International Society for the Advancement of Ki anthropometry ISAK. The anthropometry instruments were all standard anthropometry instrument.

Stature (Standing Height)

The measurement was taken as the maximum vertical distance from the floor to the vertex of the head. Technically, the vertex is defined as the highest point on the skull when the head is held in the Frankfort plane. This position is achieved when the line joining the orbital to the tragion is horizontal or at right angles to the long axis of the body. In taking the stature measurement, the subject was asked to stand erect on a flat surface on bare foot with heels together, both heels touching the base of the wall, and arms hanging naturally by the sides. The heels, buttocks, upper part of the back and usually, but not necessarily, the back of the head are in contact with the vertical wall. The subject was then instructed to "look straight ahead" and "take a deep breath". One of the scientists ensured that the subject's heels are not elevated and applied a stretch force, by cupping the subject's head and applying firm traction alongside the mastoid processes while the other scientist draw the stadiometer down to the vertex of the head. The vertical distance from floor to pencil mark on the stadiometer will be recorded. The subject was asked to step away from the wall, all subjects will be measured approximately at same time, owing to the diurnal variation of stature, and measurements were read to the nearest 0.1cm [32] (Figure 1 & 2).

Figure 1: Height Measurement.

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Figure 2: Hand length Measurement.

Hand Measurement

Flexures or joint lines are the major markings found in areas of synovial joints. They are produced by adhesions of skin to subadjacent deep fascia. The creases found on the skin surface of the hand, especially on the flexor surface of the wrist, palm and digits are the sites for folding and movement of the hand. These flexures are important landmarks use to estimate hand measurements. The subjects were asked to place their hands on a flat surface in a supine position; these landmarks were marked and measured using a sliding vernier caliper.

Hand length: (Mid-stylion – Dactylion), this is the midpoint of the mid-styli online of the wrist (line joining the stylion ulnare and stylion radiale), to the anterior projection of the skin of the middle finger.

Hand breath: This is the distance from the most laterally placed point of the radial side of the first metacarpophalyngeal to the most medially placed point located on the head of the fifth metacarpophalyngeal.

Digital length: This is the distance between the proximal flexion crease of the finger to the tip of the respective finger using anthropometry formula where the thumb is 1, index finger is 2, middle finger is 3, ring finger is 4 and the little finger is 5. Hence the digit is named 1D, 2D, 3D, 4D and 5D respectively.

Palm length: This is the distance between the mid stylion to the wrist and the first crease of the middle finger where it continues with the pharyngeal bone Table 1-4.

Table 1: Showing descriptive and inferential statistics of participants' pooled stature.

Stature	N	Range	Minimum	Maximum	Mean		
	Statistic	Statistic	Statistic	Statistic	Statistic	SD	Std. Error
MALE	240	65.6	125.7	191.3	159.1	14.77	0.953
FEMALE	243	61.5	125.1	186.6	155.9	12.29	0.788

Table 2: Showing Descriptive and Inferential Statistics of Stature.

Age Group (Years)	Male (n=240)				Female (n=243)					T-test		Differences
	MEAN (cm)	SD(cm)	MIN. (cm)	MAX. (cm)	MEAN(cm)	SD(cm)	MIN. (cm)	MAX. (cm)	t-Value(cm)	P-Value(cm)	MEAN (cm)	SEM(cm)
10 (n=52)	142.57	6.69	125.7	161.8	144.55	5.8	132.9	153.4	1.128	0.2646	1.98	1.76
11 (n=82)	145.59	6.66	135	159.5	147.61	9.87	128.8	180.5	1.063	0.2911	2.02	1.9
12 (n=75)	148.83	7.18	135.6	169.5	150.7	15.92	161.5	167	0.618	0.5385	1.87	3.03

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13 (n=52)	155.2	9.13	137.6	177.5	157.68	7.16	144.5	172.5	0.9015	0.3718	2.48	2.75
14 (n=53)	162.63	11.12	136	186.6	159.63	7.17	144	171.6	1.156	0.2534	-3	2.6
15 (n=55)	169.14	9.61	152	191.3	164.38	5.53	154.7	174.9	2.269	0.0275	4.76	2.1
16 (n=55)	173.94	7.84	157.8	186.1	165.72	9.04	150.4	186.6	3.789	0.0004	-8.22	2.17
17 (n=59)	173.9	8.98	143.4	189	164.35	7.54	151.4	177.6	4.311	<0.0001	-9.55	2.22

Table 3: Descriptive statistics for data used in Stature estimation of right-hand dimensions.

Right hand		Mean±SD	Minimum	Maximum	SEM
Palm length	Male	10.24±3.8	4.6	9.9	0.25
	Female	10.06±5.1	5.3	8.71	0.33
	Combined	10.15±4.5	4.6	8.9	0.2
Hand length	Male	17.62±2.3	12.3	21.5	0.15
	Female	17.21±2.3	11.1	19.9	0.15
	Combined	17.41±2.3	12.1	21.5	0.1
Thumb ID length	Male	5.64±0.7	4	8	0.04
	Female	5.52±0.6	3.4	7.7	0.42
	Combined	5.58±0.7	3.4	8	0.03
Index 2D length	Male	6.27±0.8	4.7	8.8	0.51
	Female	6.27±0.6	4.3	8	0.42
	Combined	6.27±0.7	4.3	8.8	0.33
Middle 3D length	Male	7.23±0.8	5.4	9.5	0.05
	Female	7.19±0.7	5	9.3	0.04
	Combined	7.21±0.7	5	9.5	0.03
Ring 4D length	Male	6.61±0.8	4.9	8.9	0.05
	Female	6.54±0.6	4.9	8.6	0.43
	Combined	6.58±0.7	4.9	8.9	0.03
Little 5D length	Male	5.13±0.6	3.7	7.2	0.67
	Female	5.08±0.6	3.5	7.4	0.03
	Combined	5.11±0.6	3.5	7.4	0.02
Hand breath	Male	9.05±1.9	3.3	6.4	0.12
	Female	8.51±1.3	3.5	6.2	0.08
	Combined	8.78±1.7	3.3	6.4	0.07
Wrist width	Male	5.05±3.0	2.4	5.12	0.19
	Female	4.70±0.5	3	6.8	0.03
	Combined	4.87±2.1	2.4	6.2	0.09

SEM: Standard Error of Means; SD: Standard Deviation

Table 4: Descriptive statistics for data used in sex and Stature estimation of left-hand dimensions.

Left hand		Mean±SD	Minimum	Maximum	SEM
Palm length	Male	10.15±2.88	4.6	5.12	0.18
	Female	10.00±5.18	5.1	8.9	0.33
	Combined	10.09±4.1	4.6	8.92	0.19

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Hand length	Male	17.72±3.0	10.7	21.7	0.19
	Female	17.15±2.2	9	20.09	0.14
	Combined	17.644±2.7	9.7	21.7	0.12
Thumb ID length	Male	5.68±0.7	4.1	7.9	0.04
	Female	5.54±0.6	4.5	9.4	0.44
	Combined	5.61±0.7	3.5	9.4	0.03
Index 2D length	Male	6.29±0.7	4.9	8.1	0.05
	Female	6.27±0.6	4.3	8.3	0.04
	Combined	6.28±0.7	4.3	8.3	0.03
Middle 3D length	Male	7.24±0.8	5.2	9.5	0.05
	Female	7.21±0.7	5.4	9.3	0.04
	Combined	7.22±0.7	5.2	9.5	0.7
Ring 4D length	Male	6.62±0.7	4.8	8.5	0.05
	Female	6.54±0.6	4.4	8.6	0.43
	Combined	6.58±0.7	4.4	8.6	0.03
Little 5D length	Male	5.17±0.6	3.7	7.3	0.6
	Female	5.03±0.5	3.4	7.1	0.03
	Combined	5.07±0.6	3.4	7.3	0.02
Hand breath	Male	8.94±1.6	3.3	5.7	0.1
	Female	8.44±1.3	3.7	7.8	0.08
	Combined	8.69±1.5	3.3	8.5	0.06
Wrist width	Male	5.08±3.7	3.1	6.23	0.24
	Female	4.71±0.5	3.1	8.7	0.03
	Combined	4.89±2.6	3.1	6.23	0.12

SEM: Standard Error of Means; SD: Standard Deviation

Wrist width: This is the distance from the stylion ulnare and stylion radiale. The landmark was palpated by having the subject relax while the anthropometrist slightly manipulates the subject's hand from side to side, checking and marking the landmark. The small sliding Vernier caliper will be placed at the landmarks on both side of the wrist, after which will be removed from the subjects' hand and readings will be recorded.

Bilateral symmetry

Table 5: Paired t-test for comparing left- and right-hand measurement.

	Difference in Mean (Right-Left)	SE (Difference)	95% Confidence Interval		t-value	p-value
			Lower	Upper		
Wrist Width	-0.016	0.024	-0.063	0.031	-0.669	0.504
Hand Breadth	0.088	0.02	0.048	0.128	4.371	0.001*
Hand Length	-0.023	0.048	-0.119	0.072	-0.483	0.629
Palm Length	0.058	0.039	-0.018	0.135	1.491	0.137
D1 (Thumb)	-0.032	0.016	-0.06	0	-1.927	0.005*
D2 (Index)	-0.011	0.014	-0.04	0.01	-0.766	0.444
D3 (Middle)	-0.014	0.011	-0.037	0.007	-1.328	0.002*
D4 (Ring)	-0.001	0.011	-0.024	0.021	-0.124	0.901
D5 (Little)	0.033	0.012	0.008	0.057	2.687	0.001*

*statistically significant; SE: Standard Error

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The result of the paired t-test as shown in Table 5, found in most cases the mean differences between the left and right sides were less than 5mm in all cases, with Hand breadth and little finger (D5) length showing the highest level of asymmetry at $p<0.001$*. The t-test also shows that there is bilateral asymmetry on D1 and D3 at $p<0.002$* and $p<0.005$* respectively. Other measured dimensions were not statistically significant. Despite the mean differences between all the measured dimensions being very small, side-specific models for stature estimation were created for each dimension.

Discussion

As important as hand anthropometry might appear to biological profile reconstruction, a critical aspect of forensic investigation of juveniles is the assessment of maturity status. Previous studies on juvenile stature and body mass prediction rarely took this into account [45]. This would be akin to an anecdotal experience of utter confusion which would occur if one visited a clothing store to purchase school uniforms for a 14-year-old boy and the attendant simply pointed to the children section displaying clothes without age-range tags attached to the uniforms! In the current study, the classification of the data on the basis of age and sex is consistent with the argument of [17], that for stature prediction models to be appropriate to juveniles, they must be independently constructed. Also, the estimation of stature by analyzing the impact of multiple dimensions and maturity status of the hand suggests that the combination of multiple measurements provided a more accurate estimate than each measurement been analyzed individually. This finding is consistent with those of [40] in a study of 552 boys and 542 girls aged 6 to 20 years on the second metacarpal. By considering their skeletal maturity (i.e. age), living stature could be readily estimated from the second metacarpal with significant degrees of accuracy in children, using a multiple linear model in immature individuals. While sex and age factors are useful for the estimation of stature in juveniles, these variables are often unknown in the isolated bone. Besides, studies on juvenile stature and body mass prediction rarely take account of skeletal maturity. The samples are simply divided into immature and mature groups (according to skeletal maturity), while the mature group are considered with adults for this purpose. In most growth studies, however, skeletal maturity estimates are often radiological [46]. Juvenile development is affected not just by genetics, but also social factors ranging from parental socioeconomic status to marital distance [47,48].

The reporting of juvenile stature is frequently biased through studies relying on self-reporting [49] or not accounting for diurnal stature variation [50,51]. Utilizing these estimation studies as framework, the current study creates new stature estimation formulae, carefully considering the merits of age class cohorts, and sex-based regression formulae [52,53]. In this current study, at early adolescence, the stature for boys at age 10 years was 142.57(± 6.69) cm, ranged 125.7-161.8cm, while for 10 years old girls, stature was 144.55 (±5.8) cm ranged 132.9-153.4cm. With a $t=1.128$ and $p=0.2646$, there was no statistically significant difference between stature of boys and girls. By late adolescence, however, the stature for boys at age 17 years was 173.9 (±8.98) cm, ranged 143.4-189cm, while stature for 17 years old girls was 164.35 (±7.54) cm, ranged 151.4-177.6cm. At $t=4.311$ and $p<0.0001$, the boys were now significantly taller than the girls. As shown in Table 2, the progression of skeletal growth in females, indicated by increased stature, from age 10 years, was faster than the age-matched boys up to age 13 years with a consistent mean difference in stature of approximately 2cm. At age 13 years, the girls enter the phase of maximum acceleration of growth in stature to reach the maximum velocity at 15 years. For the males, they begin to accelerate at 12 years, catch up with the females at 14 years and reach maximum velocity at 16 years. The features described appear to be consistent with the prediction based on the adolescent growth spurt in stature model of [54]. Table 6a-6r indicates that at all ages, except 12 years, the simple linear regression models for stature prediction were statistically significant for all predictor variables. While the exact reason is not clear at this stage, it may not be unconnected with the well accepted notion that the period coincides with the "take-off" of the adolescent growth spurt in stature for boys. The girls, on the other hand, enter the period of maximum acceleration for growth in stature by 9-10 years [55-57]. Some authorities have suggested that some girls enter the adolescent period as early as 8 years [58]. The data in (Table 6a-6r) also suggests that acceleration of growth in stature followed by an overtake which began at about the age of 12 years in boys was most probably concluded by the age of 16 years. It shows that during this period, the incremental growth had approximated 7cm per annum in boys during age 13-15 years while the quantum had significantly reduced from 7cm at 12-13 years to 2-3cm during the same period in the girls. According to (Table 6a-6r) the numerical value of the regression coefficient R and coefficient of determination R2 was largest for all dimensions at age 14 years. This finding is consisted with the predictions of [59] and [60].

Table 6a: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =6.28(WWR)+116.41	0.4713	0.2221	<.001
11	Stature =4.77(WWR)+125.15	0.2903	0.08426	0.009
12	Stature =7.87(WWR)+113.48	0.269	0.07234	0.02

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13	Stature =1.83(WWR)+147.75	0.1657	0.02747	0.25
14	Stature =8.78(WWR)+117.69	0.4063	0.1651	0.003
15	Stature =7.05(WWR)+131.7	0.4367	0.1907	<.001
16	Stature =13.18(WWR)+103.63	0.6364	0.405	<.001
17	Stature =13.45(WWR)+100.4	0.6721	0.4517	<.001

Wrist Width Right (WWR)

Table 6b: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =6.59(WWL)+114.99	0.4333	0.1877	0.001
11	Stature =4.47(WWL)+126.63	0.2743	0.07525	0.013
12	Stature =5.62(WWL)+123.93	0.2027	0.04111	0.081
13	Stature =1.61(WWL)+148.85	0.1426	0.02033	0.323
14	Stature =7.56(WWL)+123.28	0.3776	0.1426	0.006
15	Stature =6.45(WWL)+134.71	0.3973	0.1579	0.003
16	Stature =11.55(WWL)+112.02	0.5676	0.3222	<.001
17	Stature =12.09(WWL)+107.67	0.6388	0.4081	<.001

Wrist Width Left (WWL)

Table 6c: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =2.41(HBR)+125.36	0.3516	0.1236	0.011
11	Stature =5.68(HBR)+101.71	0.4846	0.2349	<.001
12	Stature =3.3(HBR)+122.93	0.1918	0.03678	0.099
13	Stature =6.05(HBR)+104	0.5686	0.3233	<.001
14	Stature =5.39(HBR)+111.39	0.5531	0.3059	<.001
15	Stature =5.18(HBR)+118.83	0.5766	0.3325	<.001
16	Stature =1.79(HBR)+153.31	0.2979	0.08877	0.02
17	Stature =4.95(HBR)+121.65	0.4879	0.238	<.001

Hand Breadth Right

Table 6d: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =2.63(HBL)+124.01	0.3678	0.1353	0.008
11	Stature =5.39(HBL)+104.34	0.4801	0.2305	<.001
12	Stature=1.75(HBL)+135.75	0.1021	0.01042	0.384
13	Stature =4.92(HBL)+113.99	0.4761	0.2266	<.001
14	Stature =5.28(HBL)+112.54	0.5596	0.3132	<.001
15	Stature =5.14(HBL)+119.43	0.5725	0.3277	<.001
16	Stature =1.76(HBL)+153.76	0.2931	0.08591	0.022
17	Stature =4.68(HBL)+124.85	0.4873	0.2374	<.001

Hand Breadth Left

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Table 6e: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =1.34(HLR)+122.76	0.3859	0.1489	0.005
11	Stature =0.48(HLR)+138.78	0.1642	0.02695	0.143
12	Stature =1.52(HLR)+124.66	0.1876	0.03519	0.107
13	Stature =5.36(HLR)+62.65	0.8269	0.6837	<.001
14	Stature =6.23(HLR)+48.72	0.7427	0.5515	<.001
15	Stature =2.35(HLR)+123.79	0.6119	0.3744	<.001
16	Stature =3.59(HLR)+103.96	0.6934	0.4808	<.001
17	Stature =2.84(HLR)+117.25	0.5885	0.3463	<.001

Hand Length Right

Table 6f: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =3.69(HLL)+85.61	0.6891	0.4749	<.001
11	Stature =0.53(HLL)+137.95	0.1674	0.02803	0.135
12	Stature =1.58(HLL)+123.64	0.2073	0.04296	0.074
13	Stature =5.31(HLL)+63.7	0.8323	0.6928	<.001
14	Stature =5.69(HLL)+58.26	0.7256	0.5265	<.001
15	Stature =2.42(HLL)+122.59	0.626	0.3919	<.001
16	Stature =3.55(HLL)+104.94	0.6973	0.4863	<.001
17	Stature =2.84(HLL)+117.39	0.5759	0.3317	<.001

Hand Length Left

Table 6g: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =3.83(PLR)+109.14	0.5263	0.277	<.001
11	Stature =5.88(PLR)+92.99	0.5338	0.2849	<.001
12	Stature =-0.08(PLR)+150.79	-0.0608	0.003701	0.604
13	Stature =9.05(PLR)+66.87	0.7745	0.5999	<.001
14	Stature =10.66(PLR)+52.81	0.7381	0.5449	<.001
15	Stature =7.57(PLR)+87.35	0.7518	0.5652	<.001
16	Stature =6.95(PLR)+96.86	0.5973	0.3567	<.001
17	Stature =8.3(PLR)+81.77	0.6044	0.3653	<.001

Palm Length Right

Table 6h: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =3.8(PLL)+109.67	0.5065	0.2566	<.001
11	Stature =4.67(PLL)+104.46	0.4786	0.229	<.001
12	Stature =0.09(PLL)+150.88	-0.0675	0.004556	0.565
13	Stature =8.17(PLL)+75.65	0.6927	0.4799	<.001
14	Stature =10.68(PLL)+51.8	0.7585	0.5753	<.001
15	Stature =7.56(PLL)+87.57	0.7245	0.5248	<.001
16	Stature =7.76(PLL)+87.93	0.6555	0.4297	<.001
17	Stature =8.56(PLL)+79.06	0.5913	0.3496	<.001

Palm Length Left

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Table 6i: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =7.12(D1R) +107.18	0.6617	0.4379	<.001
11	Stature =5.98(D1R) +116.11	0.4079	0.1664	<.001
12	Stature =2.94(D1R) +134.28	0.145	0.02101	0.215
13	Stature =9.13(D1R) +106.46	0.6475	0.4193	<.001
14	Stature =9.16(D1R) +107.67	0.5683	0.323	<.001
15	Stature =8.71(D1R) +114.84	0.6179	0.3818	<.001
16	Stature =9.34(D1R) +114.64	0.6287	0.3953	<.001
17	Stature =8.01(D1R) +121.1	0.5981	0.3577	<.001

D1 (Thumb) Right

Table 6j: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =7.23(D1L) +106.23	0.6619	0.4381	<.001
11	Stature =8.57(D1L) +102.97	0.4868	0.237	<.001
12	Stature =2.08(D1L) +138.64	0.1282	0.01644	0.273
13	Stature =8.09(D1L) +112	0.5962	0.3554	<.001
14	Stature =7.82(D1L) +114.85	0.5495	0.302	<.001
15	Stature =8.03(D1L) +119.13	0.5793	0.3356	<.001
16	Stature =8.81(D1L) +117.45	0.6085	0.3703	<.001
17	Stature =8.9(D1L) +115.52	0.6084	0.3702	<.001

D1 (Thumb) L

Table 6k: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =8(D2R) +97.72	0.7692	0.5916	<.001
11	Stature =8.42(D2R) +98.42	0.4945	0.2445	<.001
12	Stature =4.77(D2R) +121	0.2216	0.04911	0.056
13	Stature =8.79(D2R) +102.35	0.7472	0.5583	<.001
14	Stature =9.78(D2R) +97.48	0.6149	0.3781	<.001
15	Stature =8.84(D2R) +107.45	0.6499	0.4224	<.001
16	Stature =9.57(D2R) +105.61	0.6937	0.4812	<.001
17	Stature =8.56(D2R) +111.91	0.565	0.3192	<.001

D2 (Index) R

Table 6l: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =8.56(D2L) +94.52	0.726	0.527	<.001
11	Stature =9.48(D2L) +92.13	0.5564	0.3096	<.001
12	Stature =3.28(D2L) +130.1	0.1694	0.02869	0.146
13	Stature =7.91(D2L) +107.15	0.6627	0.4392	<.001
14	Stature =9.28(D2L) +100.13	0.6185	0.3826	<.001
15	Stature =8.91(D2L) +107.2	0.653	0.4264	<.001
16	Stature =10.11(D2L) +102.5	0.6984	0.4878	<.001
17	Stature =10.27(D2L) +99.67	0.639	0.4084	<.001

D2 (Index) L

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Table 6m: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =7.8(D3R) +92.29	0.7494	0.5616	<.001
11	Stature =8.18(D3R) +92.54	0.5559	0.309	<.001
12	Stature =5.04(D3R) +114.79	0.2525	0.06375	0.029
13	Stature =8.56(D3R) +95.15	0.7766	0.6031	<.001
14	Stature =11.18(D3R) +77.33	0.7282	0.5302	<.001
15	Stature =8.54(D3R) +101.75	0.7103	0.5045	<.001
16	Stature =8.66(D3R) +103.24	0.7101	0.5042	<.001
17	Stature =8.46(D3R) +104.03	0.5615	0.3153	<.001

D3 (Middle Finger) R

Table 6n: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =8.16(D3L) +89.62	0.7056	0.4979	<.001
11	Stature =8.01(D3L) +93.54	0.5682	0.3229	<.001
12	Stature =3.86(D3L) +123.16	0.188	0.03534	0.106
13	Stature =7.99(D3L) +98.94	0.7474	0.5586	<.001
14	Stature =10.62(D3L) +81.05	0.6896	0.4755	<.001
15	Stature =8.39(D3L) +102.63	0.7378	0.5444	<.001
16	Stature =9.51(D3L) +96.73	0.7393	0.5466	<.001
17	Stature =8.94(D3L) +100.21	0.5719	0.3271	<.001

D3 (Middle Finger) L

Table 6o: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature=8.43(D4R) +93.08	0.7363	0.5421	<.001
11	Stature =8.79(D4R) +93.2	0.5587	0.3121	<.001
12	Stature =3.98(D4R) +124.79	0.1945	0.03782	0.095
13	Stature =9.07(D4R) +97.15	0.7803	0.6089	<.001
14	Stature =11.33(D4R) +83.51	0.7006	0.4909	<.001
15	Stature =9.72(D4R) +99.03	0.7564	0.5722	<.001
16	Stature =9.2(D4R) +105.31	0.7087	0.5023	<.001
17	Stature =7.78(D4R) +114.72	0.4986	0.2486	<.001

D4 (Ring Finger) R

Table 6p: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age Group	Equation	R	R squared	P value
10	Stature =7.93(D4L) +96.02	0.7198	0.5181	<.001
11	Stature =8.79(D4L) +93.06	0.5544	0.3074	<.001
12	Stature =3.88(D4L) +125.43	0.192	0.03686	0.099
13	Stature =9.09(D4L) +96.77	0.7785	0.606	<.001
14	Stature =10.57(D4L) +88.89	0.6276	0.3939	<.001
15	Stature =9.64(D4L) +99.77	0.7319	0.5356	<.001
16	Stature =10.74(D4L) +94.16	0.739	0.5461	<.001
17	Stature =7.22(D4L) +119.26	0.4709	0.2218	<.001

D4 (Ring Finger) L

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Table 6q: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =9.06(D5R)+101.39	0.6406	0.4104	<.001
11	Stature =8.63(D5R)+105.93	0.4696	0.2205	<.001
12	Stature =1.68(D5R)+141.64	0.07611	0.005793	0.516
13	Stature =10.38(D5R)+104.53	0.7419	0.5503	<.001
14	Stature =8.1(D5R)+117.94	0.4694	0.2204	<.001
15	Stature =7.55(D5R)+125.58	0.5695	0.3243	<.001
16	Stature =9.99(D5R)+115.49	0.6558	0.4301	<.001
17	Stature =8.36(D5R)+123.98	0.4836	0.2339	<.001

D5 (Little Finger) R

Table 6r: Age-wise simple linear regression models for Stature from measured parameters on right and left sides.

Age group	Equation	R	R squared	P value
10	Stature =8.7(D5L) +103.55	0.6172	0.381	<.001
11	Stature =9.06(D5L) +104.38	0.4547	0.2067	<.001
12	Stature=2.4(D5L) +138.22	0.1066	0.01137	0.362
13	Stature =9.49(D5L) +108.47	0.6985	0.4879	<.001
14	Stature =10.61(D5L) +104.94	0.559	0.3124	<.001
15	Stature =8.36(D5L) +121.26	0.6407	0.4105	<.001
16	Stature =10.46(D5L) +113.62	0.6358	0.4042	<.001
17	Stature =7.32(D5L) +129.8	0.4618	0.2133	<.001

D5 (Little Finger) L

The presence of symmetry of hand dimensions for the present study as presented in Table 5. The results showed that mean differences between the left and right sides were < 5mm in all cases, with hand breadth and little finger (D5) length showing the greatest asymmetry (p<0.001), while other hand dimensions were not statistically significant. Since we have no data on this variable in children, it is not clear when precisely sidedness began to be expressed as a genetic and/or environmentally determined biological variable. However, in the adult, the observation agrees with the findings of [61]. who found a small but significant degree of bilateral asymmetry in hand dimensions among Australians? also reported the presence of bilateral asymmetry in the left and right hand with the right-hand dimensions being significantly larger than the left hand. The result from this study displayed a positive correlation between stature and all hand dimensions tested. All hand dimensions were assessed for their ability to predict stature using simple linear regression based on the values of the standard error of estimate (SEEs) and coefficient of determination (R^2). The regression coefficient (R=0.853) for male left hand length and (R=0.839) for male right middle finger indicates the strongest predictors of stature while the coefficients of determination (R=0.024 and 0.028) for female right and left palm length respectively indicted that these were the weakest stature predictors among all groups as show in Table 7 & 8. The male left hand length had the lowest SEEs for all groups (±7.73cm); this single body dimension also explained the highest proportion of variation in stature, as indicated by the coefficient of determination (R^2) which predicted 73%. Among the five digits, the male right middle finger D3 and ring finger D4 length has lowest SEEs ±8.05cm and ±8.38cm, and R^2 values predicted 70.4% and 68%. These values will as such be used in deriving a regression reconstructive model of an individual's hand during identification. This finding was consistent with results achieved by [62-65]. but contrary to the findings made by [66] on subjects from Delhi, India. They reported a positive correlation existed between stature and finger lengths, and it further suggested that the index finger was best for the prediction of stature in both males and females. The SEEs obtained in this current study were higher than the comparable models in the Previous research in various populations which has demonstrated that stature can be accurately estimated from hand dimensions: e.g. Egyptian, SEEs 5cm [8], Turkish SEEs 3.91-4.59cm [9] North Indian, SEEs 3.16–5.60cm (Krishan & Sharma, 2007) ; South Indian, SEES 3.65–5.73cm [10] SEEs 4.22–5.48cm [64]. The differences in this SEEs level and R2 may be attributed to racial differences and geographical variations that exist amongst individuals of a particular tribe or region, it supported [61] and [67]. who reported correlation coefficients ranging between r = 0.45 – 0.77 for hand dimensions and the hand length demonstrated the highest correlation?

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Table 7: Simple linear regression model for Individual measurement in right hand.

	Equation	p-value	SEE	R	R2
	Wrist width				
Male	78.63+ (16.56) WW	<0.001*	10.95	0.673	0.453
Female	111.86+ (9.35) WW	<0.001*	11.26	0.405	0.164
Combined	92.87+ (13.50) WW	<0.001*	11.28	0.565	0.319
Hand Breadth					
Male	72.30+(9.70) HB	<0.001*	9.02	0.793	0.628
Female	113.97+ (4.94) HB	<0.001*	10.82	0.477	0.227
Combined	93.61+ (7.33) HB	<0.001*	10.35	0.654	0.427
Hand Length (HL)					
Male	54.00+(5.99) HL	<0.001*	8.51	0.818	0.669
Female	124.87+(1.80) HL	<0.001*	11.55	0.347	0.12
Combined	95.13+(3.59) HL	<0.001*	11.15	0.579	0.335
Palm length (PL)					
Male	72.98+ (8.61) PL	<0.001*	10.32	0.717	0.514
Female	155.30+(0.05) PL	<0.001*	12.31	0.024	0.001
Combined	152.39+(0.51) PL	<0.001*	13.54	0.139	0.019
Thumb length (1DL)					
Male	78.77+ (14.22) 1DL	<0.001*	9.97	0.739	0.546
Female	101.27+(9.90) 1DL	<0.001*	10.43	0.531	0.282
Combined	87.85+(12.48) 1DL	<0.001*	10.33	0.655	0.429
Index length (2DL)					
Male	66.19+(14.68) 2DL	<0.001*	8.89	0.8	0.639
Female	86.38+(9.89) 2DL	<0.001*	9.89	0.598	0.355
Combined	74.46+(13.22) 2DL	<0.001*	9.61	0.712	0.506
Middle length (3DL)					
Male	57.54+(14.04) 3DL	<0.001*	8.05	0.839	0.704
Female	82.15+(10.25) 3DL	<0.001*	9.93	0.591	0.349
Combined	66.67+(12.59) 3DL	<0.001*	9.24	0.737	0.543
Ring length (4DL)					
Male	59.09+(15.12) 4DL	<0.001*	8.38	0.824	0.679
Female	86.73+(10.35) 4DL	<0.001*	10.9	0.573	0.328
Combined	70.65+(13.19) 4DL	<0.001*	9.5	0.719	0.517
Little length (5DL)					
Male	76.86+(16.01) 5DL	<0.001*	10.16	0.727	0.529
Female	102.94+(10.41) 5DL	<0.001*	10.6	0.509	0.259
Combined	88.03+(13.58) 5DL	<0.001*	10.59	0.633	0.4

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Table 8: Simple linear regression model for Individual measurement in left hand.

	Equation	p-value	SEE	R	R2
	Wrist width				
Male	81.86+ (15.95) WW	<0.001*	11.33	0.643	0.414
Female	113.21+ (9.05) WW	<0.001*	11.28	0.404	0.163
Combined	95.75+ (12.92) WW	<0.001*	11.48	0.544	0.296
Hand Breadth					
Male	78.48+(9.42) HB	<0.001*	9.26	0.78	0.608
Female	115.87+ (4.76) HB	<0.001*	10.91	0.463	0.215
Combined	95.99+ (7.11) HB	<0.001*	10.49	0.641	0.411
Hand Length (HL)					
Male	40.44+(6.75) HL	<0.001*	7.73	0.853	0.727
Female	121.93+(1.98) HL	<0.001*	11.44	0.37	0.137
Combined	85.80+(3.90) HL	<0.001*	10.94	0.6	0.36
Palm length (PL)					
Male	50.80+ (10.85) PL	<0.001*	8.63	0.812	0.66
Female	155.20+(0.17) PL	<0.001*	12.31	0.028	0.001
Combined	152.19+(0.53) PL	<0.001*	13.53	0.145	0.021
Thumb length (1DL)					
Male	78.03+ (14.26) 1DL	<0.001*	9.94	0.741	0.549
Female	108.52+(8.54) 1DL	<0.001*	10.81	0.479	0.23
Combined	91.27+(11.79) 1DL	<0.001*	10.6	0.632	0.4
Index length (2DL)					
Male	64.68+(14.99) 2DL	<0.001*	8.74	0.807	0.652
Female	89.84+(10.52) 2DL	<0.001*	10.12	0.569	0.324
Combined	74.67+(13.17) 2DL	<0.001*	9.69	0.706	0.498
Middle length (3DL)					
Male	57.28+(14.06) 3DL	<0.001*	8.26	0.83	0.688
Female	81.95+(10.25) 3DL	<0.001*	9.93	0.591	0.349
Combined	66.64+(12.57) 3DL	<0.001*	9.35	0.73	0.533
Ring length (4DL)					
Male	58.53+(15.20) 4DL	<0.001*	8.95	0.796	0.634
Female	86.37+(10.62) 4DL	<0.001*	9.96	0.588	0.346
Combined	70.16+(13.28) 4DL	<0.001*	9.66	0.708	0.501
Little length (5DL)					
Male	76.66+(16.11) 5DL	<0.001*	9.95	0.74	0.548
Female	101.32+(10.80) 5DL	<0.001*	10.58	0.517	0.267
Combined	86.70+(13.94) 5DL	<0.001*	10.42	0.647	0.419

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Conclusion

There is limited existing body of knowledge supplying models for the prediction of stature estimation using hand anthropometric dimensions in west Africa and in Nigeria. So, data on adolescent age is sparse. This work has contributed by generating this population models. When using the model created in this study, one must first identify the side of the body part and then apply the appropriate formula developed for that side. Similar studies should be conducted among different Nigerian populations to get enough comparative data for stature and sex estimation using hand dimensions.

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