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Research Article

Logistic Regression Models for Sex Estimation Using Percutaneous Upper Arm and Forearm Anthropometric Dimensions in Adolescent School Children in Southwest Nigeria

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Abstract

Sex estimation has a significant bearing on the personal identification of victims of mass disasters or fatal assaults, especially from incomplete or mutilated remains and highly decomposed bodies. The scientific literature on personal identification among adolescents in Africa is limited and sparse in Nigerians. This study aims to formulate a model for sex estimation using the long bones of the upper limb in the adolescent Nigerian population.

Four anthropometric measurements, including humerus length, intercondylar humerus width, ulna length and radius length, were recorded for 483 healthy Nigerian adolescent school children (240 males and 243 females) aged 10 to 17 years.

Independent t-tests showed significant sex differences ($p < 0.05$) for all the parameters, with males having higher values than females. Regression formulae were developed for each of the parameters. In our logistic regression model, females were better classified, with an overall accuracy of 82.3%. The model presented provides new tools for standardizing sex determination in this population.

Keywords: Sex estimation; Logistic Regression; Anthropometry; Adolescent Nigerians

Introduction

Sex estimation is considered as one of the first essential steps in positive human identification [1]. However, in cases of severely decomposed, commingled, and dismembered bodies, the process may be challenging. Long bones have demonstrated their usefulness in sex assessment studies [2,3]. Dimensions from the upper limb bones (humerus, radius, ulna, and clavicle) have been used successfully to distinguish the sexes in several Europeans [4-7], Asian [8,9], Indian [10], Iranian [11], American [12] and African populations [13-15]. Saunders and Hoppa [16] reported that logistic regression equations are more frequently used to predict sex. Thus, [17-21] used logistic regression for different body dimensions in adults. While datasets of the adult population are widely available, information on adolescents is limited. In Africa, especially Nigeria, the literature is sparse [22]. It has been suggested that the accurate determination of the sex of immature skeletal remains is difficult in the absence of DNA because most sexually dimorphic features of the human skeleton develop as secondary sex characteristics during adolescence [23]. Thus, the methods of assessment of adult skeletons cannot reliably be applied to adolescent skeletons because of the transitional nature of the skeleton at puberty and the variability of the adolescent growth spurt. Reports on the use of percutaneous anthropometry in living subjects in the estimation of sexual dimorphism in Africa is sparse. Therefore, this study aimed to formulate a model for sex estimation using the long bones of the upper limb in an adolescent population in Southwest Nigeria.

Materials and Methods

This study was conducted among 483 Nigerian students of the Air Force base secondary school, Ikeja. The age range was 9.5 to 17.5 years, and the participants for the study were recruited randomly.

Ethical approval and informed consent

Ethical clearance was sought and obtained from the Research Grants and Experimentation Ethics Committee of the College of Medicine of the University of Lagos. Approval No. CMUL/HREC/03/21/818.

Informed consent forms were given to all participants while they were briefed on the purpose of the research, the procedure for measurement, how the research work will go a long way to benefit them and the society at large, then asked to sign the inform consent form, to make sure their participation was voluntary. Participants were also assured of preserving their personal information and that they had the right to withdraw at any stage of the research if they so wished.

Researcher training

Prof. N.M. Ibeabuchi, an ISAK-certified anthropometrist, trained the researchers to ISAK level-1 practical training for the measurement protocols in the Department of Anatomy's anthropology laboratory.

Research materials

SECA Stadiometer calibrated in centimeters, Spreading Calipers calibrated in centimeters, Transparent meter rule calibrated in centimeters, Flexible anthropometric tape rule calibrated in centimeters (W606PM- Lufkin's executive), Permanent markers, Anthropometric proforma containing the students' demographic data.

Measurement protocols

Protocols for direct measurements of stature and weight were adopted from those established by the International Society for the Advancement of Kinanthropometry. Marking was done based on Anatomical sites recommended by ISAK [24]. The following Anatomical sites were marked.

- **Radius Length (Radiale-Stylion)**: Radial length was measured as the distance from the marked most palpable part of the radius (radiale) to the marked most palpable part of the styloid process of the radius (stylion). The elbow was flexed, and the orientation of the calliper was such that it paralleled the long axis of the radius.
- **Ulna Length**: Ulnar length was measured as the distance from the marked most palpable part of the ulna to the styloid process of the ulna.
- **Humerus Inter-Condylar Width**: The distance between medial and lateral epicondyles of the humerus when the forearm of the subject is flexed at the elbow. The small bone calliper is applied, pointing downwards to bisect the right angle formed at the elbow.
- **Humerus Length (Acromiale-Radiale):** Humerus length was measured as the distance from the marked most palpable part of the acromial process (acromiale) to the marked most palpable part of the radius (radiale).

Results

		Mean ± S. D	MIN	MAX	SEE
		RIGHT SIDE			
Humerus	Male	29.85 ± 3.9	21.30	42.50	0.25
	Female	29.45 ± 3.1	20.30	37.20	0.20
	Combined	29.60 ± 3.5	20.00	42.50	0.16
Ulna	Male	25.94 ± 3.0	20.00	32.80	0.19
	Female	25.77 ± 2.4	19.10	33.40	0.15

	Combined	25.80 ± 2.7	19.10	33.40	0.12
Radius	Male	26.82 ± 3.0	19.90	33.70	0.20
	Female	26.44 ± 2.7	18.70	31.90	0.17
	Combined	26.63 ± 2.9	18.70	33.70	0.13
Intercondylar (ICW)	Male	7.35 ± 1.1	2.90	10.40	0.07
	Female	7.11 ± 1.0	4.20	11.30	0.06
	Combined	7.23 ± 1.0	2.90	11.30	0.04
	LEFT SIDE				
Humerus	Male	29.91 ± 3.9	21.70	42.60	0.25
	Female	29.31 ± 3.5	30.40	37.00	0.22
	Combined	29.61 ± 3.7	30.40	42.60	3.72
Ulna	Male	25.88 ± 3.0	20.20	33.60	0.19
	Female	25.70 ± 2.4	20.40	32.60	0.15
	Combined	25.70 ± 2.7	20.20	33.60	0.12
Radius	Male	26.85 ± 3.1	20.50	33.40	0.20
	Female	26.49 ± 2.8	18.20	32.10	0.18
	Combined	26.66 ± 2.9	18.20	33.40	0.13
Intercondylar (ICW)	Male	7.33 ± 1.1	3.30	10.20	0.07
	Female	7.07 ± 1.0	4.10	11.00	0.64
	Combined	7.33 ± 1.1	3.40	11.00	0.16

Table 1: Descriptive and inferential statistics for data used in sex and stature estimation.

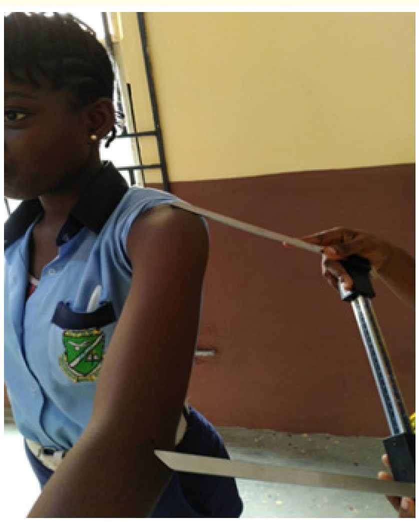

Figure A: Percutaneous measurement of Humerus length in centimeters.

Sexual dimorphism

An Independent t-test was carried out to determine the presence of sexual dimorphism in the bilateral asymmetry in upper arm and forearm dimensions. The results showed that males are significantly larger than females in all measured parameters ($p < 0.001$). The greatest degree of sexual dimorphism was observed in the left intercondylar width (male mean 7.33cm and female mean 7.07cm; $t = 2.570$). The least observed sexual dimorphism was the right ulnar length (male mean 25.94cm, female mean 25.77cm; $t = 0.692$). Stretch stature for the study sample also showed highly significant sexual dimorphism (see Figure 1 Boxplot; male mean 159.09 cm, female mean 155.86cm; $t = 3.230$).

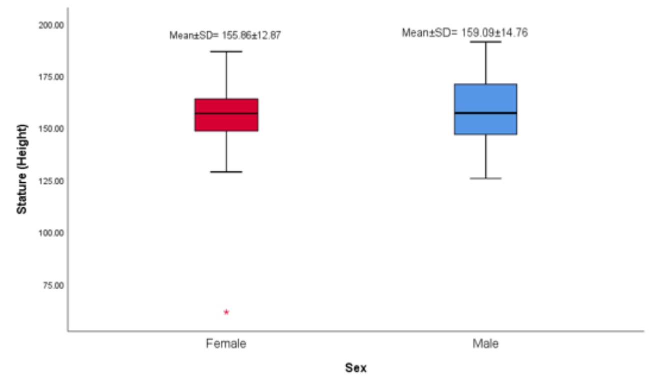

Figure 1: Box-plot of sexual dimorphism in stature for the study sample.

p-value = 0.001, t-value = 3.230

Logistic regression modeling

In all eight (8) tested logistic regression models, the single body dimensions were found to be statistically significant predictors ($p < 0.001$) except for right radial length. As shown in table, the sample data in this study suggested that females have a higher classification accuracy than males (females, right dimensions, 83.5% left dimensions, 82.2%; males, 81.2% right dimensions, 78.7% left dimensions). The combined classification accuracy for the right measured dimensions was 82.3%, while those of the left measured dimensions were 80.4%. The classification cut-off was 0.5 (0.0-0.5 males; 0.51-1.0 females).

The formulae for sex estimation from the right and left upper arm and forearm were:

Ln(P/1-p) = B0 + B1X1+ B2X2 …… BkXk

	p-value	t-value	Difference in Mean (Male-Female)	S. E	95% Confidence Interval of the Difference	
					Lower	Upper
Right						
Humerus Length	0.001*	1.208	0.393	0.325	-0.246	1.032
Intercondylar	0.001*	2.447	0.241	0.098	0.047	0.435
Ulna Length	0.001*	0.692	0.173	0.251	-0.319	0.667
Radial Length	0.001*	1.426	0.384	0.269	-0.145	0.915
Left						
Humerus Length	0.001*	1.760	0.595	0.338	-0.069	1.259
Intercondylar	0.046*	2.570	0.251	0.097	0.059	0.443
Ulna Length	0.001*	0.724	0.179	0.247	-0.307	0.665
Radial Length	0.008*	1.321	0.360	0.272	-0.175	0.896

Table 2: Result of test for sexual dimorphism for measured arm and forearm dimension.

	b0	b1	S.E. (b1)	p-value	95% C.I.for EXP(B)		Hosmer-Lemeshow p-value
					Lower	Upper	
Right							
Humerus Lt.	1.016	0.016	0.053	0.001*	0.916	0.093	1.128
Intercondylar	1.340	0.292	0.130	0.001*	1.038	5.057	1.728
Ulna Length	0.807	-0.214	0.102	0.001*	0.661	4.426	0.985
Radial Lt.	1.146	0.136	0.096	0.157	0.949	2.001	1.383
Left							
Humerus Lt.	0.052	0.106	0.046	0.001*	0.962	1.152	1.263
Intercondylar	0.304	-0.231	0.135	0.001*	1.041	1.766	5.098
Ulna Length	-0.169	0.209	0.098	0.001*	0.696	1.024	2.943
Radial Lt.	0.050	0.199	0.092	0.001*	0.877	1.259	0.929

Table 3: Logistic regression for predicting sex using single right and left upper arm and forearm dimensions.

*Statistically significant ($P < 0.001$) Lt = Length

Groups	Right			Left		
	Correct	Incorrect	Correct %	Correct	Incorrect	Correct%
Male	195	45	81.2%	189	51	78.7%
Female	203	40	83.5%	200	43	82.2%
Combined	398	85	82.3%	389	94	80.4%

Table 4: Correct classification for logistic regression.

Discussion

A primary component of any skeletal analysis is to estimate sex, and anthropologists frequently must accomplish this task in the face of incomplete or fragmentary skeletons. For this reason, developing sexing criteria from various skeletal elements has been a primary research focus in skeletal biology [25].

Long bones have especially been used because of the ease of defining measurements and better preservation [8]. Some recent studies have used the cut-off point technique as a form of discriminant function analysis [26]. A recent study determined sex from upper arm and forearm bones in an adult Nigerian population in Lagos, using logistic regression, with the best predictor being the intercondylar humerus width [15]. However, studies on the Nigerian adolescent population using logistic regression are yet to be reported.

From the sample data, the use of all eight anthropometric dimensions, four from either side, enabled (8) logistic regression equations to be derived. The individual body dimensions were found to be statistically significant predictors of sex ($p<0.001$) except for the right radial length.

The logistic regression classification model for the data in this study indicates that females have higher classification accuracy than males, with 83.5% for right dimensions and 82.2% for left dimensions. The classification accuracy for males showed 81.2% for right dimensions and 78.7% for left dimensions. The combined classification accuracy for the right measured dimensions was 82.3%, while those of the left measured dimensions were 80.4%. The classification cut-off was 0.5 (0.0-0.5 males; 0.51-1.0 females).

In forensic anthropology, the estimation of sub-adult skeletal age is typically based on long bone length, epiphyseal fusion, and dental development or eruption sequences [22]. They are known to be more precise and accurate than adult age estimates because of degenerative changes at the pubic symphysis, auricular surface, sternal rib ends, cranial sutures, or dental attrition.

However, sex estimation is usually assumed to be more accurate with adult skeletons than with sub-adults or juveniles [27,28]. Accuracy rates for sexing infant skeletons tend to hover around chance, although rates tend to improve as puberty approaches and sexual dimorphism becomes more apparent. Thus, given the age group of the participants in this current study (10 to 17 years), our results can be considered reliable.

The purpose of this study was to determine the pattern of sexual dimorphism in a sample of Nigerian schoolchildren using percutaneous anthropometry. Previous work among the adolescent age group was based on Rogers's method of morphological sex determination using the distal humerus [29] to assess the sex of adolescent skeletons ages ranging from 11 to 20 years. The technique achieved an accuracy of 81% on the combined sample of 42. This method could be applied to adolescent skeletons once the trochlea begins fusing to the humeral diaphysis, which occurred by age 11 years in the test samples.

It is pertinent to note that our percutaneous method permits the Rogers' method to be revisited in a living sample.

Conclusion

This study investigated sexual dimorphism in upper limb skeletal dimensions among adolescent school children in an African setting. The evidence suggests that statistically significant sexual dimorphism exists with a strong positive correlation between sex and the measured dimensions using the logistic regression models. This model may be useful reference material for wider-based later studies.

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